

Injuries Related to Forklifts and Other Powered Industrial Vehicles in Automobile Manufacturing

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Background *The Bureau of Labor Statistics (BLS), Census of Fatal Occupational Injuries, estimates that approximately 100 workers are fatally injured each year in forklift and other powered industrial vehicle (PIV) incidents, and an estimated 34,000 work-related injuries involving forklifts are treated in U.S. emergency rooms each year.*

Methods *This paper presents a descriptive analysis of 916 incidents involving forklifts and other PIVs that occurred in 54 plants operated by a major U.S. automobile manufacturer over a 3-year period. The injury data were obtained from a company-wide occupational injury and illness surveillance system which was implemented in 1989.*

Results *The 916 PIV-related incidents resulted in 3 fatalities and 913 nonfatal injuries. The most common incident involved pedestrians (35%) who were struck by a PIV, or the load being carried by a PIV, or a rack or bin that had been struck by a PIV. Of the 913 nonfatal injuries, 41% resulted in an employee missing work and incurred a total of 22,730 lost workdays, an average of 61 days per lost workday incident.*

Conclusions *Recommendations are presented to reduce the risk of injury, for example by separating PIV and pedestrian traffic, restricting the use of forklifts in an area where a large number of pedestrians travel and improving the training of all personnel who drive PIVs. Am. J. Ind. Med. 36:513-521, 1999. Published 1999 Wiley-Liss, Inc.[†]*

KEY WORDS: *injury; occupational; manufacturing; automotive; powered industrial vehicles; forklifts*

INTRODUCTION

This paper presents a descriptive analysis of 916 incidents involving forklifts and other powered industrial

vehicles (PIVs) in 54 automobile manufacturing plants in the U.S. over a 3-year period. PIVs are defined as mobile, power-driven vehicles that are used to carry, push, pull, lift, or stack material [Department of Labor, 1995]. PIVs include forklift trucks, high lift trucks, low lift trucks, high lift order picker trucks, counterbalanced trucks, manlifts, personnel carriers, and rider trucks. The use of forklifts and other mechanical handling of heavy loads has reduced the risk of overexertion injuries by reducing worker exposures to manual handling of heavy and bulky loads [Swartz, 1993]; however, new and perhaps more serious hazards have been introduced into the workplace. Several studies cite injury statistics indicating that PIVs contribute significantly to serious and fatal injuries. The Bureau of Labor Statistics (BLS), Census of Fatal Occupational Injuries (CFOI) estimates that approximately 100 workers are fatally injured

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each year in forklift and other PIV-related incidents [Helmer, 1994], and an estimated 34,000 work-related injuries involving forklifts are treated in U.S. emergency rooms each year [Stout-Wiegand, 1987]. This study seeks to examine factors that contribute to fatal and nonfatal PIV incidents in automobile manufacturing and make recommendations to reduce the risk of PIV-related incidents.

METHODS

Occupational injury data from a U.S. automobile manufacturer were examined for the 3-year period from July 1, 1989 to June 30, 1992. Data were analyzed for 916 work-related incidents involving PIVs in the company's 54 U.S. locations. The surveillance system was initiated in 1989 and is run jointly by both the medical and safety departments. When an incident occurs, data are entered by union and/or management representatives of the safety department and the plant's medical staff; Data are required to be entered into the system within 24hr of the occurrence of the incident and periodically updated until the employee returns to work. The data set includes information on employee characteristics (e.g., age, sex, and hourly vs. salaried employee), characteristics of the workplace and event (e.g., location in the plant, date and time of injury, a 55-character narrative text summarizing the injury-producing event), description of the injury (injury type and body part injured), and outcome (OSHA reportable lost days and restricted duty days, i.e., days on which employees reported to work but were assigned to light or alternative duties). Only OSHA recordable injuries were analyzed in this study; i.e., all injuries analyzed must have met one or more of the following conditions: (1) medical treatment required, (2) loss of consciousness, (3) restriction of work or motion, (4) transfer to another job, or (5) resulted in death [BLS, 1986].

In addition to the variables described above, the database includes a variable that asks, "Was a powered industrial vehicle a factor in this incident?" For incidents where the response was "yes", ($n = 734$) the circumstances of each incident were reviewed using variables in the database, including the 55-character narrative description of "how the injury occurred", the nature of the injury, the injured worker's job title, and recommendations to prevent future occurrences.

For the incidents where the variable "Was a PIV a factor in this incident?" was marked "no" or left blank, the narrative fields of the record were electronically searched by computer for keywords identified from the descriptions of the incidents known to involve PIVs. The following key words were identified: "forklift", "personnel carrier", "cart", "hi-lo", "mule", "jitney", "PIV", "manlift", and "powered industrial vehicle", and were searched for in these cases. This yielded an additional 269 cases, 253 of which met the case definition of a PIV-related incident.

The 54 facilities included nine assembly plants, three stamping plants, eight power train plants, 19 parts depots/distribution centers, and 15 administrative and design offices. Injury rates were calculated only for the 33 facilities involved in vehicle production and distribution and managed solely by the corporation. These included five assembly, three stamping, eight power train, and 17 parts depots/distribution centers that had been in operation since January 1, 1991, and which had at least two year-end censuses of employees available from personnel records. The 21 plants excluded from the rate calculation were six offices/technology centers, eight plants not managed solely by the corporation and did not have comparable personnel data, four plants with no production in 1991, and three plants with incomplete personnel data.

Year-end reports from the personnel department for the years 1989, 1990, and 1991 were used to estimate the number of persons working in each plant for that year. These reports represent a workforce census at the midpoint of each of the three years of injury data. The reports contain information about each employee including age, sex, employee type (hourly or salaried), and work location. To calculate the person-years of observation, each employee in the census was assumed to represent one person-year. For rate calculations, the number of injuries at the 33 plants was divided by the person-years of observation and multiplied by 100.

RESULTS

Over the 3-year period from July 1989 to June 1992, a total of 916 injury incidents were identified in the Medical and Safety Surveillance System where a PIV was involved in the incident (Table I). Of the 35,483 OSHA-recordable injuries that occurred during the 3 years, the item "Was a powered industrial vehicle a factor in the incident?" was marked "yes" in 734 incidents (Table I). However, based on the manual review of the circumstances of each of these 734 incidents, 71 incidents were excluded because they did not

TABLE I. Method of Case Identification for PIV-Related Incidents

Method of case	Total	Did not meet case definition	Valid PIV cases
Cases where "PIV" variable marked "yes"	734	71	663
Additional cases identified through keyword search of narrative fields	269	16	253
Total	1003	87	916

meet the criteria of a PIV incident as defined in this study. Thirty-nine of these incidents involved cars and trucks being assembled in the plant or a tractor trailer incident occurring outside the plant, 16 employees were using work savers (pedestrian-operated lifts) and 16 incidents did not involve PIVs.

Keyword Search

An additional 269 incidents (Table I) were identified through the keyword search of the free text describing the incident. A review of narrative descriptions of these incidents indicated that a PIV was a factor in all but 16. False positives (pivot bolt, pivoted on right leg, pivot hanger, pivot unit) identified in the computerized keyword search were picked up while searching for the string of letters PIV. A total of 253 cases (28%) were added to the 663 valid cases that had been coded “yes” and meet the study criteria, bringing the total number of PIV-related incidents that met the inclusion criteria to 916 (Table I).

Almost half of the injuries associated with PIV maintenance and mounting or dismounting were not coded as a PIV-related incident but were identified through the keyword search. Incidents where a PIV directly struck a pedestrian, a pedestrian was pinned between a PIV and a fixed object, or PIVs collided with fixed objects or other PIVs were more likely to be coded to indicate a PIV was a factor in the incident. Incidents where the injured worker was struck indirectly by a rack or a bin that was bumped or pushed by a PIV were less likely to be coded as a PIV incident.

Fatal Cases

The 916 incidents resulted in three fatalities. One electrician sustained a fatal transection of the thoracic aorta and a fractured pelvis when a forklift struck an obsolete electrical panel that fell onto the employee. An apprentice electrician was fatally injured when he was pinned between the manlift platform from which he was working and an I-beam, while elevating himself to work on an electrical fixture on the ceiling. The third fatality was a machine repairman who died from crushing injuries when he backed his forklift into an overhead chute in the basement and was pinned between the forklift and the chute.

Characteristics of Powered Industrial Vehicle Incidents

Approximately 70% of the forklifts and other PIVs are moving when the incidents occur, i.e., collisions with pedestrians, other PIVs or obstructions, passenger fallen from moving PIV, and injuries that occurred while driving over potholes or steel plates on the floor. Approximately

25% of the incidents involved vehicles that were not moving. These incidents occurred while mounting or dismounting, PIV maintenance, work from elevated platform, pedestrian tripped over the forks of a parked forklift, and driver burned after releasing radiator caps. From the limited detail provided for 5% of the incident descriptions, it could not be determined whether the vehicle was moving.

PIV-related Pedestrian Injuries ($n = 322$)

The most common type of PIV-related incident, 322 of 916 (35%), resulted in a pedestrian injury (Table II). The most frequent type of pedestrian incident was a collision with a pedestrian or a pedestrian struck by a PIV ($n = 164$, 51%). Thirty-four incidents occurred when a PIV pushed, bumped or struck an object which subsequently struck an employee, 33 when a load being carried was dropped, fell, or lowered onto a pedestrian, 25 when an employee was pinned between a moving PIV and a fixed object or a rack or a bin.

Collision with Other PIVs, Fixed Objects or Other Obstructions ($n = 143$)

Almost 16% of the incidents (143 of 916) occurred when a PIV was involved in a collision (Table III). Over half ($n = 75$) of the 143 collision incidents occurred when a PIV struck a fixed object such as a pole, wall, overhead door, or a non-fixed object such as a rack or a bin. Ten of the collision incidents occurred when the driver's foot was outside the travel lines of the vehicle and was pinned or struck on a fixed object. Five incidents involved PIV collisions with bicycles which are used for interplant transport. The 53 collisions involving two PIVs accounted for 37% of the collision incidents and 6% (53 of 916) of the total incidents involving PIVs; on average, they resulted in 94 lost workdays each.

Of the 53 incidents involving two PIVs, forklift collisions with personnel carriers/carts accounted for 54%, forklift collisions with other forklifts accounted for 35%, and carts colliding with other carts accounted for 7%. In almost 90% of the incidents involving the personnel carriers/carts, the cart collided with a forklift. It could not be determined what types of vehicles were involved in 4% of the incidents.

Mounting or Dismounting a PIV ($n = 138$)

Of the 916 incidents, 138 (15%) occurred when a driver was mounting or dismounting a PIV. The incidents primarily consisted of sprained knees and ankles, or bumped heads, knees, and elbows when entering or exiting. These incidents often involved grease or an object on the floor or slippery vehicle access steps. Of the 138 incidents that occurred

TABLE II. Frequency and Percent of PIV Incidents Involving Pedestrians, Frequency and the Percent Resulting in Lost Workdays (LWDs), and Total LWDs for Each Type of Incident

Pedestrian incidents	Frequency (%) of total pedestrian incidents	Frequency (%) with workdays	Total lost workdays	Average LWD^b per LWD incident
Pedestrian struck by PIV	164 (50.9%)	77 (47%)	3,867	50
PIV struck object which struck pedestrian	34 (10.6%) ^a	16 (47%)	2,796	175
Load, fell/lowered onto employee	33 (10.2%)	21 (64%)	2,218	106
Pedestrian pinned	25 (7.8%)	11 (44%)	947	86
Lift/position load	25 (7.8%)	9 (36%)	286	32
Pedestrian tripped/fell into PIV	16 (5.0%)	4 (25%)	169	42
Pedestrian avoiding oncoming PIV, struck object	11 (3.4%)	2 (18%)	98	49
Pedestrian struck by load	8 (2.5%)	2 (25%)	12	6
PIV ran over pedestrian's foot	6 (1.9%)	4 (67%)	68	17
Total pedestrian incidents	322 (100%)	146 (45%)	10,461	72

^aIncludes one fatality.^bLWD = Lost Workdays.**TABLE III.** Frequency of Collision Incidents, Frequency (%) of Collision Incidents Resulting in Lost Workdays (LWDs), Total Lost Workdays, and Average Lost Workdays

Collision incidents	Frequency	Frequency (%) with lost workdays	Total LWDs^b	Average LWD/LWD incident
Collision w/fixed object	75 ^a	23 (31%)	1,173	51
2 PIV collision	53	28 (53%)	2,624	94
Foot outside travel lines	10	7 (70%)	205	29
Collision with a bicycle	5	2 (40%)	13	7
Total	143 (100%)	60 (42%)	4,015	67

^aIncludes one fatality.^bLWD = Lost Workdays.

while mounting/dismounting vehicles, 59 (43%) of the incidents resulted in lost workdays, a total of 2,489 lost workdays, an average of 42 days per incident.

Other Incident Types

Fifty-eight (6%) incidents occurred while performing maintenance on PIVs. Twelve occurred when radiator caps were removed and employees were burned by hot radiator fluid. The other maintenance-related incidents included a variety of tasks such as changing batteries or propane tanks, and making adjustments.

Mechanical failure of the PIV was a factor in 29 incidents (3%). A stuck accelerator was mentioned as a

contributing factor in four of the incidents. In three incidents, the driver was injured when the PIV accelerated and lunged forward unexpectedly. Broken hydraulic lines and radiator hoses accounted for two incidents each, brake failure contributed to two, and a locked steering column was listed as a factor in two incidents. In three incidents, the driver was injured when the PIV's overhead guard fell and struck him. The remaining 11 mechanical failure incidents were single events such as a broken axle on a personnel carrier or a forklift which caught fire.

Twenty-seven injuries occurred while an employee was working from a platform that was elevated by a forklift or a scissor jack, aerial basket, manlift, or maintenance scissors. Twenty-five incidents (3%) occurred when employees were

manually positioning or adjusting a load or lifting material from a forklift. Twenty-two incidents (2%) occurred when the driver or a passenger fell or jumped from a moving PIV. This category does not include employees working from elevated platforms. Eleven of these injuries resulted when an employee was riding as a passenger on a personnel carrier or a cart and fell from the vehicle. In the other 11 incidents, the driver either jumped or was thrown from a runaway vehicle descending a ramp.

Twenty-three injuries (2.5%) occurred when a PIV rode over an uneven floor surface such as a pothole, dock plate, railroad tracks, or a steel plate. These injuries were primarily sprain/strain injuries involving the back, shoulders, and wrists. Fifteen other incidents occurred when the PIV drove over an object and the steering wheel spun, twisting the wrist or hand of the driver.

Seven incidents occurred when a PIV either fell out of the back of a tractor trailer between the loading dock and tractor trailer (2), into a railroad well (1), a pit (1), or off a ramp (3). In the two incidents where the forklift fell out of the back of a tractor trailer, the forklift did not overturn because it was suspended between the tractor trailer and the loading dock. The PIV overturned in the other five incidents. In the incidents where a PIV tipped over, three forklifts and two 3-wheeled carts were involved.

Description of the Injuries

The most common injuries were contusions (35%), sprains/strains (28%), lacerations (11%), fractures (10%), burns (4%), foreign bodies in the eye (3%), and abrasions (3%). Together, these seven types of injuries accounted for more than 94% of all the PIV-related injuries. The body part most commonly injured was the foot or ankle (15%), lower leg or knee (14%), and back (13%). Forty-eight percent of all contusions involved the lower extremities which includes thigh, hip, and toe. The back was injured in almost one-third

of sprains and strains. Fractures most commonly involved the toes, feet, and ankles (51%).

Rates of Injury Associated with Powered Industrial Vehicles

The 33 plants involved in vehicle production and distribution had an overall PIV-related injury rate of 5.4 injuries/1,000 workers per year (Table IV). The highest average injury rate (17.9 PIV-related incidents/1,000 workers per year) occurred among the 17 Parts Depots, in which rates ranged from zero to 42.6 injuries/1,000 workers per year. The average injury rate among the three stamping plants in the study sample was 8.4/1,000 workers per year, with a range of 5.4–12.9. The eight power train plants averaged 4.0 PIV-related injuries/1000 workers per year, with a range of 3.1–5.9. The lowest injury rate occurred among the five assembly plants in the study sample (3.7 PIV-related injuries/1,000 workers per year, range 2.3–5.3).

Days Away From Work Associated with Powered Industrial Vehicle Incidents

Of the 913 non-fatal injuries, 41% resulted in an employee missing at least one full day of work. These 372 lost workday incidents incurred a total of 22,730 lost workdays, the minimum number of days away was one and the maximum was 652 with an average of 61 days per lost workday incident with a median value of 17 days. In contrast, the average number of lost workdays associated with all non-PIV injuries resulting in lost time in this worker population was seven [Warner et al., 1998], almost a nine-fold difference. Sixty-six workers were off work for 100 or more days due to injuries sustained in a PIV incident. These 66 incidents resulted in 16,306 lost workdays, an average of 247 days per incident. Almost half (47%) of the injuries requiring more than 100 days off involved pedestrians.

TABLE IV. Rate of PIV Related Injury Per 1,000 Person—Years (Hourly Workers in 33 Plants)

Plant type	# of PIV related injuries	Person years	Rate per 1,000 person-years
Parts (n = 17, 1/90–6/92)	104	5,820	17.9
Stamping (n = 3, 7/89–6/92)	237	28,227	8.4
Power train (n = 8, 7/89–6/92)	167	41,480	4.0
Assembly (n = 5, 7/89–6/92)	214	57,480	3.7
All plants combined	722	133,007	5.4

Fifteen percent of collisions involving two PIVs and 10% of pedestrian injuries resulted in 100 or more lost work days each.

Age of the Injured Workers

More than 75% of the injuries occurred to workers between the ages of 35 and 54. Reflecting the generally mature work force in this corporation; only 3% of the injured workers were less than 30 years old. The age distribution of injured pedestrians was similar to that of injured PIV operators.

Gender

Eighty-eight percent of the workers injured in PIV-related incidents were males. Females were overrepresented in incidents where a passenger fell from a PIV; five of the 11 (45%) injured workers were female. Twenty-four percent (13 of 53) of the workers injured in two-vehicle collisions were female.

Hourly vs. Salaried Workers

Of the 916 injured employees, 867 (95%) were hourly workers. Incidents where a pedestrian was struck by a PIV were the most frequent type of incident among both hourly and salaried workers. Salaried workers were overrepresented in collisions involving two PIVs (9 of 53 incidents, or 17%), typically as occupants of personnel carriers or carts.

Time in Job Classification

More than 20% of the PIV-related injuries (190 of 916) occurred to workers in the first year in their job class (Table V). Among the employees with less than one year in their job class, 40% of the injured pedestrians and 50% of PIV operators involved in collision of two PIVs were injured in the first month in their job class. Thirty-five percent of the injuries associated with driving a PIV (twisting around backwards to drive, vibration, seat not absorbing bumps) occurred to workers in the first year in their job class.

TABLE V. Time in Job Class for Workers Injured in PIV-related Incidents

Time in class	Number
<1 month	76
1–5 months	48
6–11 months	66
1–4 years	130
5+ years	596
Total	916

Conversely, 85% of the injuries that occurred when a load was dropped or lowered onto an employee or when the employee was mounting/dismounting involved workers with more than one year in their job class. Ten of the 11 (91%) passengers who were thrown or fell from a PIV had one or more years of experience in their job class. Forty-three of 46 injuries (93%) that occurred during a maintenance task occurred to workers with more than one year in their job class. Eleven of the 12 employees who were burned by antifreeze after releasing a radiator cap had more than five years of experience in their job class.

Shift

Slightly over half (52%) of all PIV-related injuries occurred on the first shift, 37% on the second shift, and 12% on the third shift. The circumstances of the incidents varied across shifts, probably because the first and second are typically production shifts while the third concentrates primarily on maintenance activities. During the third shift, fewer pedestrian injuries occurred and no PIVs fell from tractor trailer trucks or off loading docks. A larger proportion of incidents on the third shift were associated with passengers falling from PIVs, operators who had something fly in their eye while driving, and operators traveling with their foot outside the travel lines of the PIV. Regarding the time of day when incidents occurred, “pedestrian struck by PIV” incidents most frequently occurred between 9 a.m. to 10 a.m., 11 a.m. to 1 p.m., and 4 p.m. to 6 p.m.

DISCUSSION

Powered industrial vehicles are associated with exceptionally severe injuries, as reflected by the average of 61 lost workdays per lost workday injury, almost nine times the average for all other automobile manufacturing injuries reported by Warner et al. [1998]. This research also demonstrates one of the uses of an injury and illness surveillance system that collects data from a large number of automobile manufacturing plants and merges the data into a single corporate system. The surveillance system provided a rich source of data from which the details of a range of occupational illness and injury problems can be examined. This system can also be used to identify specific plants or specific types of injury problems that can be targeted for intervention. This work also demonstrates the value of using computerized keyword searches to identify PIV-related incidents that were not coded as a PIV incident. This paper focused on injuries associated with PIVs because of their relative frequency and potentially severe consequences.

The single largest group of PIV-related incidents involved pedestrians who were struck by a forklift or other

PIV. During the 3-year study period, PIVs striking pedestrians resulted in one fatality and over 10,000 lost work days, an average of 72 days per lost workday incident. Pedestrians struck by PIV injuries resulted in slightly more than 10 times the lost workdays for other types of injuries in the surveillance system, which resulted in an average of seven days away from work per lost workday incident. One common injury scenario involved employees who moved suddenly into the aisle from behind fixed equipment and were struck by a PIV. The pedestrian was usually not visible to the driver of the PIV, nor was the PIV visible to the pedestrian until just before the incident happened. "Pedestrian struck by PIV" incidents were overrepresented during shift changes and other plant-wide breaks. PIV traffic should be minimized during times of peak pedestrian flow. Traffic planning should take into consideration the path and destination of the pedestrian flow (e.g., time clocks, plant exits, cafeterias, etc.). Consideration should be given to separating PIV and pedestrian traffic by installing barriers to protect pedestrians or assigning separate aisles for PIV traffic and others for pedestrians. It may be useful to restrict the use of forklifts and other PIVs near time clocks, exits, break rooms, and cafeterias, particularly when a large number of pedestrians must pass through an area in a short time, such as at the end of a shift or during plant-wide breaks.

The most severe injuries occurred to pedestrians who were struck by PIVs and PIV operators involved in collision incidents. Even though seven nonfatal injuries occurred when a forklift fell from a loading dock or overturned, a study of forklift-related deaths shows that nationally these type of incidents are the most frequent circumstance leading to forklift-related fatalities [Collins et al., 1999b].

More than half of the collision incidents occurred when a PIV struck a fixed object such as a roof supporting pole or a non-fixed object such as a rack or bin. The PIV driver was generally injured when the PIV struck a fixed object; however, in most of the incidents in which the PIV struck a non-fixed object, it was a pedestrian who was injured. The incidents where a rack, bin, or other object was pushed into a pedestrian by a PIV resulted in 175 lost workdays per lost workday incident, more lost workdays per lost workday incident than any other type of incident. Supervisors and each employee should examine the area around his/her workstation to determine if there are bins, racks, tables or other objects that, if struck by a powered industrial vehicle, could create a pinch point or result in an employee's injury. Consideration should be given to installing poles or other fixed barriers to prevent encroachment of equipment into workspaces where a risk of worker entrapment exists. Improving ways to move materials in and out work areas and/or improving rack and bin delivery and storage at workstations should be considered.

Personnel carriers/carts were overrepresented in collision incidents involving two PIVs (60% of crashes). Employees who drive personnel carriers, floor scrubbers, three-wheel carts, and PIVs other than forklifts, generally do not receive the same level of training as forklift operators and the operators of these vehicles are likely to benefit from more extensive training on their safe operation.

The task of mounting or dismounting PIVs is responsible for a significant number of injuries. If steps or hand grips are poorly designed, or inconveniently located, the driver may be tempted to jump off the vehicle. The manufacturers of industrial vehicles should consider design improvements that make it simple and safe to enter and exit the cab without contorting the body into awkward positions or requiring the driver to jump up or down from the vehicle. A significant number of the injuries occurred when a PIV driver jumped from the vehicle and twisted a knee or ankle when landing on a greasy spot on the floor or a bolt or other small part. Employers should practice good housekeeping to keep floors free of debris, grease, and oil.

In an analysis of 24,708 worker injuries presenting to a sample of hospital emergency rooms in the National Electronic Injury Surveillance System, more than 70% of the PIV-related injuries among the general working population involved workers 35 years of age or younger [Stout-Wiegand, 1987]. In the current study, over 75% of the injuries occurred to workers between the ages of 35 and 54. The older age structure among automobile manufacturing workers can in part account for this difference. The higher than average wages, low turnover rates, and union efforts to preserve jobs all contribute to the career orientation and older age of automobile manufacturing workers. Additionally, in this corporation, newly hired workers are expected to begin their career on the assembly line and move into the position of forklift operator after several years of experience.

One of the key findings in this study is the overrepresentation of vehicle operators with limited experience; 40% of all incidents involving first-year operators occurred during their first month as an operator. Unfortunately, information on the experience of all drivers is not available. The requirements for becoming a skilled operator of a powered industrial vehicle include meeting physical requirements for vision, hearing, and coordination, participating in powered industrial vehicle training, and passing a test of knowledge and ability as an operator before obtaining a forklift operator's license. A safe area should be sectioned off for newly trained drivers to become thoroughly familiar with their vehicle and practice picking up, transporting, and stacking loads before working in production areas.

As part of every employee's safety training, each employee should be made aware of the hazards associated with working near PIVs. Two major differences between the operation of PIVs and automobiles should be emphasized to

operators with regard to pedestrian safety. First, the field of vision of the PIV operator is much more restricted and the driver's ability to recognize oncoming hazards can be significantly diminished, particularly when the vehicle is loaded and/or the driver is looking over his shoulder to drive backwards. Secondly, once a forklift driver identifies a hazard, the stopping capability of a forklift, particularly when it is loaded, is much less than that of an automobile traveling at a similar speed. Sudden stops can cause the PIV's load to fall and strike a pedestrian or cause the forklift to overturn.

Despite driver training, our highway system would never survive without the laws and well established rules that govern highway travel. Safe driving practices and rules of the road should be clearly explained to PIV drivers and enforced when appropriate. To help supervisors know and understand the safety rules they are responsible for enforcing, it has been recommended that supervisors should be encouraged to participate in training programs for PIV operators [Swartz, 1993].

During interviews in a follow-up case-control study [Collins et al., 1999b], vehicle operators commented that 5-minute safety talks are a useful way of disseminating safety information to employees. These safety talks are part of the ongoing safety training at the company and are presented to small groups of workers by their supervisor or a representative of the Safety Department to describe a recent injury to a fellow employee or other safety information.

Company policy requires that all PIVs be painted yellow to make them clearly visible to pedestrians and other PIV operators. Every effort should be made to improve worker awareness when a PIV is in close proximity. The use of audible beepers might be effective in work environments where ambient noise levels will not interfere with their detection by coworkers. Lights that flash when a PIV is in operation may improve awareness levels regardless of plant noise levels.

This study of powered industrial vehicle injuries provides information that can be used by safety professionals, lift truck manufacturers, PIV operators, supervisors, union personnel, and workstation designers to reduce the risk of PIV incidents. Reducing the risk of powered industrial vehicle incidents requires a combination of a safe work environment, comprehensive training for operators of all types of PIVs, and implementing and enforcing systematic traffic management.

RECOMMENDATIONS FOR PREVENTION EMERGING FROM THIS STUDY

1. A common injury scenario involved employees who moved suddenly into the aisle from behind fixed equipment or stored materials. Pedestrians should be extremely cautious when entering aisles that are

traveled by forklifts and other powered industrial vehicles (PIVs). The operators of forklifts and other PIVs should be alert for pedestrians stepping out from between machines or stored materials.

2. Forklift and other PIV traffic should be minimized during shift changes or other times when a large number of pedestrians pass through an area in a short period of time.
3. Consideration should be given to separating pedestrian and PIV traffic by installing barriers to protect pedestrians or assigning aisles that are available only to PIV traffic and other aisles that are only available for pedestrian traffic.
4. The area around each workstation should be examined to determine if there are racks, bins, tables, or other objects that if struck by a forklift or other PIV could create a pinch point that could result in an employee's injury.
5. Employees who drive personnel carriers, floor scrubbers, three-wheel carts, and PIVs other than forklifts, should receive training on the safe operation of these vehicles.
6. Due to the significant number of injuries that occur while mounting and dismounting, the manufacturers of PIVs should consider design improvements that make it simple and safe to enter and exit the cab without contorting the body into awkward positions or requiring the driver to jump up or down from the vehicle.
7. A significant number of dismounting injuries occurred when the operator jumped from the vehicle and twisted a knee or ankle when landing on a greasy spot on the floor or a bolt or other small part. Employers should practice good housekeeping to keep floors free of debris, grease, and oil.
8. A safe area should be sectioned off for newly trained operators to become thoroughly familiar with their vehicle and practice picking up, transporting, and stacking loads before working in production areas.
9. Safe driving practices and rules of the road should be clearly explained to PIV operators and enforced when appropriate.
10. In work environments where the ambient noise levels will not interfere, the use of audible beepers might be an effective means of notifying workers when a PIV is in close proximity. Lights that flash when a PIV is in operation may improve awareness levels regardless of plant noise levels.

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