Work-related Amputations in Michigan, 2007

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Michigan Department of Community Health

MDCH

Jennifer M. Granholm, Governor

Janet Olszewski, Director

MICHIGAN STATE UNIVERSITY

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A Joint Report

of the

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EXECUTIVE SUMMARY

The Division of Occupational and Environmental Medicine at Michigan State University has developed a system for collecting data on work-related amputations in Michigan. This report characterizes these injuries for 2007. The salient findings are as follows:

- The system identified a total of 708 Michigan resident work-related amputations. This corresponds to a rate of 15.2 per 100,000 workers. In comparison, the official U.S. Department of Labor estimate (160)[1] was 77% lower.
- Hospital medical records identified 597 cases. Workers' compensation lost work time claims data identified 111 additional cases which were not found using medical records alone.
- The amputation rate for males was seven times that for females. Among males, rates were highest for those aged 20-24.
- Forty-five percent of the incidents occurred among those working in the manufacturing industry. The specific manufacturing groups with the highest rates were Paper Manufacturing and Primary Metal Manufacturing.
- Power saws were the leading cause of amputations.
- Ninety-five percent of amputations involved fingers. One in nine of these finger injuries involved the loss of multiple fingers.
- Overall, upper extremity amputations occurred most often on the left side. However, left-hand dominant workers sustained more right-side injuries.
- Workers' compensation was the expected source of payment of hospitalization or emergency department care for 76% of the cases for which payment source was identified. Payer source could not be determined for 8.4% of medical records reviewed.
- The Michigan Occupational Safety and Health Administration (MIOSHA) inspected 68 of the 140 worksites referred by MSU and assessed an average of nine violations and $1,175 in fines per inspection.

All 131 Michigan acute care hospitals participated in this surveillance system and were the primary source of data for most (84%) of the identified cases for 2007. Data provided by the Michigan Workers' Compensation Agency identified an additional 16% of cases that were missed by hospital-based surveillance alone. The workers' compensation data were limited to individuals who requested wage replacement and did not include individuals who had claims for medical care cost reimbursement alone. Therefore, the surveillance system missed those cases in which injured workers were treated in non-hospital settings or at out-of-state hospitals and did not request wage replacement.

The Michigan work-related amputation surveillance system produces valuable information. It identifies hazardous worksites that otherwise might go undetected and facilitates remediation at these worksites. It provides information that can be used to characterize workers and industries with high amputation rates. Finally, it provides the best estimate of the true number of amputations that occur in Michigan. This asset has been demonstrated in just the system's second year: while the surveillance system of the Bureau of Labor Statistics in the U.S. Department of Labor – which generates an estimate based on a sample of employer injury logs – reported that the number of Michigan workers sustaining an amputation decreased 70% between 2006 and 2007 (590 and 160 cases, respectively), our surveillance system – based on medical records and workers' compensation claims data – found a decrease of only 4.3% between 2006 and 2007 (740 and 708 cases, respectively).

This report will be updated annually and made available on the websites of the Michigan Department of Community Health, Division of Environmental Health, and the Michigan State University Division of Occupational and Environmental Medicine.

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INTRODUCTION

An amputation is one of the most debilitating injuries that can occur in the workplace. Unlike many other types of injuries, amputations often cannot be fully mended through medical or surgical treatment. Thus, workers sustaining amputations may be forced to make significant physical and psychological adjustments both in the workplace and their personal lives.

The Bureau of Labor Statistics estimates that 7,320 amputations resulting in days away from work occurred nationally in the private sector in 2007. The median number of lost workdays was 21 for amputation cases compared to seven days for all work-related injuries.[1] Reducing the incidence of work-related amputations is a federal priority. Between 2001 and 2004, the National Institute for Occupational Safety and Health (NIOSH) collaborated with the Council of State and Territorial Epidemiologists (CSTE) and staff from NIOSH-funded states to develop a set of nineteen occupational health indicators.[2] Two of the indicators were measures of work-related amputations.

The Michigan Occupational Safety and Health Administration (MIOSHA) was established in 1974. MIOSHA is part of the Michigan Department of Energy, Labor and Economic Growth (MDELEG). Its mission is to help assure the safety and health of Michigan workers through education and training, consultation, and enforcement. MIOSHA developed a strategic plan for 2004-2008 that included an objective to reduce amputations by 20%[3]. One general strategy listed is to develop cooperative efforts with the occupational safety and health community to identify and address workplace hazards.

In May 2004, staff in the Occupational and Environment Medicine (OEM) Division within Michigan State University's College of Human Medicine began reviewing hospital records for patients treated for amputations and referring cases meeting designated criteria to MIOSHA. MIOSHA referrals were tracked through 2005. Beginning with 2006 data, a surveillance system to track all work-related amputations treated at Michigan hospitals was established.[4] In addition, data were obtained from the Michigan Workers' Compensation Agency to supplement the hospital-based data and provide a more complete count of work-

related amputations. This report summarizes work-related amputations identified by this surveillance system for the second full year of data, 2007.

DATA SOURCES and METHODS

Data Sources

Medical records were used to identify work-related amputation cases treated at hospitals. Under the Michigan Public Health Code, Michigan hospitals are required to report these conditions.[5] MSU administers this law for MDELEG and medical records are sent directly to MSU's OEM Division.

The MDELEG Workers' Compensation Agency provided access to a database of claims for wage replacement due to lost work time. To be eligible for wage replacement, an individual must have been out of work seven consecutive days (i.e. five weekdays and two weekend days) or have sustained "specific losses." These specific losses include amputations in which at least a full phalanx is lost.

MIOSHA inspection reports were the source of information on the number of violations cited and the total penalties assessed for worksites referred to MIOSHA by the surveillance system for inspection.

The Current Population Survey (CPS), conducted by the U.S. Census Bureau for the Bureau of Labor Statistics, was the source of the estimated number of employed Michigan residents by defined age groups, gender, and industry groups for 2007. The BLS Local Area Unemployment Statistics (LAUS) system, which utilizes CPS data in combination with data from the BLS Current Employment Statistics program and State unemployment insurance systems, was the source of the number of Michigan residents employed by county of residence. The CPS and LAUS employment data were used to calculate worker-based amputation rates.

Methods

A case identified using hospital medical records was defined as an individual aged 16 years or older receiving medical treatment at a Michigan hospital for whom: a) an amputation diagnosis was assigned (ICD-9-CM[6] codes 885.0-.1, 886.0-.1, 887.0-.7, 895.0-.1, 896.0-.3, and 897.0-.7); and b) the incident was documented as having occurred at work in 2007. The level of hospital care included outpatient surgery, emergency department visit, and hospital admission. A workers' compensation case was defined as an individual aged 16 years or older who submitted a claim for lost work time wage replacement for an injury occurring in 2007 that was coded as an amputation. Cases that listed body parts that were inconsistent with upper or lower extremity amputation (e.g., "eye", "back") were excluded.

Worksites of hospital-treated cases[*] that met the following additional criteria were referred to MIOSHA: a) the worksite was located in Michigan; and either b) the company was within an industry identified by MIOSHA as having a high injury rate or c) the amputation was caused by a mechanical power press.[Δ] Up through mid-September 2008, the industry groups meeting the second criterion above were those that had two-digit Standard Industry Classification (SIC)[7] major industry group codes among the following: 20, 24, 25, 30, 33, 34, 35, 37.[†] MIOSHA then revised this list and defined the industries using North American Industry Classification System (NAICS)[8] codes. These industries

[*] Cases identified solely through workers' compensation records were not referred to MIOSHA. Data provided by the Michigan Workers' Compensation Agency can be used only for research and not for enforcement purposes.

[Δ] Employers are required to report injuries caused by mechanical power presses directly to MIOSHA within 30 days of the incident. MIOSHA uses referrals for amputations caused by power presses to identify companies that fail to comply with this reporting regulation. Worker's names are used in this process.

[†]

SIC Major Group Code	Industry
20	Manufacturing – Food and Kindred Products
24	Manufacturing – Lumber and Wood Products, Except Furniture
25	Manufacturing – Furniture and Fixtures
30	Manufacturing – Rubber and Miscellaneous Plastics Products
33	Manufacturing – Primary Metal Industries
34	Manufacturing – Fabricated Metal Products, Except Machinery and Transportation Equipment
35	Manufacturing – Industrial and Commercial Machinery and Computer Equipment
37	Manufacturing – Transportation Equipment

were within industry subsectors defined by NAICS three-digit codes 312, 321, 326, 327, 331, 332, 333, 336 and specific industry six-digit codes 423930 and 561730.*

An MSU referral to MIOSHA consisted of copies of medical records that documented the injury, its cause, and the employer (workers' names were suppressed except for cases potentially involving power presses). MIOSHA staff reviewed referred cases to determine if they would conduct a worksite inspection.

Some medical records lacked information as to whether an amputation occurred at work. In addition, for some work-related cases, the employer was not identified, information necessary to determine if an amputation met the criteria for a MIOSHA referral. In either of these instances, MSU staff attempted to interview the patient by phone to ascertain the salient information.

Referrals were made to MIOSHA between February 2008, when hospitals started to provide medical records for 2007 to MSU, and March 2009.

For all work-related amputation incidents identified from hospital medical records, data collected included: hospital name, date of admission, patient demographics, city and county of residence, primary source of payment, company name, address, SIC code, NAICS code, injury date and time, nature of injury (i.e., body part and amount amputated), dominant hand, and cause of injury. For cases referred to MIOSHA, additional information was obtained, including: date of referral, whether an inspection

*

NAICS Code	Industry
312	Beverage and Tobacco Product Manufacturing
321	Wood Product Manufacturing
326	Plastics and Rubber Products Manufacturing
327	Nonmetallic Mineral Product Manufacturing
331	Primary Metal Manufacturing
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
336	Transportation Equipment Manufacturing
423930	Recyclable Material Merchant Wholesalers
561730	Landscaping Services

was performed, inspection date, number of violations, power press violations, total fines assessed, and whether the company had been on MIOSHA's "priority list[*]."

Once case ascertainment from medical record review and patient interviews was completed, records in the work-related amputation database were manually linked to records in the workers' compensation claims database. There were several steps in the record-linkage process. First, definite matches were identified. Of the remaining cases in each database, possible matches were identified and critical data elements were compared to identify additional definite matches. Initially, definite matches were those for which: a) full social security number and injury date were identical; or b) last four digits of social security number, first three letters of last name and injury date were identical; or c) last four digits of social security number, date of birth and injury date were identical. Possible matches among the remainder involved matches on any of the following: last four digits of social security number, first three letters of last name, date of birth, date of injury (when this was unknown, hospital admission date was used), and company. The matching process was performed on the entire 2007 workers' compensation claims database to allow for links to cases not categorized as amputations by that system. Upon completion of record linkage, cases were assigned to one of the following categories: 1) medical record amputation case matched to a workers' compensation amputation case; 2) medical record amputation case matched to a workers' compensation non-amputation case; 3) medical record amputation case with possible match to a workers' compensation case (any injury type); 4) medical record amputation case with no match to a workers' compensation case; or 5) a workers' compensation amputation case with no match to medical record amputation case.

Work-related amputation rates were calculated by gender, age group, county of residence and type of industry by dividing the number of workers sustaining an amputation by the

[*] Each year, MIOSHA develops a priority list of establishments to inspect. These companies are selected because, as identified using workers' compensation records, they have a higher number of injuries or illnesses resulting in seven or more lost workdays than other companies performing similar work. In addition, MIOSHA inspects a random sample of employers each year. To evaluate if safeguards are maintained, MIOSHA also performs some re-inspections at establishments previously inspected who were found to have five or more serious violations.

number employed and multiplying the result by 100,000. Rates were not calculated for groups with fewer than six cases because these were considered statistically unreliable. Asterisks identify these cases in the tables.

SYMBOLS USED IN TABLES	
No cases occurred within category	–
Rate is considered statistically unreliable	*

Database management was conducted using Microsoft Access. Data analysis was performed using SAS software, version 9.1 of the SAS System for Windows (copyright 2002-2003 by SAS Institute Inc.).

RESULTS

One hundred twenty (120) of Michigan's 131 acute care hospitals submitted medical records to MSU. Each of the eleven hospitals that submitted no records reported that they had no work-related amputation cases in 2007. The total number of records received and reviewed was 2,063. Project staff attempted to interview 172 patients to ascertain work-relatedness and/or employer information and completed 106 of these interviews (a 62% success rate).

In 2007, 606 individuals were treated at a Michigan acute care hospital following a work-related amputation[*]. These workers made a total of 709 hospital visits for care (92 of the 606 workers made multiple hospital visits). Nearly all workers (98.5%) were Michigan residents (N=597) (Table 1). The work-related amputation rate for these hospital-treated amputations among Michigan residents was 12.8 per 100,000 workers.

[*] Some of the cases identified solely through workers' compensation records may also have been treated at a Michigan acute care hospital, but this could not be determined via analysis of that dataset.

TABLE 1
Workers treated for an amputation
at a Michigan acute care hospital, 2007

Characteristics of Workers and Healthcare Utilization	Number of Workers	%
Received treatment at a Michigan acute care hospital	606	100.0
Michigan resident	*597*	*98.5*
One hospital visit	*505*	*83.3*
Multiple hospital visits (followup care or transfer to another hospital)	*92*	*15.2*
Out-of-state resident	*9*	*1.5*
One hospital visit	*9*	*1.5*
Multiple hospital visits (followup care or transfer to another hospital)	*0*	*0.0*

Data Source: Michigan hospital medical records

Two-hundred-fifty-one (251) Michigan residents submitted workers' compensation claims for lost work time due to work-related amputation injuries in 2007. Of these 251 cases, 140 (56%) were matched with an amputation case identified from medical record review. One hundred sixty two (27%) of the 606 hospital-record-based amputation cases matched workers' compensation claims records for which the type of injury listed in the claims data was something other than an amputation (e.g., crush, fracture, laceration). Finally, medical records for 47 individuals did not provide enough information to determine work-relatedness and this could not be ascertained from subsequent attempts to interview the patients or link to workers' compensation records. Table 2 illustrates the number of cases ascertained by the two data sources and the results of the matching process.

TABLE 2
Results of matching Michigan resident work-related amputation cases ascertained from hospital medical records (N=597) and workers' compensation lost work time claims, 2007

Was Michigan Resident in Workers' Compensation Database?	Was Medical Record the Initial Source of Identification of Work-related Amputation?	
	Yes	No
Yes, with amputation injury	140	111
Yes, with a non-amputation injury	162	*
Yes, but unclear if for same incident**	6	*
No	289	*

* Cases in these cells were not ascertained because they were not relevant to identifying work-related amputations.
** These individuals were in the workers' compensation claims database, but information on injury type and incident date were missing thereby precluding linkage.

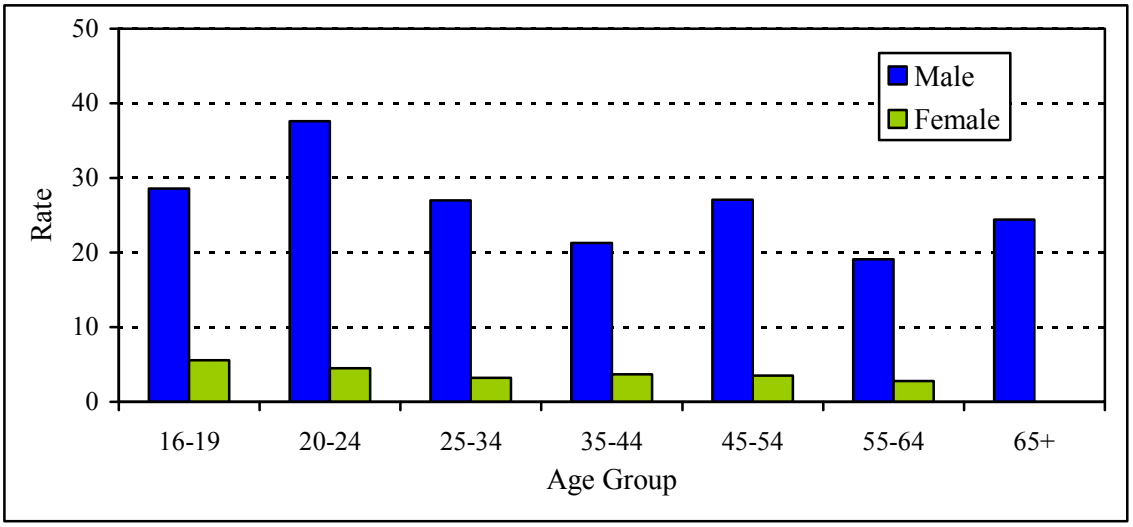
Adding the 111 cases found solely from workers' compensation records to the 597 hospital-based cases yields a total of 708 Michigan resident workers. This corresponds to a rate of 15.2 amputations per 100,000 workers. The following analyses examine these 708 cases.

Characteristics of Injured Workers

Age and Gender

Males comprised 88% of workers who sustained an amputation. Among males, rates were highest for workers aged 20-24. Figure 1 displays amputation rates by age group and gender.

FIGURE 1
Work-related amputation rates
by age group and gender
Michigan residents, 2007



Rates are the number of workers sustaining an amputation per 100,000 workers.
Statistically valid rates could not be calculated for females over age 64 due to insufficient numbers of cases.
Data Sources: Number of amputations – Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency; Number of workers employed by age group used to calculate rates - Bureau of Labor Statistics' Current Population Survey

Race and Hispanic Ethnicity

Information on patient race and Hispanic ethnicity was missing in 32% and 96% of medical records, respectively, and is not collected in workers' compensation claims (see Table A-2 in Appendix A). Due to these levels of missing information, rates for racial/ethnic groups were not calculated. Of the workers for whom race was specified (N=385), whites comprised 84% and African Americans 13%, very similar to the racial composition of Michigan workers overall (85% and 11%, respectively).

Body Part and Severity

As shown in Table 3 nearly all amputations were to fingers (95.3%). Five-hundred-seventy-eight finger amputation cases were identified through hospital medical records. These records provided more detail on finger injuries than workers' compensation claims data, thus the following analyses are limited to these cases. Of 578 finger amputation incidents, 66 (11.4%) involved multiple fingers. The distal phalanges of the middle and index fingers (sections G and J in Figure 2) were the most frequently amputated areas.

The distal phalanges comprised 81% of all finger sections lost (excluding cases in which this information was unknown). Table A-3 and Table A-4 in Appendix A provide these data for the left and right hand separately for single-finger and multiple-finger amputation incidents, respectively.

TABLE 3
Work-related amputations
by injured body part
Michigan residents, 2007

Part of Body Amputated	Number of Workers	%
Upper Extremity	684	96.6
Finger	*675*	*95.3*
Hand	*3*	*0.4*
Arm	*6*	*0.8*
Lower Extremity	22	3.1
Toe	*16*	*2.3*
Foot	*3*	*0.4*
Leg	*3*	*0.4*
Unspecified Body Part	2	0.3
Total	708	100.0

Data Sources: Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency

Overall, workers sustained more upper extremity injuries to their left side than their right side. However, left-hand dominant workers sustained more injuries to the right side (Table 4). For 36% of the 583 upper extremity amputation cases, hand dominance was not specified in medical records.

FIGURE 2
Work-related finger amputations
by digit and portion of finger lost
Michigan residents, 2007

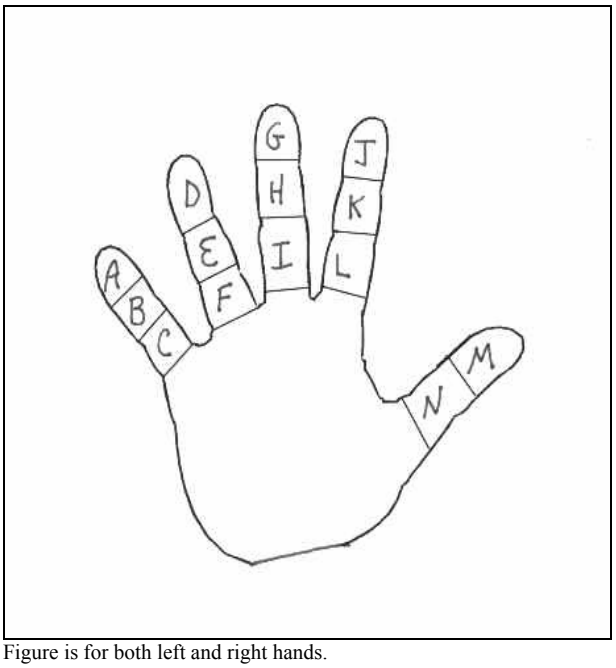


Figure is for both left and right hands.

Finger	Section	Number	%
Little	A	48	7.4
	B	20	3.1
	C	9	1.4
Ring	D	73	11.2
	E	17	2.6
	F	8	1.2
Middle	G	163	25.0
	H	19	2.9
	I	3	0.5
Index	J	150	23.0
	K	32	4.9
	L	5	0.8
Thumb	M	94	14.4
	N	10	1.5
Total		651	100.0

In 21 cases, the section(s) of finger lost was unknown.
In one case, the digit was unknown.
Data Source: Michigan hospital medical records

TABLE 4
Work-related upper extremity amputations
by side injured and dominant hand
Michigan residents, 2007

Side Injured	Dominant Hand				Total
	Right	Left	Both	Unknown	
Right	152	28	0	95	275
Left	169	19	1	116	305
Both	0	1	0	0	1
Unknown	2	0	0	0	2
Total	323	48	1	211	583

Data Source: Michigan hospital medical records

County of Residence

Table 5 illustrates the number of workers sustaining an amputation and the corresponding rate by a worker's county of residence. Note that the table does not necessarily reflect the counties with the highest risk worksites because people may work in a county other than the one in which they live. Thirteen counties had no cases and another 37 had between one and five, too few to calculate statistically valid rates. Charlevoix County had the highest rate although there were only nine cases. Among the most populous counties in the state, St. Clair County had the highest rate (26.2 per 100,000 workers) while Washtenaw County had the lowest (6.7 per 100,000).

Case Study One

A sixteen-year-old male sustained an amputation to his middle finger while working with a press brake. MSU referred the case to MIOSHA. MIOSHA subsequently inspected this worksite. They fined the company $2,400 for nine violations including one for a hazardous press brake and another for failure to report this amputation on their injury log.

TABLE 5
Number and rate of work-related amputations
by county of residence, Michigan residents, 2007

County	Number	Rate	County	Number	Rate
Alcona	1	*	Lapeer	9	22.2
Alger	2	*	Leelanau	0	-
Allegan	5	*	Lenawee	3	*
Alpena	0	-	Livingston	15	16.8
Antrim	4	*	Luce	1	*
Arenac	1	*	Mackinac	0	-
Baraga	0	-	Macomb	71	18.2
Barry	5	*	Manistee	2	*
Bay	6	11.6	Marquette	5	*
Benzie	3	*	Mason	7	50.6
Berrien	12	16.1	Mecosta	6	32.2
Branch	7	33.8	Menominee	2	*
Calhoun	10	15.3	Midland	7	17.1
Cass	6	23.3	Missaukee	1	*
Charlevoix	9	69.5	Monroe	7	9.6
Cheboygan	1	*	Montcalm	8	33.5
Chippewa	2	*	Montmorency	1	*
Clare	0	-	Muskegon	13	15.6
Clinton	8	22.2	Newaygo	8	37.6
Crawford	2	*	Oakland	63	10.7
Delta	4	*	Oceana	5	*
Dickinson	1	*	Ogemaw	2	*
Eaton	5	*	Ontonagon	0	-
Emmet	0	-	Osceola	3	*
Genesee	24	12.5	Oscoda	1	*
Gladwin	1	*	Otsego	1	*
Gogebic	0	-	Ottawa	23	17.9
Grand Traverse	9	19.5	Presque Isle	2	*
Gratiot	3	*	Roscommon	0	-
Hillsdale	5	*	Saginaw	11	12.2
Houghton	1	*	St. Clair	20	26.2
Huron	6	38.8	St. Joseph	10	33.5
Ingham	15	10.4	Sanilac	3	*
Ionia	4	*	Schoolcraft	0	-
Iosco	0	-	Shiawassee	7	21.0
Iron	1	*	Tuscola	3	*
Isabella	3	*	Van Buren	9	23.9
Jackson	16	22.2	Washtenaw	12	6.7
Kalamazoo	15	11.7	Wayne, including Detroit	98	12.1
Kalkaska	1	*	*Detroit*	*36*	*11.5*
Kent	55	18.0	Wexford	2	*
Keweenaw	0	-	Unknown	14	-
Lake	0	-	Michigan	708	15.2

* Statistically reliable rate could not be calculated. See *Methods*.
Rates are the number of workers sustaining an amputation per 100,000 workers.
Data Sources: Number of amputations – Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency; Number of workers used to calculate rates – Bureau of Labor Statistics' Local Area Unemployment Statistics

Industry

Table 6 illustrates the number and corresponding rate of work-related amputations by industry. For 25% of cases, there was insufficient information in either the medical records provided or workers' compensation claims data to make an industry classification. Thirty-nine workers were described in medical records as self-employed. Industry could be ascertained for four of these self-employed workers; the remaining 35 were included in Unknown Industry. Among two-digit NAICS industry sectors, Agriculture/Forestry/Fishing/Hunting had the highest rate (45.3 per 100,000 workers). However, there were ten times as many incidents within Manufacturing. In addition, certain three-digit NAICS subsectors within Manufacturing had very high rates, such as Paper Manufacturing (133.2 per 100,000) and Primary Metal Manufacturing (102.8 per 100,000).

TABLE 6
Number and rate of work-related amputations
by worker industry, Michigan residents, 2007

Industry Classification (NAICS industry sector code)	Number	Rate
Agriculture, Forestry, Fishing, Hunting (11)	23	45.3
Mining (21)	2	*
Utilities (22)	1	*
Construction (23)	65	24.0
Manufacturing (31 – 33)	240	27.7
Food Manufacturing (311)	*15*	*65.9*
Wood Product Manufacturing (321)	*11*	*67.3*
Paper Manufacturing (322)	*11*	*133.2*
Plastics & Rubber Products Manufacturing (326)	*17*	*36.1*
Primary Metal Manufacturing (331)	*28*	*102.8*
Fabricated Metal Product Manufacturing (332)	*41*	*52.2*
Machinery Manufacturing (333)	*23*	*37.6*
Transportation Equipment Manufacturing (336)	*47*	*12.4*
Furniture & Related Product Manufacturing (337)	*9*	*23.1*
Wholesale Trade (42)	20	14.2
Retail Trade (44 – 45)	27	5.0
Transportation & Warehousing (48 – 49)	18	11.3
Information (51)	0	-
Finance & Insurance (52)	1	*
Real Estate and Rental & Leasing (53)	7	10.9
Professional, Scientific, and Technical Services (54)	2	*
Management of Companies & Enterprises (55)	1	*
Administration & Support Services and Waste Management & Remediation Services (56)	22	12.8
Educational Services (61)	11	2.6
Health Care & Social Assistance (62)	3	*
Arts, Entertainment & Recreation (71)	13	18.9
Accommodation & Food Services (72)	50	16.2
Other Services (81)	8	3.4
Public Administration (92)	15	8.6
Unknown Industry	179	-
Total	708	15.2

* Statistically reliable rate could not be calculated. See *Methods*.
Rates are the number of workers sustaining an amputation per 100,000 workers.
Data Sources: Number of amputations – Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency; Number of workers by industry used to calculate rates: Bureau of Labor Statistics' Current Population Survey

Causes of Amputations

Causes of work-related amputations are illustrated in Table 7. (This information was unavailable in workers' compensation claims data, so the table is limited to the 597 cases that were identified via medical record review.) Sharp objects were identified in nearly one-third (32.2%) of the cases. Within this category, power saws (e.g., table saws, miter saws) predominated. Presses caused one in ten (10.2%) amputations. Medical records generally did not specify the type of press.

TABLE 7
Number of work-related amputations, by cause of injury
Michigan residents, 2007

Cause of Injury	Number	%
Sharp object	192	32.2
Power saw	*87*	*14.6*
Knife	*40*	*6.7*
Meat slicer	*17*	*2.8*
Lawn mower	*11*	*1.8*
Jointer	*4*	*0.7*
Router	*3*	*0.5*
Other sharp object	*30*	*5.0*
Press	61	10.2
Mechanical/punch/stamping press	*7*	*1.2*
Hydraulic press	*4*	*0.7*
Other press	*13*	*2.2*
Unspecified type of press	*37*	*6.2*
Pinched between objects	72	12.1
In door	*12*	*2.0*
Struck by falling object	40	6.7
Struck by object – other	8	1.3
Caught in chain/pulley/gears/belt	36	6.0
Grinder	15	2.5
Roller	7	1.2
Fan	5	0.8
Snowblower	3	0.5
Machine – other specified type	27	4.5
Machine – unspecified type	46	7.7
Other specified cause	40	6.7
Unspecified cause	45	7.5
Total	597*	100.0

* Workers' compensation claims data do not contain cause of injury information and thus are excluded from the table.
Data Source: Michigan hospital medical records

An assortment of other machinery, many of which were unspecified in the medical records reviewed, caused one in eight amputations. Another frequent cause of amputations was workers getting pinched or crushed between objects, such as doors. Finally, medical records provided no information on cause in 7.5% of cases.

Source of Payment

As shown in Table 8, workers' compensation was the expected payer in 416 (69.7%) of the 597 cases identified through hospital medical records. For 50 cases payment source could not be identified. Note that of the 181 cases for which workers' compensation was not listed as a payment source in medical records, 54 were linked to workers' compensation claims data.

TABLE 8
Work-related amputations
by payment source
Michigan residents, 2007

Expected Source of Payment	Number	%
Workers' compensation	416	69.7
Commercial insurance	82	13.7
Other	49	8.2
Not specified	50	8.4
Total	597	100.0

Data Source: Michigan hospital medical records

Temporal Characteristics

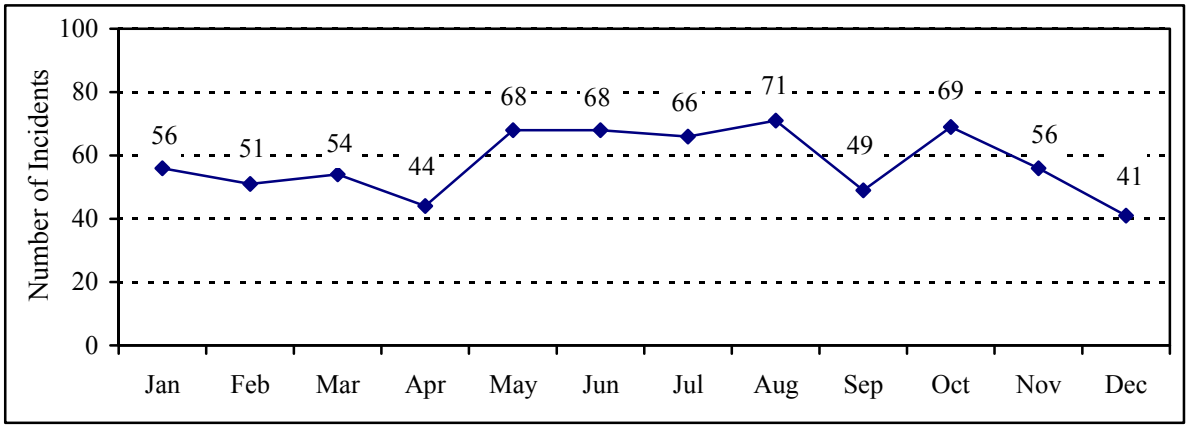
Incidents by Month

The frequency of amputation incidents was slightly elevated in the summer months while the least number occurred in December (Figure 3).

Incidents by Day of Week

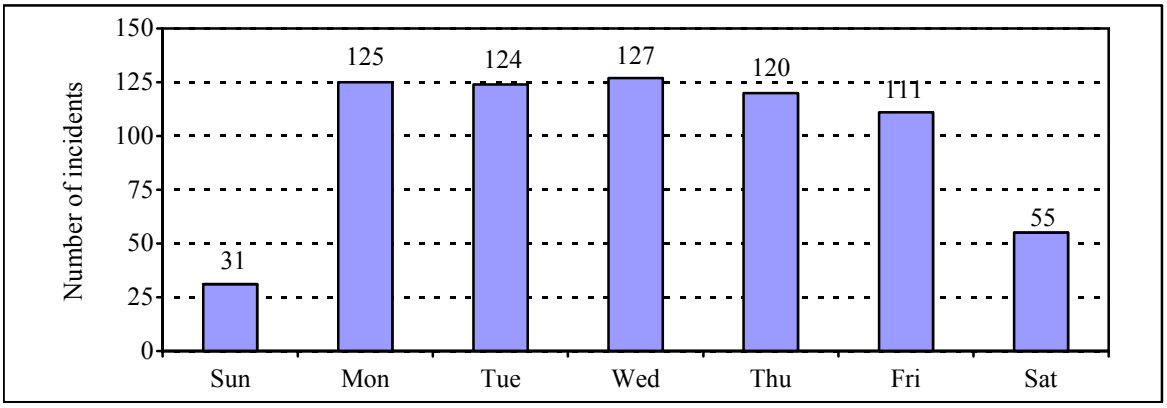
Amputations occurred more often during the normal work week (Monday through Friday) than during the weekend (Figure 4). Among the five weekdays, incidents were least frequent on Friday.

FIGURE 3
Work-related amputations
by incident month
Michigan residents, 2007



Month of incident was unknown for fifteen cases.
Data Sources: Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency

FIGURE 4
Work-related amputations
by day of incident
Michigan residents, 2007

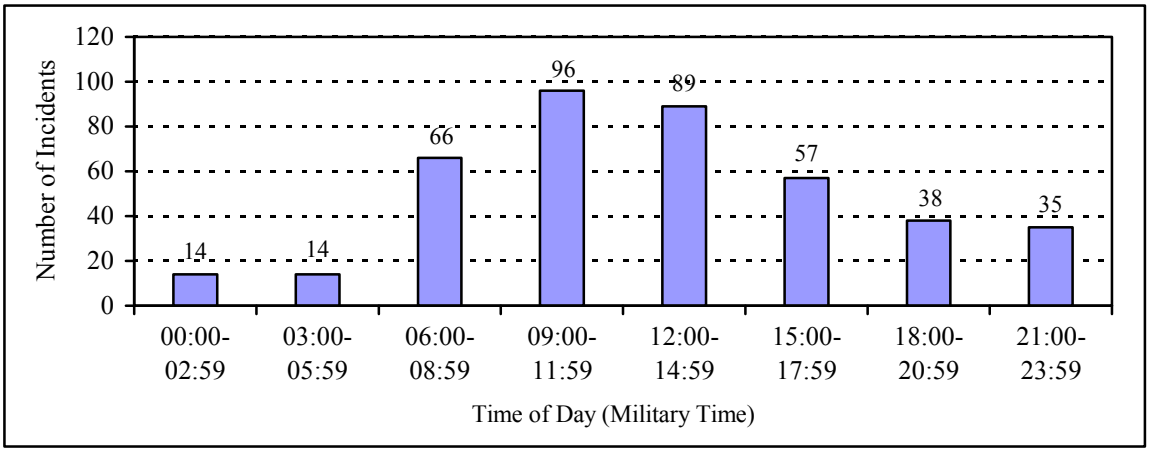


Day of incident was unknown for fifteen cases.
Data Sources: Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency

Incidents by Time of Day

Figure 5 illustrates the number of amputations by incident time. Most occurred between 9:00 AM and 2:59 PM. (Cases identified solely via workers' compensation claims are not shown because these records do not include incident time.) For 31% of incidents, the time of occurrence was unavailable in medical records.

FIGURE 5
Work-related amputations
by time of incident
Michigan residents, 2007



Time of incident was unknown for 188 cases.
Data Source: Michigan hospital medical records

Referrals to MIOSHA

One hundred forty four (144) of the 597 work-related amputations identified from hospital medical records met the MIOSHA referral criteria.* Most of these cases (N=136) involved one amputation per worksite. However, at four worksites, two separate amputation incidents occurred. Thus, MSU referred 140 worksites to MIOSHA.

MIOSHA inspected 68 worksites subsequent to MSU referrals (Table 9). It is likely that at least 55 of these worksites would not have been inspected if not for the MSU referrals since they were not on MIOSHA's priority list. Referrals were likely responsible for many of the inspections at the remaining thirteen worksites. All thirteen were inspected within six months of an MSU referral with nine receiving inspections within two months of a referral. Because of limited resources, MIOSHA does not inspect all the companies on their priority list.

* Cases identified solely through workers' compensation records were not referred to MIOSHA. See *Methods*.

TABLE 9
Outcome of work-related amputation referrals to MIOSHA
Michigan residents, 2007

Outcome of Referral	Number of Worksites	%
Worksite inspected subsequent to referral	68	48.6
Company not on MIOSHA priority list	*55*	*39.3*
Company on MIOSHA priority list	*9*	*6.4*
Unknown if company on MIOSHA priority list	*4*	*2.9*
Worksite not inspected subsequent to referral	70	50.0
Worksite inspected prior to referral	*11*	*7.9*
Worksite not inspected	*59*	*42.1*
Not yet determined*	2	1.4
Total	140	100.0

* As of December 2009, the final resolution of two referrals had yet to be determined.

Table 9 also illustrates that in 70 cases, MIOSHA did not perform inspections following MSU referrals. In eleven instances, they had already inspected the worksite prior to receiving the MSU referral. For 59 worksites that were referred, MIOSHA conducted no inspections. For twenty of these, the reasons listed by MIOSHA for not inspecting included: a) the company had closed, moved, or otherwise could not be found; b) the worksite was too large;[*] c) the company had agreed to work with MIOSHA's Consultation, Evaluation and Training (CET) Division[**]; and d) the cause of injury was a hydraulic press, not a mechanical press. For the remaining 39 referrals, MIOSHA did not provide individual explanations for their decision to not inspect. MIOSHA does not assign a referral for inspection when: there is no MIOSHA rule to cover the condition; the amputation is outside the scope of MIOSHA coverage; or the time for assigning a referral for inspection has been exceeded. MIOSHA is more apt to assign for inspection when the cause of the amputation is likely to be found by the MIOSHA safety inspector. For example, a worksite in which a machine with potentially insufficient safety features

[*] MIOSHA conducts a "focused inspection" – one that is limited to a specific alleged hazard – if they learn of an injury within six months of its occurrence. Otherwise, MIOSHA conducts a "planned inspection" which covers the entire worksite. At very large worksites, planned inspections require extensive resources.

[**] In working with the MIOSHA CET Division, employers voluntarily request an inspection and are protected from penalties. They must agree to correct all serious violations found during the voluntary inspection.

caused an amputation is more likely to be inspected than a worksite in which a worker's finger was pinched between two heavy steel beams.

The following analyses examine the outcome of the 68 MIOSHA inspections that were performed subsequent to an MSU referral. These represent inspections that were likely due to MSU referrals because, as noted previously, they either involved companies not on MIOSHA's priority list or occurred within six months after the referral.

Table 10 summarizes the number of violations identified in these inspections. For seven inspections, no violations were noted. The maximum number of violations was 39 and the median was nine. Table 11 illustrates the distribution of assessed penalties. The highest penalty was $15,750 and the median was $1,175. Most penalties were between $1,000 and $5,000. MIOSHA cited twelve companies for mechanical power press violations.

TABLE 10
Violations identified in worksite inspections
conducted following an MSU referral
Michigan residents, 2007

Number of Violations	Number of Inspections	%
0	7	10.3
1-9	29	42.6
10-19	23	33.8
20+	9	13.2
Total	68	100.0

Data Source: MIOSHA inspection reports

TABLE 11
Penalties assessed in worksite inspections
conducted following an MSU referral
Michigan residents, 2007

Penalty Assessed	Number of Inspections	%
$0	12	17.6
$1 - $999	17	25.0
$1,000 - $4,999	30	44.1
$5,000 - $9,999	8	11.8
$10,000 and above	1	1.5
Total	68	100.0

Data Source: MIOSHA inspection reports

Case Study Two

A medical record indicated that a "press" (the specific type of press was unspecified) crushed a worker's hand causing the loss of half his left middle, ring, and little fingers. Because the record did not specify the company, the worker was interviewed to ascertain this information. During the interview, in addition to identifying the company, the worker noted that he had been off work for 700 days due to this incident. The case was referred to MIOSHA. The subsequent inspection resulted in $1,850 in fines due to 20 violations, including four specific to mechanical power presses.

Discussion

The Michigan work-related amputation surveillance system is valuable in several ways. First, the system provides information to allow MIOSHA to inspect worksites and find hazards that might otherwise remain undetected. In 2007, there were as many as 68 such cases. This identification and referral system directly provides support to MIOSHA in addressing Objective 1.1 of their 2009-2013 Strategic Plan[9]:

> *Reduce by 20% the rate of worker injuries and illnesses in high-hazard industries (defined as those in the following NAICS subsectors: 312, 321, 326, 327, 331, 332, 333, 336, 423930, 561730, 622, 623).*

In addition, the system provides information on the number of amputation incidents by worker demographics and type of industry. The corresponding rates identify high risk worker groups and industries. Lastly, the system can be used to highlight temporal characteristics and the leading causes of amputations.

Evaluation of Surveillance System Attributes

There are seven measures by which a surveillance system can evaluated to determine if it is effective and efficient.[10] These attributes are used to characterize the Michigan work-related amputation surveillance system.

Sensitivity – the proportion of all cases that are detected by the surveillance system

The surveillance system is designed to detect work-related amputations treated in Michigan hospitals or for which the worker submits a claim for wage reimbursement. The following factors prevented the system from being 100% sensitive in 2007:

1) *Incomplete submission of cases by hospitals* – Eleven hospitals reported treating no work-related amputations cases in 2007 and consequently submitted no medical records to MSU. An analysis of a database consisting of Michigan outpatient and inpatient visits[*] in 2007 identified 27 patients

[*] This database is comprised of outpatient procedures and hospitalizations (inpatient stays). Thus, it misses most patients who are treated and released from emergency departments.

treated at five of these hospitals that had an amputation diagnosis and workers' compensation listed as a source of payment. (Based on matching zip code of residence, date of birth and date of injury/hospital admission, ten of these twenty-seven individuals were among the 111 cases identified solely through workers' compensation claims data.)

Several hospitals submitted medical records only for amputations that they identified as work-related. Because work-relatedness is not always readily apparent (e.g., MSU staff were able to identify some cases only through an interview), it is likely that these hospitals did not submit records for all cases. Statewide emergency department data would provide the best estimate of under-reporting due to incomplete record submission by hospitals. However, this data source currently does not exist in Michigan. The surveillance system's sensitivity would be improved if all hospitals submitted medical records for all amputations and did not attempt to filter out non-work-related cases.

2) *Incomplete identification of cases by MSU* – For 47 cases, work-relatedness could not be determined because attempts to interview these patients were unsuccessful. Some of these amputations may have been work-related although none were found among workers' compensation claims data.

3) *Incomplete identification of amputation injuries in workers' compensation claims records* – For a substantial number of work-related amputations identified via medical record review (N=162; see Table 2), the injury type listed in the workers' compensation claims records was something other than an amputation (e.g., laceration, crush). There may have been other instances in which injuries that clinicians would diagnose as amputations were coded otherwise in workers' compensation records.

There are other work-related amputations that occur in Michigan that the system is not designed to capture, but are worth noting:

1) *Treatment at out-of-state hospitals* – Some amputations that occurred at Michigan worksites were likely treated at out-of-state hospitals. These hospitals were not required to report the incidents to MIOSHA/MSU. The Michigan Inpatient Database (MIDB) can be used to approximate the number of incidents that were not identified for this reason. While the MIDB does not specify state of injury occurrence, it does contain information on Michigan residents hospitalized out of state. In 2007, 5.8% of Michigan resident inpatients with an amputation diagnosis were hospitalized in either Indiana, Ohio, or Wisconsin. Some of these injuries likely occurred in Michigan. Based on this information, it is estimated that in 2007, the surveillance system missed approximately 5% (about 30 cases) of work-related amputations occurring in Michigan due to treatment at out-of-state hospitals. Note that some of these cases could have been captured via the surveillance system's workers' compensation claims component.

2) *Non-hospital medical treatment with no workers' compensation claim submission* – The hospital record component of the surveillance system misses workers who either are not treated medically (an unlikely occurrence) or are treated at non-hospital settings (e.g., company clinics, urgent care centers). The workers' compensation component misses cases in which injured workers do not submit a claim for wage reimbursement for lost work time. The number of such cases is unknown but presumably limited to the less severe cases.

While the surveillance system does not identify all work-related amputations in Michigan, it is much more sensitive than the system conducted by the Bureau of Labor Statistics (BLS). The BLS reported 160 work-related amputations in Michigan in 2007 – 77%

fewer than our system (N=708). There are some definitional differences between the two systems: BLS measures those who work in Michigan, not Michigan residents, and excludes the self employed and individuals without lost work time. In addition, their estimate is based on a sample of employer-reported injuries and thus is dependent upon the sample drawn and the degree to which employers record worker injuries. Finally, some injuries classified as amputations by our system may have been recorded by employers as something else (e.g., crush, laceration).

Predictive Value Positive (PVP) – the proportion of persons identified as cases that actually have the condition being monitored

The PVP of cases identified from hospital medical records is likely high (i.e., greater than 95%). For these to be classified as cases: 1) the incident must have occurred at work; and 2) the injury must have been coded as an amputation. Incidents were coded as work-related if: a) medical records documented that they occurred at work; b) the expected payer was workers' compensation; or c) the patient reported the incident as work-related during the phone interview. In a few instances, injuries were described as serious avulsions in medical records, but were subsequently coded (using ICD-9-CM) as amputations. The PVP of cases identified solely through workers' compensation records may be slightly lower because information on injury type is provided by employers rather than medical professionals.

Representativeness – the degree to which identified cases accurately describe all cases

The surveillance system appears to represent work-related amputations well geographically. Most hospitals submitted medical records. The 8% of hospitals that reported having no cases were distributed throughout all regions of the state. Self-employed workers were more likely than other workers to be under identified because work-relatedness often could not be determined from medical records and this group is not covered by workers' compensation.

Timeliness – the delay between any two or more steps in the system

The timeliness of the system is its weakest attribute. Medical records for patients treated in 2007 were initially received in February 2008. The last reporting hospital submitted records in July 2009. In October 2009, patient interviewing was completed (i.e., either patients were successfully contacted and interviewed or it was determined that the patient could not be interviewed), all medical records were reviewed and data on work-related amputations entered into a database. At this point, data from workers' compensation claims were obtained and record matching was performed. Timeliness is also a concern with regard to making referrals to MIOSHA. Worksite inspections could be better targeted if the time between injury incidence and MIOSHA referral was reduced. However, the timeliness of referrals is limited due to the timeframe in which medical records are submitted by hospitals.

Flexibility – the ability of the system to adapt to changing needs

The system is highly flexible. Data items ascertained from medical records or through follow-up interviews have been added or deleted as their usefulness has become apparent. In addition, the criteria for cases to be referred to MIOSHA have evolved. For example, in September 2008, MIOSHA changed the composition of industry types eligible for referral. The surveillance system was able to immediately comply with this change in a seamless fashion.

Simplicity – the ease of operating the system and the complexity of its design

The case definition is easy to apply and usually cases are identified quickly. For 172 of 2,063 (8.3%) of the medical records reviewed case identification was more complex because additional information was sought through an interview. However, with the recent addition of workers' compensation data to the system, this number should decrease in future years as work-relatedness will be resolved through record matching. Almost none of the data items ascertained from medical records or MIOSHA inspection reports are complex. There are a small number of individuals involved in maintaining the system. At MSU, one person is responsible for pursuing hospital medical record submission, one

person reviews medical records, makes referrals to MIOSHA, performs data abstraction, data entry, and analysis. A third person is responsible for linking medical records and workers' compensation claims records. All individuals working on the system spend only a portion of their time on this project. At MIOSHA, there is one point of contact who receives referrals and returns inspection reports.

Acceptability – the willingness of individuals and organizations to participate

All hospitals responded to MSU's request for medical records on work-related amputations either by submitting records or reporting having no cases. Project staff had a 62% success rate in obtaining information from patients via phone interview. Unsuccessful attempts were due mainly to an inability to contact patients because of out-of-date mailing addresses or phone numbers. A few were due to their unwillingness to participate. MIOSHA has stated that they value referrals although they would prefer better timeliness. The Workers' Compensation Agency readily provides access to their data.

Limitations

The surveillance system had several limitations due to the quality and type of information provided in medical records and workers' compensation claims data.

1. Medical records often were non-specific in documenting the causes of amputations. This was especially detrimental when injuries were caused by a "press": either a power press was incorrectly listed as the cause, or a power press was in fact the cause, but not explicitly noted.
2. Medical records sometimes provided insufficient information to identify an industry and assign a NAICS code without patient interviews. This is likely to have resulted in some cases not being referred to MIOSHA that should have been.
3. Hospitals varied substantially in the degree to which they provided information on patient race and Hispanic ethnicity. Overall, there was too much missing information for these important demographics to be analyzed.

4. Workers' compensation claims data did not include information on injury cause and lacked detailed injury information (e.g., single vs. multiple digit loss, which hand/finger was injured). Thus, results on these characteristics could not be fully described.
5. The success of record linkage depended upon the accuracy of the linking variables. If any case listed by workers' compensation as an amputation should have been linked to a medical record but was not, it was counted more than once.

Conclusions

This surveillance system, which uses hospital reporting and workers' compensation claims data, provides a more accurate estimate of the true number of work-related amputations than the employer-based reporting system maintained by the Bureau of Labor Statistics, which is the basis for the official count of workplace injuries. In addition, the hospital-based data can be used for public health interventions to identify and mitigate the hazards that cause amputations. Given the success of the surveillance system, we plan to continue tracking amputations and facilitating workplace investigations. The ultimate objective is to significantly reduce the incidence of this serious injury.

APPENDIX A

Data Tables

TABLE A-1
Number and rate of work-related amputations
by age and sex
Michigan Residents, 2007

Age Group	Male		Female		Total	
	Number	Rate	Number	Rate	Number	Rate
16-19	30	28.6	6	5.6	36	16.9
20-24	86	37.6	10	4.5	96	21.4
25-34	131	27.0	14	3.2	145	15.8
35-44	130	21.3	19	3.7	149	13.3
45-54	164	27.1	19	3.5	184	15.9
55-64	62	19.1	9	2.8	71	11.1
65+	22	24.4	4	*	26	15.6
Total	626	25.6	81	3.7	708	15.2

* Statistically stable rate could not be calculated.
Rates are the number of workers sustaining an amputation per 100,000 workers.
Age was unknown for one male.
Gender was unknown for one case aged 45-54.
Data Sources: Number of amputations – Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency; Number of workers employed by age group used to calculate rates - Bureau of Labor Statistics' Current Population Survey

TABLE A-2
Number of work-related amputations
by race and Hispanic ethnicity
Michigan residents, 2007

Race	Hispanic Ethnicity			Total
	Yes	No	Unknown	
White	0	0	323	323
Black	0	0	49	49
Other	0	0	13	13
Unknown	23	0	300	323
Total	23	0	685	708

Data Sources: Michigan hospital medical records and Michigan Department of Energy, Labor and Economic Growth Workers' Compensation Agency

TABLE A-3
Work-related single-finger amputation incidents (N=512)
by injured hand and amount of finger lost
Michigan residents, 2007

Hand	Finger	Section Lost				Total
		Distal Phalanx	Middle Phalanx	Proximal Phalanx	Unknown	
Right	Thumb	41		1	1	43
	Index	55	6	2	4	67
	Middle	67	2	0	2	71
	Ring	25	3	2	2	32
	Little	17	5	0	3	25
Left	Thumb	50		3	1	54
	Index	71	10	1	0	82
	Middle	62	1	0	1	64
	Ring	28	0	1	1	30
	Little	30	6	4	0	40
Total		449[1]	33	14	15	512[2]

1. For three cases, the distal phalanx was amputated, but medical records did not provide enough information (i.e., specific finger, right or left hand) to allow these cases to be categorized in the cells presented. These three are included in the Distal Phalanx total.
2. For one case, neither the digit nor the degree of loss was specified. This case is included in the overall total.
Data Source: Michigan hospital medical records

TABLE A-4
Work-related multiple-finger amputation incidents (N=66)
by injured hand and amount of finger lost
Michigan residents, 2007

Hand	Finger	Section Lost				Total
		Distal Phalanx	Middle Phalanx	Proximal Phalanx	Unknown	
Right	Thumb	1		1	1	3
	Index	14	6	2	2	24
	Middle	19	6	2	4	31
	Ring	10	5	2	4	21
	Little	1	4	2	1	8
Left	Thumb	2		5	0	7
	Index	8	10	0	0	18
	Middle	15	10	1	0	26
	Ring	10	9	3	0	22
	Little	0	5	3	0	8
Total		80	55	21	12	168

Data Source: Michigan hospital medical records

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