Work-related Amputations in Michigan, 2014

March 2016

MICHIGAN STATE
UNIVERSITY

Work-related Amputations in Michigan, 2014

A Joint Report

of the

Michigan Department of Health and Human Services
Bureau of Disease Control, Prevention, and Epidemiology
Division of Environmental Health
201 Townsend Street
PO Box 30195
Lansing, Michigan 48909

and the

Michigan State University
College of Human Medicine
Division of Occupational and Environmental Medicine
117 West Fee Hall
East Lansing, Michigan 48824

and the

Michigan Department of Licensing and Regulatory Affairs
Michigan Occupational Safety and Health Administration
530 West Allegan Street
PO Box 30643, Lansing, MI 48909

March 2016

State of Michigan
Governor – Rick Snyder, JD, MBA

Michigan Department of Health and Human Services
Director – Nick Lyon

Population Health and Community Services Administration
Senior Deputy Director – Susan Moran, MPH

Bureau of Disease Control, Prevention, and Epidemiology
Director – Corinne Miller, DDS, PhD

Authors
Thomas W. Largo, MPH – Bureau of Disease Control, Prevention, and Epidemiology, MDHHS
Kenneth Rosenman, MD – Michigan State University

Contributors
Mary Jo Reilly, MS – Michigan State University
Martha Stanbury, MSPH – Bureau of Disease Control, Prevention, and Epidemiology, MDHHS
Barton G. Pickelman, Acting Director, MIOSHA

Acknowledgments
Tracy Carey – Michigan State University
Ruth Vander Waals – Michigan State University
Student Interviewers – Michigan State University

This report would not have been possible without the participation of
staff at Michigan hospitals who provided medical records.

This publication was supported by grant number U60 OH008466 from the U.S. Centers for Disease Control and Prevention – National Institute for Occupational Safety and Health (CDC-NIOSH). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of CDC-NIOSH.

EXECUTIVE SUMMARY

The Division of Occupational and Environmental Medicine at Michigan State University in collaboration with the Michigan Department of Health and Human Services maintains a multi-source system for collecting data on work-related amputations in Michigan. This report characterizes these injuries for 2014. The salient findings are as follows:

- The system identified a total of 519 Michigan resident work-related amputations. This corresponds to a rate of 11.8 per 100,000 workers. In comparison, the official U.S. Department of Labor estimate (150) was 71% lower.

- From 2006 to 2014, the number of work-related amputations in Michigan decreased 29.9% and the rate decreased 24.8%. In 2006, there were 740 cases with a corresponding rate of 15.7 per 100,000. The number and rate of work-related amputations decreased from 2006 to 2009. From 2009 to 2011, the number and rate were level. From 2012 to 2013, the number increased 15.3% and the rate increased 12.9%. And from 2013 to 2014, the number decreased 8.3% and the rate decreased 9.9%.

- Hospital/emergency department medical records identified 458 cases. Workers' Compensation lost work time claims data identified 177 cases, 119 of which were linked to medical records (one of these was an amputation case for which work-relatedness could not be determined based on the medical record). There were 61 cases that would have been missed had Workers' Compensation claims data not been used to supplement medical records.

- The amputation rate for males was almost nine times the rate for females. Among males, rates were highest for those aged 20-24 years.

- Forty-two percent of the amputations occurred among those working in the manufacturing industry. The specific manufacturing group with the highest rate was Wood Product Manufacturing.

- Power saws and presses were the leading causes of amputations, accounting for 14.0% and 11.8%, respectively, of cases for which injury cause was specified.

- Ninety-six percent of amputations involved fingers. Nearly one in six (15.0%) finger amputation injuries involved multiple fingers.

- Upper extremity amputations occurred more often on the left side than the right side (53% v. 47%, respectively).
- Workers' Compensation was the expected source of payment of hospitalization or emergency department care for 82.0% of the cases for which payment source was identified. Payer source could not be determined for 9.0% of medical records reviewed.
- The Michigan Occupational Safety and Health Administration (MIOSHA) inspected 28 worksites identified through medical records and assessed an average of one violation and $3,000 in penalties per worksite inspected.

All of Michigan's hospitals are required to report work-related amputation cases and were the primary source of data for most (88%) of the identified cases for 2014. Data provided by the Michigan Workers' Compensation Agency identified an additional 12% of cases that were not identified by hospital-based surveillance alone. The Workers' Compensation data were limited to individuals who requested wage replacement for being off work for more than seven consecutive days or received a set amount based on the percentage of finger(s) amputated and did not include individuals who had claims for medical care cost reimbursement alone. Therefore, Michigan's surveillance system missed those cases in which injured workers were treated in non-hospital/emergency department settings or at out-of-state hospitals and did not file a Worker Compensation claim for 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, by combining data from two separate systems, medical records and Workers' Compensation claims, it provides the best estimate of the true number of amputations that occur in Michigan. The 519 amputations identified are appreciably larger than the official employer-based estimate of 150.

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

TABLE OF CONTENTS

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 4,900 amputations resulting in days away from work occurred nationally in 2014. The median number of lost workdays was 19 for amputation cases compared to 9 days for all work-related injuries.[1] Reducing the incidence of work-related amputations is a public health priority. The Council of State and Territorial Epidemiologists (CSTE) in collaboration with the National Institute for Occupational Safety and Health (NIOSH) has developed a set of twenty-two occupational health indicators,[2] two of which are measures of work-related amputations.

The Michigan Occupational Safety and Health Administration (MIOSHA) was established in 1974. MIOSHA, which is part of the Michigan Department of Licensing and Regulatory Affairs (LARA), strives to work collaboratively with employers and employees to better prevent workplace injuries, illnesses, and fatalities and to protect earned wages and fringe benefits. One strategy MIOSHA uses to assist employers in improving the safety and health of their employees 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. Only those cases resulting in a MIOSHA referral were tracked through 2005. Beginning with 2006 data, a surveillance system to track all work-related amputations treated at Michigan hospitals/emergency departments was established.[3] 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 2014.

DATA SOURCES and METHODS

Data Sources

Medical records were used to identify work-related amputation cases treated at hospitals/emergency departments. Under the Michigan Public Health Code, Michigan hospitals are required to report these conditions.[4] MSU acts as MDHHS's bona fide agent to administer this law and medical records are sent directly to MSU's OEM Division.

Under a Memorandum of Understanding Agreement (MUA), the LARA 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 more than 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 (BLS), was the source of the estimated number of employed Michigan residents by defined age groups, gender, and industry groups for 2014. 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 at the time of injury receiving medical treatment at a Michigan hospital/emergency department for whom: a) an amputation diagnosis was assigned (codes 885.0-.1, 886.0-.1, 887.0-.7, 895.0-.1, 896.0-.3, and 897.0-.7 per the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM[5])); and b) the incident was documented as having occurred at work in 2014. The level of hospital care included outpatient surgery, emergency department visit, and hospital admission. A case identified using the Workers' Compensation system was defined as an individual aged 16 years or older at the time of injury who was in the WC lost work time wage replacement database with an accepted work-related amputation occurring in 2014. Cases that listed body parts that were inconsistent with upper or lower extremity amputation (e.g., "eye", "back") were excluded.

Worksites of hospital/emergency department-treated cases* that met the following criteria were referred to MIOSHA: a) the worksite was located in Michigan; and b) the amputation potentially was caused by a mechanical power press$^{\Delta}$ or another hazard likely to be found upon inspection. Worksites were not referred when the cause of injury was vaguely described in medical records (e.g., "pinched between objects").

An MSU referral to MIOSHA included a description of the injury, its cause, and employer information. MIOSHA staff reviewed referred cases to determine if they would conduct a worksite inspection. Referrals of 2014 cases were made to MIOSHA between April 2014 and April 2015.

* 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.

$^{\Delta}$ 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. Often medical records fail to specify the type of press (e.g., mechanical, hydraulic). Thus, cases where the medical record notes only that the injury was caused by a "press" were considered potential mechanical power press cases and were referred.

Some medical records lacked information as to whether an injury 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 missing information.

For all work-related amputation incidents identified from hospital/emergency department medical records, data collected included: hospital name, date of admission, patient demographics, city and county of residence, primary source of payment, company name, address, NAICS[6] code, injury date, body part amputated, ICD-9-CM code(s), and cause of injury. For cases referred to MIOSHA, additional information was obtained, including: whether an inspection was performed, inspection date, number of violations, number of violations presumably pertaining to the hazard identified by MSU staff, whether hazards had been abated at the time of the MIOSHA inspection, power press violations, and total fines assessed.

Once case ascertainment from medical record review and patient interviews was completed, records in the work-related amputation database were linked to records in the Workers' Compensation claims database using SAS® software, version 9.2 of the SAS® System for Windows (copyright 2002-2008 by SAS Institute Inc.). There were several steps in the record-linkage process. First, matches were identified using various combinations of social security number (either all nine digits or the last four digits which often were all that medical records provided), date of injury (or date of hospital admission), worker's name, and date of birth. For cases that matched, the linked record was visually verified. The matching process was performed on the entire 2014 Workers' Compensation claims database to allow for links to cases not categorized as amputations by that system.

Upon completion of record linkage, work-related amputations were assigned to one of the following six categories: 1) Workers' Compensation case where injury was an amputation

and was matched with a work-related amputation from the medical records; 2) Workers' Compensation case where injury was an amputation and was matched with an amputation from the medical records in which work-relatedness could not be determined from the medical records; 3) Workers' Compensation case where injury was an amputation but could not be matched with an amputation from the medical records; 4) Workers' Compensation case where injury was not an amputation but was matched with a work-related amputation from the medical records; 5) Workers' Compensation case where injury was not an amputation but was matched with an amputation from the medical records in which work-relatedness could not be determined from the medical records; and 6) work-related amputation from the medical records but with no match to Workers' Compensation. The remaining two categories assigned were: 1) Workers' Compensation case where injury was not an amputation and was not matched with an amputation from the medical records; and 2) unknown if work-related amputation from the medical records and could not be matched to Workers' Compensation.

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

RESULTS

All 132 non-federal acute care hospitals and four Veteran's Administration (VA) medical centers in Michigan complied with the reporting requirement. Twenty-eight of the facilities submitted no records and reported that they had no work-related amputation cases in 2014. The total number of records received and reviewed was 1,378, including 83 from the VA medical centers. Project staff attempted to interview 46 patients to ascertain work-relatedness and/or employer information and completed 29 (63.0%) of these interviews.

In 2014, 466 individuals were treated at a Michigan hospital/emergency department (ED) following a work-related amputation.[*] These include 463 originally identified through medical records and another three that were treated at a Michigan hospital, but could not be identified as work-related until linked to a Workers' Compensation record. These workers made a total of 573 hospital visits for care (85 of the 466 workers made multiple hospital visits). Nearly all workers (98.9%) were Michigan residents (N=461) (Table 1). The work-related amputation rate for these hospital-treated amputations among Michigan residents was 10.5 per 100,000 workers.

TABLE 1
Workers Treated for an Amputation at a
Michigan Hospital/ED, 2014

Characteristics of Workers and Healthcare Utilization	Number of Workers	%
Received treatment at a Michigan hospital/ED		
Michigan resident	461	98.9
One hospital visit	*376*	*80.7*
Multiple hospital visits (followup care or transfer to another hospital)	*85*	*18.2*
Out-of-state resident	5	1.1
One hospital visit	*5*	*1.1*
Multiple hospital visits (followup care or transfer to another hospital)	*0*	*0.0*

Data Source: Michigan hospital/ED medical records

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

Table 2 illustrates the number of cases ascertained by the two data sources and the results of the matching process. The Workers' Compensation database contained 177 lost work time claims from Michigan residents with amputations. One hundred seventy one (171) were paid for lost work time and two more were expected to receive payment. There was no indication that the remaining four individuals were paid for lost work time. For all four, the amputation was not contested as being work-related. Some of the individuals paid for lost work time may not have been out of work more than seven consecutive days because, as described previously (Page 2), workers are eligible for wage replacement if they sustain "specific losses," such as the loss of a phalanx.

TABLE 2
Results of Matching Michigan Resident Work-related Amputation Cases Ascertained from Hospital/ED Medical Records and Workers' Compensation Lost Work Time Claims, 2014

Was Michigan Resident in Workers' Compensation Database?	Was Michigan Resident Amputation Work-related per Hospital/ED Medical Record?		No Match to Medical Record	Total
	Yes	Unknown		
Yes, with amputation injury	118	1	58	177
Yes, with a non-amputation condition	127	2	22,663	22,792
No	213	14	NA	227
Total	458	17	22,721	23,196

Shaded cells illustrate work-related amputation cases.

One hundred eighteen (118) of the 177 Workers' Compensation claims (66.7%) matched an amputation case identified from medical record review. For 58 cases, hospitals/EDs did not submit a medical record of an amputation (first row of Table 2). One hundred twenty seven (127) of the 458 hospital-record-based amputation cases (27.7%) 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) (first column of Table 2). There were 17 cases in which medical records did not indicate whether the amputation was work-related or not. Three of these were matched to Workers' Compensation claims records, two of which had the injury as something other than an amputation (second column of Table 2).

Adding the 458 cases that were identified using medical records to the 61 that could be identified only through linkage to Workers' Compensation records yields a total of 519 Michigan resident workers. This corresponds to a rate of 11.8 amputations per 100,000 workers. The following analyses examine these 519 cases.

Characteristics of Injured Workers

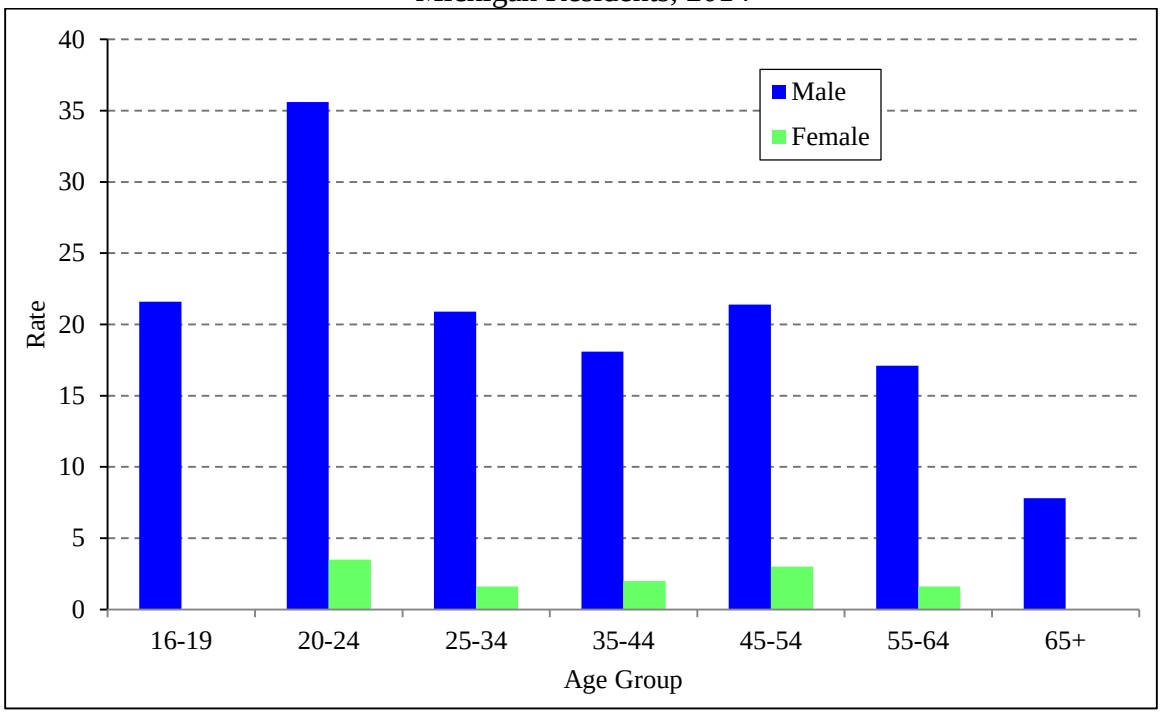
Age and Gender

Males comprised 90.6% of workers who sustained an amputation. Among males, rates were highest for those aged 20-24 years. Among females, rates were highest for those aged 20-24 years. Figure 1 displays amputation rates by age group and gender. (Also, see Table A-1 in Appendix A.)

Race and Hispanic Ethnicity

Information on patient race and Hispanic ethnicity was missing in 46% and 79% 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.

FIGURE 1
Work-related Amputation Rates
by Age Group and Gender
Michigan Residents, 2014



Rates are the number of workers sustaining an amputation per 100,000 workers.
A statistically valid rate could not be calculated for females aged 16-19 and 65+ due to insufficient numbers of cases.
Data Sources: Number of amputations – Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Workers' Compensation Agency; Number of workers employed by age group used to calculate rates - Bureau of Labor Statistics' Current Population Survey

Body Part and Severity

As shown in Table 3, nearly all workers (96.3%) sustained finger amputations. Data from hospital/ED medical records, which provide more detail on finger injuries than Workers' Compensation claims data, were available for 446 finger amputation cases. The following analyses are limited to these cases. Of 446 finger amputation incidents, 67 (15.0%) involved multiple fingers. The distal phalanx of the middle finger (Section G in Figure 2) was the most frequently amputated area. The distal phalanges comprised 84.6% 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, 2014

Part of Body Amputated	Number of Workers	%
Upper Extremity	507	97.7
Finger	*500*	*96.3*
Hand	*5*	*1.0*
Arm	*2*	*0.4*
Lower Extremity	12	2.3
Toe	*10*	*1.9*
Foot	*0*	*0.0*
Leg	*2*	*0.4*
Unknown Body Part	1	0.2
Total	519	100.0

Note: subtotals do not sum to total because one worker sustained amputations to multiple body parts.
Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Workers' Compensation Agency

Overall, workers sustained slightly more injuries to their left side than their right side (53.2% vs. 46.8%, respectively) (Table 4).

FIGURE 2
Work-related Finger Amputations
by Digit and Section of Finger Lost
Michigan Residents, 2014

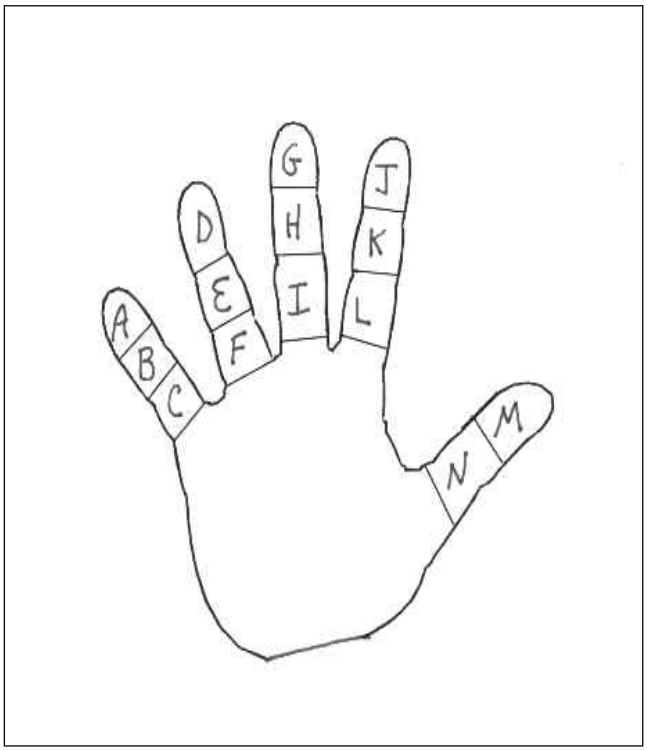


Figure is for both left and right hands.

Finger	Section	Number	%
Little	A	43	8.2
	B	6	1.1
	C	5	1.0
	Unknown	1	0.2
Ring	D	74	14.1
	E	6	1.1
	F	6	1.1
	Unknown	4	0.8
Middle	G	132	25.2
	H	14	2.7
	I	8	1.5
	Unknown	2	0.4
Index	J	117	22.4
	K	17	3.3
	L	7	1.3
	Unknown	1	0.2
Thumb	M	64	12.2
	N	9	1.7
	Unknown	6	1.1
Unknown	Unknown	1	0.2
Total		523	100.0

Includes sections lost in single and multiple-finger loss incidents.
Workers' Compensation claims data do not contain data on section of finger lost and thus are excluded from the table.
Data Source: Michigan hospital/ED medical records

TABLE 4
Work-related Amputations
by Side and Extremity Injured
Michigan Residents, 2014

Injured Side	Number of Workers		
	Upper Extremity	Lower Extremity	Total
Right	210	3	213
Left	238	4	242
Both	2	0	2
Unknown	1	0	1
Total	451	7	458

Workers' Compensation claims data do not contain information on injured side and thus are excluded from the table.
Data Source: Michigan hospital/ED 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. Twelve counties had no cases and another 49 had between one and five, too few to calculate statistically valid rates. Mason County had the highest rate (51.1 per 100,000 workers). Among the most populous counties in the state, Muskegon County had the highest rate (19.7 per 100,000 workers) while Oakland County had the lowest (4.6 per 100,000).

Case Study One

A 43-year-old male was hired at a company via a temporary employment agency. In a phone interview with this worker, he stated that his manager instructed him to clean a saw while it was still powered up and spinning. He had received no training, nor was he given any safety instructions. While he was cleaning the machine, some debris bypassed his safety glasses and entered his eye. While removing this debris from his eye, his middle finger was caught in the moving saw blade causing an amputation of his entire middle finger. The company was referred to MIOSHA. They cited the company for 4 violations and fined the company $5,000.

TABLE 5
Number and Rate of Work-related Amputations
by County of Residence, Michigan Residents, 2014

County	Number	Rate	County	Number	Rate
Alcona	0	-	Lapeer	5	*
Alger	1	*	Leelanau	1	*
Allegan	12	21.3	Lenawee	5	*
Alpena	2	*	Livingston	8	9.0
Antrim	1	*	Luce	0	-
Arenac	0	-	Mackinac	1	*
Baraga	0	-	Macomb	50	13.0
Barry	5	*	Manistee	1	*
Bay	10	20.2	Marquette	5	*
Benzie	0	-	Mason	7	51.1
Berrien	7	10.2	Mecosta	2	*
Branch	9	50.0	Menominee	1	*
Calhoun	4	*	Midland	3	*
Cass	2	*	Missaukee	0	-
Charlevoix	2	*	Monroe	8	11.3
Cheboygan	1	*	Montcalm	5	*
Chippewa	1	*	Montmorency	1	*
Clare	2	*	Muskegon	14	19.7
Clinton	3	*	Newaygo	2	*
Crawford	0	-	Oakland	27	4.6
Delta	3	*	Oceana	2	*
Dickinson	1	*	Ogemaw	1	*
Eaton	5	*	Ontonagon	0	-
Emmet	2	*	Osceola	1	*
Genesee	22	12.9	Oscoda	2	*
Gladwin	1	*	Otsego	0	-
Gogebic	2	*	Ottawa	13	9.2
Grand Traverse	5	*	Presque Isle	0	-
Gratiot	4	*	Roscommon	1	*
Hillsdale	6	31.6	Saginaw	4	*
Houghton	0	-	St. Clair	8	12.0
Huron	3	*	St. Joseph	5	*
Ingham	12	8.8	Sanilac	1	*
Ionia	9	32.8	Schoolcraft	3	*
Iosco	1	*	Shiawassee	3	*
Iron	0	-	Tuscola	1	*
Isabella	1	*	Van Buren	8	24.4
Jackson	10	14.7	Washtenaw	13	7.3
Kalamazoo	19	15.8	Wayne, including Detroit	74	10.7
Kalkaska	3	*	*Detroit*	26	*12.4*
Kent	28	8.8	Wexford	2	*
Keweenaw	1	*	Unknown	30	-
Lake	1	*	Michigan	519	11.8

* 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/ED medical records and Michigan Department of Licensing and Regulatory Affairs 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 56 cases (10.8%), there was insufficient information in either the medical records provided or Workers' Compensation claims data to make an industry classification. Nine workers were described in medical records as self-employed. Industry could be ascertained for all of these self-employed workers. Among two-digit NAICS industry sectors, Agriculture, Forestry, Fishing, and Hunting had the highest rate (35.8 per 100,000 workers). All 25 cases occurred specifically within the Agriculture subsector. The greatest number of cases occurred within Manufacturing, which comprised 46.7% of the 463 incidents in which industry could be determined. Certain three-digit NAICS subsectors within Manufacturing had very high rates, notably Wood Product Manufacturing (155.9 per 100,000).

Case Study Two

A 22-year-old female was working with an unspecified type of press. When something got stuck in the machine, she reached in and sustained a near amputation of the distal phalanx of her index finger. In subsequent surgery, the entire distal phalanx had to be removed. The company was referred to MIOSHA which cited the company for 21 violations, including two for press violations, and fined the company $14,300.

TABLE 6
Number and Rate of Work-related Amputations
by Worker Industry, Michigan Residents, 2014

Industry Classification (NAICS industry sector code)	Number	Rate
Agriculture, Forestry, Fishing, and Hunting (11)	25	35.8
Crop Production (111) and Animal Production (112)	*25*	*42.1*
Mining (21)	3	*
Utilities (22)	0	-
Construction (23)	39	19.3
Manufacturing (31 – 33)	216	26.1
Food Manufacturing (311)	*8*	*16.9*
Wood Product Manufacturing (321)	*16*	*155.9*
Paper Manufacturing (322)	*9*	*112.0*
Plastics and Rubber Products Manufacturing (326)	*15*	*55.7*
Primary Metal Manufacturing (331)	*18*	*74.9*
Fabricated Metal Product Manufacturing (332)	*51*	*112.5*
Machinery Manufacturing (333)	*20*	*25.2*
Transportation Equipment Manufacturing (336)	*34*	*9.0*
Furniture and Related Product Manufacturing (337)	*11*	*44.0*
Wholesale Trade (42)	26	25.9
Retail Trade (44 – 45)	49	9.8
Transportation and Warehousing (48 – 49)	14	8.5
Information (51)	0	-
Finance and Insurance (52)	2	*
Real Estate and Rental and Leasing (53)	3	*
Professional, Scientific, and Technical Services (54)	7	2.7
Management of Companies and Enterprises (55)	0	-
Administration and Support Services and Waste Management and Remediation Services (56)	19	10.1
Educational Services (61)	5	*
Health Care and Social Assistance (62)	4	*
Arts, Entertainment and Recreation (71)	2	*
Accommodation and Food Services (72)	34	11.6
Food Services and Drinking Places (722)	*32*	*12.1*
Other Services (81)	11	5.9
Public Administration (92)	4	*
Unknown Industry	56	
Total	519	11.8

* 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/ED medical records and Michigan Department of Licensing and Regulatory Affairs 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 the Workers' Compensation claims data, so the table is limited to the 458 cases for which a medical record was available. Sharp objects were identified in about one-quarter (24.9%) of the cases. Power saws (e.g., table saws, miter saws) comprised about half of sharp object injuries. Presses caused one in nine (10.7%) amputations.

TABLE 7
Number of Work-related Amputations, by Cause of Injury
Michigan Residents, 2014

Cause of Injury	Number	%
Sharp object	114	24.9
Power saw	*58*	*12.7*
Knife	*25*	*5.5*
Food slicer (including "meat saw")	*19*	*4.1*
Lawn mower	*1*	*0.2*
Other sharp object	*11*	*2.4*
Press	49	10.7
Mechanical	*4*	*0.9*
Other and unspecified type of press	*45*	*9.8*
Pinched between objects	42	9.2
In door/safe	*10*	*2.2*
Struck by falling object	27	5.9
Struck by object - other	12	2.6
Caught in chain/pulley/gears/belt	36	7.9
Grinder	7	1.5
Forklift/Hi-lo	7	1.5
Machine - other specified type	40	8.7
Machine - unspecified type	38	8.3
Other specified cause	43	9.4
Unspecified cause	43	9.4
Total	458	100.0

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

An assortment of other machinery, many of which were unspecified in the medical records, caused about one in six (17.0%) amputations. Another frequent cause of

amputations (9.2%) was workers getting pinched or crushed between objects, such as doors. Finally, medical records provided no information on cause for 9.4% of cases.

Source of Payment

As shown in Table 8, Workers' Compensation was the expected payer in 342 (74.7%) of the 458 cases for which there was a medical record. For 41 cases, payment source could not be identified. Note that of the 116 cases for which Workers' Compensation was not listed as a payment source in medical records, 43 were linked to Workers' Compensation claims data. Workers' Compensation was the expected payer for 75.9% of the 449 patients that were not self-employed.

TABLE 8
Work-related Amputations
by Payment Source Overall and for Non-self-employed Workers
Michigan Residents, 2014

Expected Source of Payment	Total		Non-self-employed	
	Number	%	Number	%
Workers' Compensation	342	74.7	341	75.9
Commercial insurance	35	7.6	32	7.1
Other	40	8.7	37	8.2
Not specified	41	9.0	39	8.7
Total	458	100.0	449	100.0

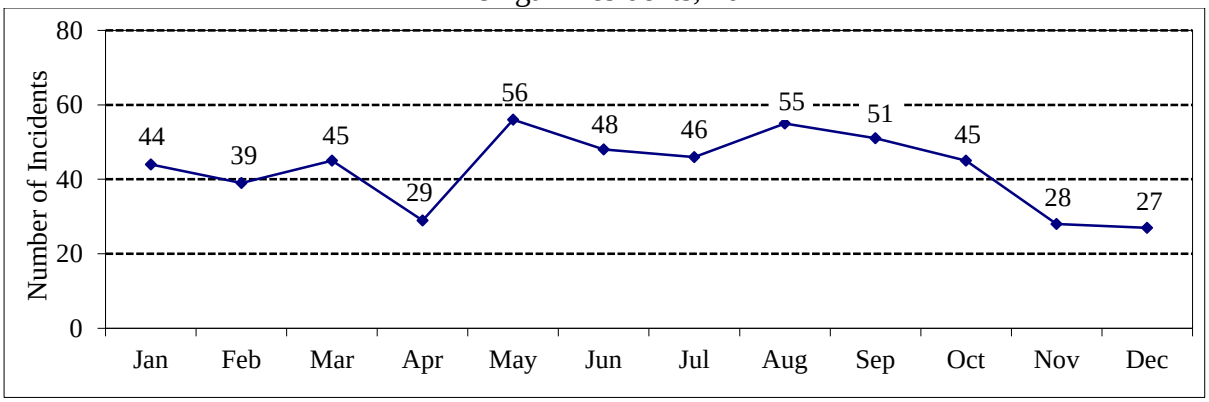
Data Source: Michigan hospital/ED medical records

Temporal Characteristics

Incidents by Month

No seasonal trend was apparent. The greatest number of events occurred in May and August (Figure 3).

FIGURE 3
Work-related Amputations
by Incident Month
Michigan Residents, 2014

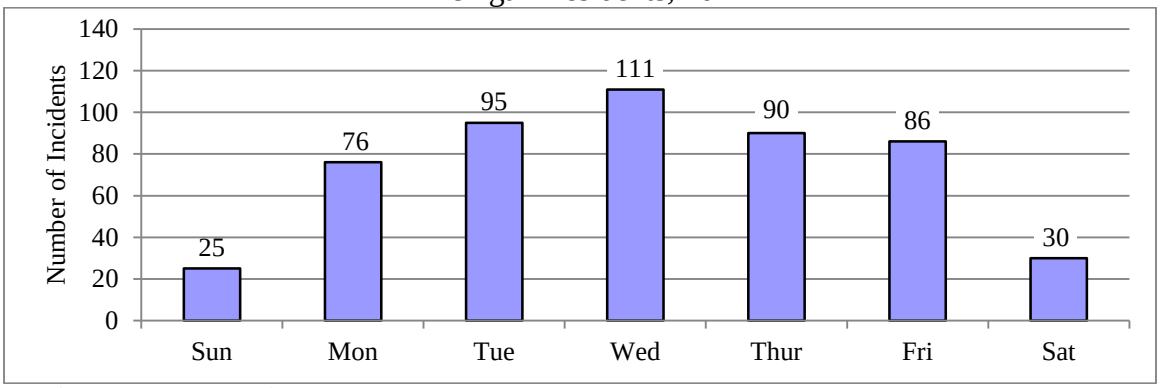


Month of incident was unknown for six cases.
Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Workers' Compensation Agency

Incidents by Day of Week

Amputations occurred most frequently on Wednesdays and were much less frequent during the weekend (Figure 4).

FIGURE 4
Work-related Amputations
by Day of Incident
Michigan Residents, 2014

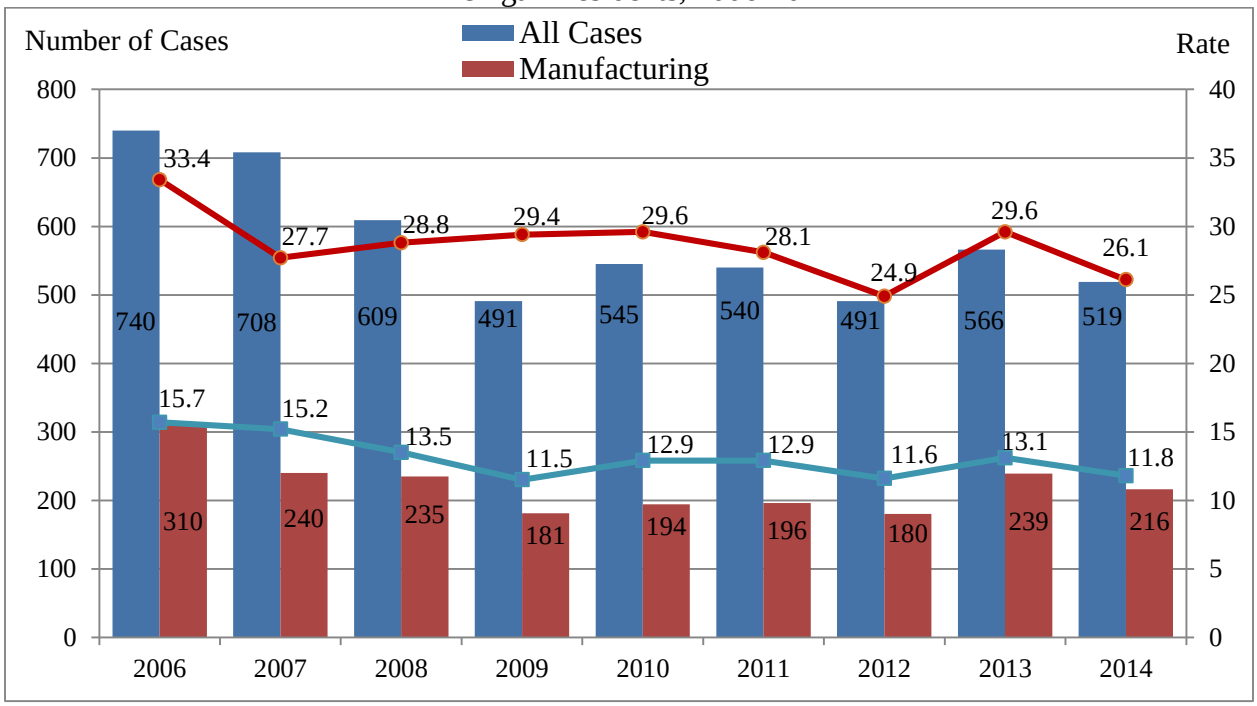


Day of incident was unknown for six cases.
Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Growth Workers' Compensation Agency

Incidents by Year

During the nine years that the surveillance system has been in place, the annual number of cases has decreased by 29.9% – from 740 in 2006 to 519 in 2014 (Figure 5). This decline in the number of amputations for the most part cannot be explained by the economic recession with fewer individuals employed because rates also decreased, 24.8% (15.7 to 11.8 per 100,000 workers), although the percentage decrease in the rate was slightly smaller than the decrease in the number of amputations. Figure 5 also illustrates the annual number of cases and corresponding rates for manufacturing, the industry in which the greatest number of amputations occur. Rates and frequencies for manufacturing were highest in 2006, but both have leveled off in subsequent years.

FIGURE 5
Annual Numbers and Rates of Work-related Amputations
by Year of Incident
Michigan Residents, 2006-2014



Rates are the number of workers sustaining an amputation per 100,000 workers.
Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Workers' Compensation Agency

Referrals to MIOSHA

Forty seven (47) of the 458 work-related amputations for which there was a hospital/ED medical record met the MIOSHA referral criteria.* Two amputation incidents occurred at the same worksite, three months apart. MSU referred these 46 worksites to MIOSHA.

MIOSHA inspected 28 worksites subsequent to a referral based on a hospital/ED medical record (Table 9). All 28 inspections occurred within 90 days of MSU referrals.

TABLE 9
Outcome of Work-related Amputation Referrals to MIOSHA
Michigan Residents, 2014

Outcome of Referral	Number of Worksites	%
Worksite inspected subsequent to referral	28	60.9
Inspected within 90 days of referral	*28*	*60.9*
Worksite not inspected subsequent to referral	18	39.1
Worksite inspected prior to referral	*7*	*15.2*
Worksite not inspected	*11*	*23.9*
Total	46	100.0

The following analyses examine the outcome of the 28 MIOSHA inspections. Table 10 summarizes the number of violations identified in these inspections. The number of violations ranged from zero to 21 with a median of one. Table 11 illustrates the distribution of assessed penalties. For six cases, there was no penalty. The maximum penalty was $14,300 and the median was $3,000. MIOSHA cited three companies for mechanical power press violations.

* Cases identified solely through Workers' Compensation records were not referred to MIOSHA. See *Methods*.

TABLE 10
Violations Identified in Worksite Inspections
Conducted Following an MSU Referral
Michigan Residents, 2014

Number of Violations	Number of Inspections	%
0	6	21.4
1	14	50.0
2	3	10.7
3-5	4	14.3
6+	1	3.6
Total	28	100.0

Data Source: MIOSHA inspection reports

TABLE 11
Penalties Assessed in Worksite Inspections
Conducted Following an MSU Referral
Michigan Residents, 2014

Penalty Assessed	Number of Inspections	%
$0	6	21.4
$1-$999	1	3.6
$1,000-$9,999	20	71.4
$10,000+	1	3.6
Total	28	100.0

Data Source: MIOSHA inspection reports

Case Study 3

A 48-year-old male was working with a large saw, lost control of the saw, and his hand caught in the saw. He sustained an amputation of his entire hand at the wrist level. The company was referred to MIOSHA. They cited the company for 2 violations and fined the company $1,250.

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 2014, there were 28 such worksites. This identification and referral system directly provides support to MIOSHA in addressing Objective 1.1 of their 2014-2018 Strategic Plan[7]:

> *Reduce by 15% the rate of worker injuries and illnesses in high-hazard industries (defined as those in the following NAICS subsectors: 312, 331, 332, 333, 336, 488, 493, 622, 623, 721).*

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 be evaluated to determine if it is effective and efficient.[8] 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 2014:

1) *Incomplete submission of cases by hospitals* – An analysis of Michigan inpatient and outpatient visits (MIDB-MODB)[*] in 2014 identified 15 Michigan residents treated at five of the 28 hospitals that reported they had no work-related amputations that had an amputation diagnosis and Workers' Compensation listed as a source of payment. Five of these fifteen

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

were found in the Workers' Compensation database as an amputation. In addition, there were four hospitals that submitted a total of seven fewer medical records than the number of work-related amputation cases identified from these hospitals via MIDB-MODB. One of these seven was found in the Workers' Compensation database as an amputation. Thus, had hospitals reported all amputations identified in the MIDB-MODB database, at least another 16 work-related amputation cases would have been identified by our surveillance system. This represents 3.5% of our total number.

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 does not exist in Michigan.

2) *Incomplete identification of work-relatedness in medical records* – For 14 amputations, work-relatedness could not be determined by a review of their medical records, we were unable to interview the patients, and we were unable to find them listed in the Workers' Compensation claims data base. Some of these amputations may have been work-related.

3) *Amputation cases coded by hospitals as non-amputations* –In 2013, we began to conduct surveillance of crush injuries (ICD-9-CM codes 925-929), patterned after the methodology used for amputations. As part of their medical record review, staff from that project noted whether the injury was described as an amputation or if amputation revision surgery was performed. In 2014, there were 16 crush injuries that were noted by staff to be described as amputations that were not identified as amputations in the

hospital's coding of the medical record nor in the Worker's Compensation system.

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 out-of-state hospitals were not required to report the incidents to Michigan agencies. The MIDB-MODB can be used to approximate the number of incidents that were not identified for this reason. While the MIDB and MODB do not specify state of injury occurrence, they do contain information on Michigan residents treated out of state. In 2014, four Michigan residents were treated for an amputation at an out-of-state hospital (all in Ohio) with Workers' Compensation listed as a primary or secondary payer. None of these four individuals were identified by the surveillance system. Based on this information, it is estimated that in 2014, the surveillance system missed 0.9% of Michigan resident work-related amputations due to treatment at out-of-state hospitals.

2) *Non-hospital medical treatment with no Workers' Compensation claim submission* – The hospital/ED 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. Workers' Compensation claims are also not available for those not covered by the system, such as the self-employed.

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 150 work-related amputations in Michigan in 2014 – 71% fewer than our system (N=519). There are some definitional differences between the two systems: the BLS measures those who work in Michigan, not Michigan residents, and excludes the self-employed (N=9) and individuals without lost work time. The BLS figure is not actually a count of all amputations but rather is an estimate 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 in medical records 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; or b) the expected payer was Workers' Compensation; or c) the patient reported the incident as work-related during the phone interview. The PVP of cases identified solely through Workers' Compensation records may be slightly lower than 95% 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 be geographically representative. Hospitals either submitted medical records or responded that they had no cases and it appears that only a

[†] Prior to 2011, another reason for a discrepancy may have been that the BLS required bone loss to classify an injury as an amputation whereas our system did not. As of 2011, this restriction was removed making the BLS system potentially more comparable to ours. However, even with this change, the BLS estimate of the number of amputations remained appreciably less than our multisource system in 2013 and does not explain the BLS undercount, which is comparable to previous years, when BLS only counted amputations that included bone loss (2010 – 67% fewer, 2009 – 65% fewer, 2008 – 59% fewer, 2007 – 77% fewer and 2006 – 20% fewer).

few cases were lost due to hospitals that did not provide records (see sensitivity discussion above). Self-employed workers were more likely than other workers to be under identified because work-relatedness for this group often could not be determined from medical records and they are not covered by Workers' Compensation. While self-employed workers comprised 2.0% of the 458 Michigan resident work-related amputation cases for which there was a medical record, they comprised 28.6% of the 14 cases for which work-relatedness could not be determined.

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

The timeliness of the system has improved substantially. Prior to 2011, hospitals submitted medical records for the twelve-month calendar year. Even submissions from the earliest reporting (i.e., February following the end of the year of interest) hospitals would contain cases more than a year old. Beginning in 2011, hospitals were required to report quarterly. Thus, medical records for patients treated in January-March of 2014 were initially received in May 2014 and the last records for 2014 were received in early December 2015. In late December 2015, patient interviewing was completed (i.e., either patients were successfully contacted and interviewed or it was determined that they could not be interviewed), all medical records were reviewed and data on work-related amputations entered into a database. Lastly, in January 2016, data from Workers' Compensation claims were linked to the medical records database. The improved timeliness of the system has allowed more cases to be referred to MIOSHA within six months of the incident. Consideration will be given in future years to requiring the hospitals to report within ten days of the occurrence of the amputation, as required in the reporting regulations.

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.

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 46 of 1,378 (3.3%) of the medical records reviewed case identification was more complex because additional information was sought through an interview. The number of interviews has decreased significantly starting in 2009 (during 2006-2008, there were an average of 165 interviews per year). More recently, the Workers' Compensation Agency has provided their claims database sooner so that work-relatedness and/or employer name often can quickly be determined by searching for the case in the database. Few of the data items ascertained from medical records or MIOSHA inspection reports are complex (the most time-consuming item is the identification of employer NAICS code). There are a small number of individuals involved in maintaining the system. At MSU, one person is responsible for pursuing hospital medical record submission, and there is one person who performs medical record reviews, data abstraction and data entry, makes MIOSHA referrals, links medical records and Workers' Compensation claims records, and performs data analysis. All individuals working on the system spend only a portion of their time on this project.

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 63% success rate in obtaining information from patients via phone interview. MIOSHA has stated that they value referrals. 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." MIOSHA is particularly interested in injuries caused by mechanical power presses, however, medical records rarely provide such specificity (in only 4 of the 49 injuries caused by presses were mechanical power presses specifically mentioned).
2. Medical records sometimes provided insufficient information to identify an industry and assign a NAICS code. Patient interviews were not attempted to ascertain this information alone when it could be determined that the case would not be a MIOSHA referral (e.g., the case was more than six months old).
3. Almost none of the medical records provided visual documentation of injuries (e.g., photograph), making it difficult to clearly comprehend the injury. It is unclear why coders assigned an amputation diagnosis code when, for example, a patient sustained a tissue-only laceration that was subsequently sutured.
4. 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.
5. Workers' Compensation claims data did not include information on injury cause and lacked detailed injury information (e.g., single vs. multiple digit loss, which finger was injured). Thus, results on these characteristics could not be fully described.
6. The success of record linkage depended upon the accuracy of the linking variables. If a 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 much higher estimate of the 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. We are encouraged that the number and rate of amputations has decreased since 2006. However, since 2008, rates have been in the narrow range of 11.5 to 13.5 per 100,000 workers. The ultimate objective is to significantly reduce the incidence of this serious injury.

REFERENCES

1. United States Department of Labor, Bureau of Labor Statistics' Survey of Occupational Injuries and Illnesses. Washington, D.C. http://data.bls.gov/GQT/servlet/InitialPage. Accessed February 18, 2016.

2. Council of State and Territorial Epidemiologists. Occupational health indicators: A guide for tracking occupational health conditions and their determinants. Atlanta, GA. August 2006. Last updated June 2015. http://c.ymcdn.com/sites/www.cste.org/resource/resmgr/PDFs/2015_Ed_of_OHI_Guidance_Manu.pdf. Accessed February 18, 2016.

3. Largo T, Rosenman K. Work-related amputations in Michigan, 2006. A joint report by Michigan State University and Michigan Department of Community Health. East Lansing, Michigan. June 2009. http://www.oem.msu.edu/userfiles/file/Annual%20Reports/Amputations/2006%20MI%20work-related%20amputations.pdf. Accessed February 18, 2016.

4. Michigan Public Health Code (Article 368, Part 56, P.A. 1978).

5. Commission on Professional and Hospital Activities. International Classification of Diseases, Ninth Revision, Clinical Modification. Ann Arbor, Michigan. 1986.

6. Executive Office of the President, United States Office of Management and Budget. North American Industry Classification System, United States, 2002. Springfield, Virginia. National Technical Information Service. 2002.

7. Michigan Department of Licensing and Regulatory Affairs, Michigan Occupational Safety and Health Administration. MIOSHA goals for FY 2014-2018. Lansing, MI. http://www.michigan.gov/lara/0,4601,7-154-11407_30928-303423--,00.html. Accessed March 21, 2016.

8. Centers for Disease Control and Prevention. Updated guidelines for evaluating public health surveillance systems: recommendations from the guidelines working group. *MMWR* 2001;50(No. RR-13):13-24.

APPENDIX A

Additional Data Tables

TABLE A-1
Number and Rate of Work-related Amputations
by Age and Sex
Michigan Residents, 2014

Age Group	Male		Female		Total	
	Number	Rate	Number	Rate	Number	Rate
16-19	16	21.6	4	*	20	12.2
20-24	80	35.6	8	3.5	88	19.5
25-34	100	20.9	6	1.6	106	12.3
35-44	90	18.1	9	2.0	100	10.4
45-54	110	21.4	14	3.0	124	12.5
55-64	64	17.1	6	1.6	70	9.4
65+	10	7.8	1	*	11	4.7
Total	470	20.5	48	2.3	519	11.8

* Statistically stable rate could not be calculated.
Gender was unspecified for one person aged 35-44.
Rates are the number of workers sustaining an amputation per 100,000 workers.
Data Sources: Number of amputations – Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs, 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, 2014

Race	Hispanic Ethnicity			Total
	Yes	No	Unknown	
White	3	72	129	204
Black	0	7	30	37
Other	3	3	2	8
Unknown	6	0	203	209
Total	12	82	364	458

Data Source: Michigan hospital/ED medical records

TABLE A-3
Work-related Single-finger Amputation Incidents (N=379)
by Injured Hand and Amount of Finger Lost
Michigan Residents, 2014

Hand	Finger	Section Lost				Total
		Distal Phalanx	Middle Phalanx	Proximal Phalanx	Unknown	
Right	Thumb	29		2	6	37
	Index	41	7	0	1	49
	Middle	39	3	2	2	46
	Ring	21	1	2	2	26
	Little	14	2	1	1	18
Left	Thumb	31		3	0	34
	Index	54	5	2	0	61
	Middle	53	1	1	0	55
	Ring	22	1	2	2	27
	Little	22	1	2	0	25
Unknown	Unknown	0	0	0	1	1
Total		326	21	17	15	379

Data Source: Michigan hospital/ED medical records

TABLE A-4
Work-related Multiple-finger Amputation Incidents (N=67)
by Injured Hand and Amount of Finger Lost
Michigan Residents, 2014

Hand	Finger	Section Lost				Total
		Distal Phalanx	Middle Phalanx	Proximal Phalanx	Unknown	
Right	Thumb	1		2	0	3
	Index	10	0	3	0	13
	Middle	22	2	3	0	27
	Ring	16	1	1	0	18
	Little	3	1	1	0	5
Left	Thumb	3		2	0	5
	Index	12	5	2	0	19
	Middle	18	8	2	0	28
	Ring	15	3	1	0	19
	Little	4	2	1	0	7
Total		104	22	18	0	144

Data Source: Michigan hospital/ED medical records