Work-related Amputations in Michigan, 2012

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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 in collaboration with the Michigan Department of Community Health maintains a multi-source system for collecting data on work-related amputations in Michigan. This report characterizes these injuries for 2012. The salient findings are as follows:

- The system identified a total of 491 Michigan resident work-related amputations. This corresponds to a rate of 11.6 per 100,000 workers. In comparison, the official U.S. Department of Labor estimate (200)[1] was 59% lower.
- The number of work-related amputations in Michigan has decreased 34% since 2006, while the rate has decreased 26%. In 2006, there were 740 cases with a corresponding rate of 15.7 per 100,000.
- Hospital/emergency department medical records identified 442 cases. Workers' compensation lost work time claims data identified 134 cases, 88 of which were linked to medical records. There were 49 cases that would have been missed had workers' compensation claims data not been used to supplement medical records.
- The amputation rate for males was more than six times the rate for females. Among males, rates were highest for those aged 20-24.
- Forty-four percent of the incidents occurred among those working in the manufacturing industry. The specific manufacturing groups with the highest rates were Wood Product Manufacturing and Paper Manufacturing.
- Power saws were the leading cause of amputations, accounting for 15% of cases for which injury cause was specified.
- Ninety-four percent of amputations involved fingers. Slightly more than one in eight finger amputation injuries involved multiple fingers.
- There was bone loss – either from the initial injury or from subsequent surgery – in 47% of incidents.
- Upper extremity amputations occurred slightly more often on the left side (52%).

- Workers' compensation was the expected source of payment of hospitalization or emergency department care for 74% of the cases for which payment source was identified. Payer source could not be determined for 13% of medical records reviewed.
- The Michigan Occupational Safety and Health Administration (MIOSHA) inspected 13 worksites identified through medical records and assessed an average of one violation and $2,400 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 (90%) of the identified cases for 2012. Data provided by the Michigan Workers' Compensation Agency identified an additional 10% 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, the 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 491 amputations identified are appreciably larger than the official employer-based estimate of 200.

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 5,280 amputations resulting in days away from work occurred nationally in 2012. The median number of lost workdays was 26 for amputation cases compared to eight 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 has developed a set of twenty-one 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 is part of the Michigan Department of Licensing and Regulatory Affairs (LARA). Its mission is to help assure the safety and health of Michigan workers through education and training, consultation, and enforcement. One strategy MIOSHA uses to assist employers to improve 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 2012.

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 MDCH's bona fide agent to administer this law and medical records are sent directly to MSU's OEM Division.

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 2012. 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/emergency department for whom: a) an amputation diagnosis was assigned (ICD-9-CM[5] 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 2012. 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 who was in their lost work time wage replacement database with an accepted work-related amputation occurring in 2012. 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[Δ] 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 consisted of records that documented the injury, its cause, and the employer (workers' names were suppressed). MIOSHA staff reviewed referred cases to determine if they would conduct a worksite inspection. Referrals of 2012 cases were made to MIOSHA between May 2012 and March 2013.

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

[*] 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. 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 cause by a "press" were considered potential mechanical power press cases and were referred.

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, description of injury (e.g., complete amputation, crush), involvement of bone, type of surgery received (e.g., reimplantation, amputation revision) and cause of injury. For cases referred to MIOSHA, additional information was obtained, including: whether an inspection was performed, inspection date, number of violations, 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, date of birth, and zip code of residence. For cases that matched, the linked record was visually verified. The matching process was performed on the entire 2012 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) workers' compensation case where injury was an amputation matched with a work-related amputation per medical record; 2) workers' compensation case where injury was an amputation matched with a case in which work-relatedness could not be determined from the medical record; 3) workers' compensation case where injury was an

amputation not matched with an amputation per medical records; 4) workers' compensation case where injury was not an amputation matched with a work-related amputation per medical record; 5) workers' compensation case where injury was not an amputation matched with a case in which work-relatedness could not be determined from the medical record; 6) workers' compensation case where injury was not an amputation not matched with an amputation per medical records; 7) work-related amputation per medical record with no match to workers' compensation; 8) unknown if work-related amputation per medical record with no match 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

One hundred and two (102) of Michigan's 128 non-federal acute care hospitals submitted medical records to MSU. The remaining 26 acute care hospitals submitted no records but reported that they had no work-related amputation cases in 2012. Records were also provided by three VA hospitals. The total number of records received and reviewed was 1,609. Project staff attempted to interview 71 patients to ascertain work-relatedness and/or employer information and completed 52 (73%) of these interviews.

In 2012, 459 individuals were treated at a Michigan hospital/emergency department (ED) following a work-related amputation.[*] These include 453 originally identified through medical records and another six that were treated at a Michigan hospital, but could not be identified as work-related until linked to workers' compensation records.

These workers made a total of 540 hospital visits for care (71 of the 459 workers made multiple hospital visits). Nearly all workers (97.4%) were Michigan residents (N=447) (Table 1). The work-related amputation rate for these hospital-treated amputations among Michigan residents was 10.8 per 100,000 workers.

TABLE 1
Workers treated for an amputation at a
Michigan hospital/ED, 2012

Characteristics of Workers and Healthcare Utilization	Number of Workers	%
Received treatment at a Michigan hospital/ED	459	100.0
Michigan resident	*447*	*97.4*
One hospital visit	*377*	*82.1*
Multiple hospital visits (followup care or transfer to another hospital)	*70*	*15.3*
Out-of-state resident	*12*	*2.6*
One hospital visit	*11*	*2.4*
Multiple hospital visits (followup care or transfer to another hospital)	*1*	*0.2*

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 134 lost work time claims from Michigan residents with amputations. One hundred twenty eight (128) were paid for lost work time. There was no indication that the remaining six individuals were paid for lost work time. For each of these, the amputation was not contested as being work-related. Some of the 128 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, 2012

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	88	0	46	134
Yes, with a non-amputation condition	127	3	22,966	23,096
No	227	30	NA	257
Total	442	33	23,012	23,487

Shaded cells illustrate work-related amputation cases.

Eighty eight (88) of the 134 workers' compensation claims (66%) matched an amputation case identified from medical record review. For 46 cases, hospitals/EDs did not submit a medical record of an amputation (first row of Table 2). One hundred twenty seven (127) of the 442 hospital-record-based amputation cases (29%) 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). Finally, of 33 cases for which work-relatedness could not be determined via medical records, three matched worker's compensation files, each of them a non-amputation injury (third column of Table 2).

Adding the 49 cases that were identified using workers' compensation records to the 442 hospital-based cases yields a total of 491 Michigan resident workers. This corresponds to a rate of 11.6 amputations per 100,000 workers. The following analyses examine these 491 cases.

Characteristics of Injured Workers

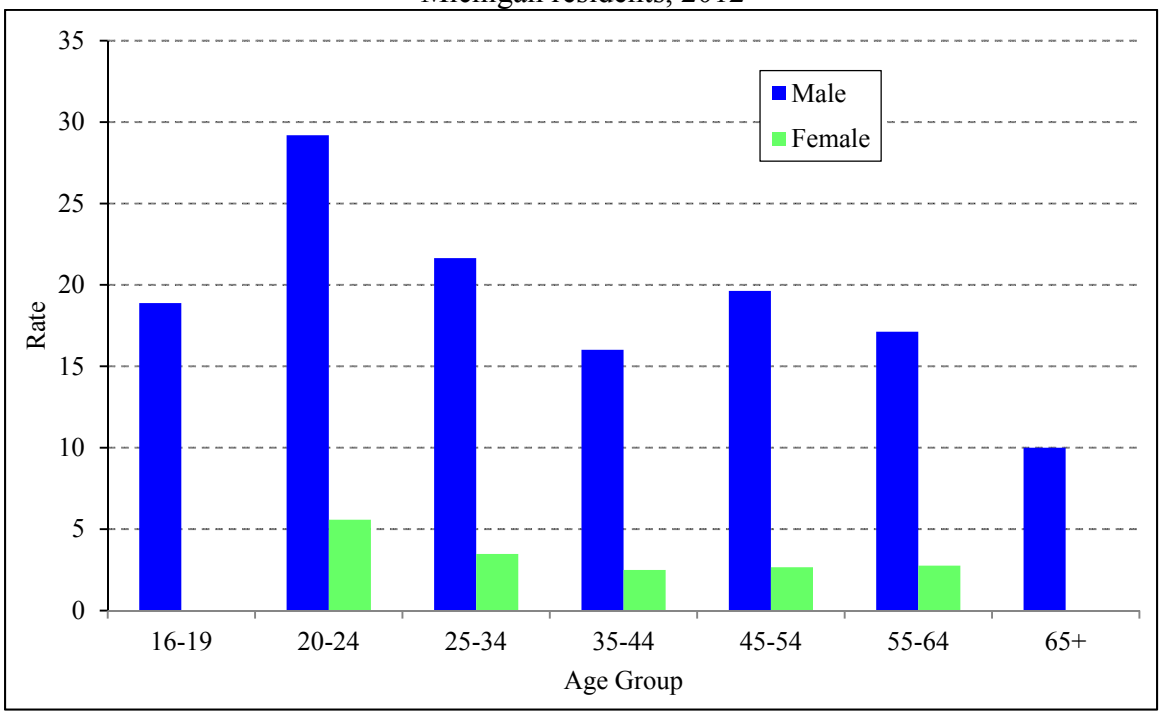
Age and Gender

Males comprised 87% of workers who sustained an amputation. Among both sexes, rates were highest for workers aged 20-24. Figure 1 displays amputation rates by age group and gender.

Race and Hispanic Ethnicity

Information on patient race and Hispanic ethnicity was missing in 39% and 95% 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=269), whites comprised 83% and African Americans 14%, similar to the racial composition of Michigan workers overall (84% and 11%, respectively).

FIGURE 1
Work-related amputation rates
by age group and gender
Michigan residents, 2012



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

An injury was considered to involve bone loss if: a) there was a complete or near complete amputation through and through bone or a joint; or b) a revision amputation was performed (trimming away of bone to optimize healing). Among the cases for which there were medical records (N=442), there were 123 complete or near-complete amputations (27.8%) and another 85 revision amputations in which there was not initial bone loss (19.2%).

As shown in Table 3, nearly all workers (94.1%) sustained finger amputations. Data from hospital/ED medical records, which provide more detail on finger injuries than workers' compensation claims data, were available for 424 finger amputation cases. The following

analyses are limited to these cases. Of 424 finger amputation incidents, 55 (13.0%) involved multiple fingers. The distal phalanx of the index finger (section J in Figure 2) was the most frequently amputated area. 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, 2012

Part of Body Amputated	Number of Workers	%
Upper Extremity	471	95.7
Finger	*463*	*94.1*
Hand	*5*	*1.0*
Arm	*3*	*0.6*
Lower Extremity	20	4.1
Toe	*13*	*2.6*
Foot	*3*	*0.6*
Leg	*4*	*0.8*
Unknown body part	1	0.2
Total	492*	100.0

*One worker sustained an amputation to the leg and arm, thus the total is 492, not 491.
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 (225 vs. 214, respectively) (Table 4).

FIGURE 2
Work-related finger amputations
by digit and section of finger lost
Michigan residents, 2012

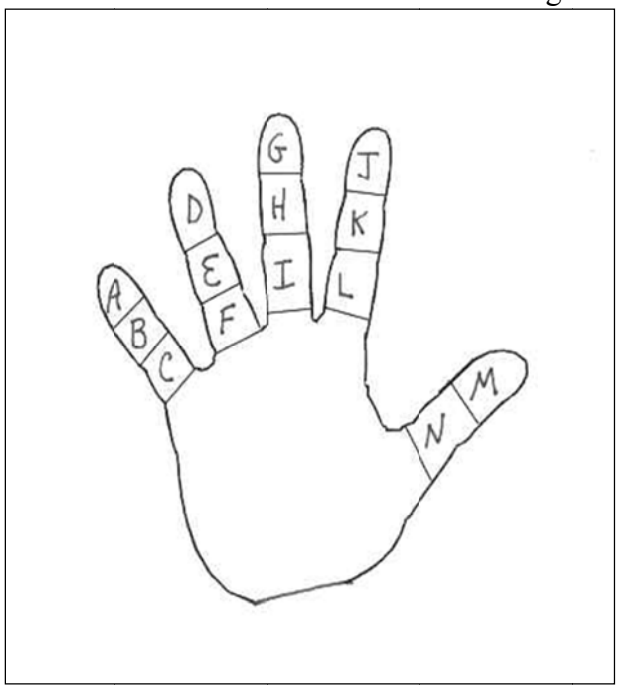


Figure is for both left and right hands.

Finger	Section	Number	%
Little	A	33	6.6
	B	11	2.2
	C	3	0.6
Ring	D	73	14.7
	E	7	1.4
	F	6	1.2
Middle	G	104	20.9
	H	16	3.2
	I	7	1.4
	Unknown	1	0.2
Index	J	119	23.9
	K	24	4.8
	L	15	3.0
	Unknown	3	0.6
Thumb	M	68	13.7
	N	5	1.0
	Unknown	1	0.2
Unknown	Unknown	1	0.2
Total		497	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, 2012

Injured Side	Number of Workers		
	Upper Extremity	Lower Extremity	Total
Right	205	9	214
Left	222	3	225
Both	1	0	1
Unknown	2	0	2
Total	430	12	442

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. Seventeen counties had no cases and another 48 had between one and five, too few to calculate statistically valid rates. Hillsdale County had the highest rate although there were only six cases. Among the most populous counties in the state, Kent County had the highest rate (14.3 per 100,000 workers) while Ingham County had the lowest (6.1 per 100,000).

Case Study One

An 18 year old male's hand was caught within a press and he sustained amputations at the middle phalanges of his left middle and index fingers. MIOSHA performed an inspection within one month of an MSU referral. They cited one violation for lack of a guard on a shop press and fined the company $2,500. The hazard had not been abated prior to the inspection.

TABLE 5
Number and rate of work-related amputations
by county of residence, Michigan residents, 2012

County	Number	Rate	County	Number	Rate
Alcona	2	*	Lapeer	3	*
Alger	0	-	Leelanau	1	*
Allegan	10	20.5	Lenawee	4	*
Alpena	3	*	Livingston	3	*
Antrim	0	-	Luce	0	-
Arenac	0	-	Mackinac	0	-
Baraga	0	-	Macomb	50	13.8
Barry	8	29.5	Manistee	0	-
Bay	3	*	Marquette	2	*
Benzie	3	*	Mason	2	*
Berrien	2	*	Mecosta	3	*
Branch	3	*	Menominee	1	*
Calhoun	10	16.9	Midland	3	*
Cass	1	*	Missaukee	1	*
Charlevoix	0	-	Monroe	11	17.1
Cheboygan	1	*	Montcalm	5	*
Chippewa	0	-	Montmorency	1	*
Clare	3	*	Muskegon	10	13.2
Clinton	3	*	Newaygo	5	*
Crawford	0	-	Oakland	44	8.1
Delta	2	*	Oceana	3	*
Dickinson	4	*	Ogemaw	2	*
Eaton	3	*	Ontonagon	0	-
Emmet	1	*	Osceola	1	*
Genesee	18	10.8	Oscoda	0	-
Gladwin	1	*	Otsego	3	*
Gogebic	0	-	Ottawa	12	9.9
Grand Traverse	2	*	Presque Isle	0	-
Gratiot	2	*	Roscommon	0	-
Hillsdale	6	35.0	Saginaw	6	7.2
Houghton	4	*	St. Clair	9	13.7
Huron	4	*	St. Joseph	4	*
Ingham	8	6.1	Sanilac	2	*
Ionia	4	*	Schoolcraft	1	*
Iosco	2	*	Shiawassee	8	27.0
Iron	0	-	Tuscola	4	*
Isabella	4	*	Van Buren	3	*
Jackson	14	21.7	Washtenaw	14	8.1
Kalamazoo	4	*	Wayne, including Detroit	82	11.3
Kalkaska	2	*	*Detroit*	*33*	*11.7*
Kent	42	14.3	Wexford	1	*
Keweenaw	2	*	Unknown	6	-
Lake	0	-	Michigan	491	11.6

* 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 78 cases (16%), there was insufficient information in either the medical records provided or workers' compensation claims data to make an industry classification. Seventeen workers were described in medical records as self-employed. Industry could be ascertained for six of these self-employed workers; the remaining 11 were included in Unknown Industry. Among two-digit NAICS industry sectors, Agriculture, Forestry, Fishing, Hunting had the highest rate (57.2 per 100,000 workers). (All of the 30 cases occurred specifically within the Agriculture subsector.) The greatest number of cases occurred within Manufacturing, which comprised 44% of the 413 incidents in which industry could be determined. Certain three-digit NAICS subsectors within Manufacturing had very high rates, notably Wood Product Manufacturing (161 per 100,000) and Paper Manufacturing (154 per 100,000).

Case Study Two

A female employed by a temp agency was assigned to a manufacturing facility. She was operating a hydraulic press and reached into the stamping area to straighten out a part. The press activated and amputated her entire left index finger. MIOSHA inspected the worksite ten days after the MSU referral. They issued one citation for inadequate machine "hold time" which allowed a hand to be placed within the machine and for the machine to continue to operate. The fine was $4,000. The company had abated the hazard prior to the inspection.

TABLE 6
Number and rate of work-related amputations
by worker industry, Michigan residents, 2012

Industry Classification (NAICS industry sector code)	Number	Rate
Agriculture, Forestry, Fishing, Hunting (11)	30	57.2
Mining (21)	0	--
Utilities (22)	1	*
Construction (23)	44	21.4
Manufacturing (31 – 33)	180	24.9
Food Manufacturing (311)	*12*	*37.2*
Wood Product Manufacturing (321)	*7*	*160.6*
Paper Manufacturing (322)	*12*	*154.3*
Plastics & Rubber Products Manufacturing (326)	*19*	*55.5*
Primary Metal Manufacturing (331)	*13*	*40.4*
Fabricated Metal Product Manufacturing (332)	*45*	*82.6*
Machinery Manufacturing (333)	*20*	*34.6*
Transportation Equipment Manufacturing (336)	*30*	*9.7*
Wholesale Trade (42)	22	20.1
Retail Trade (44 – 45)	29	6.2
Transportation & Warehousing (48 – 49)	13	9.4
Information (51)	1	*
Finance & Insurance (52)	2	*
Real Estate and Rental & Leasing (53)	2	*
Professional, Scientific, and Technical Services (54)	3	*
Management of Companies and Enterprises (55)	0	-
Administration & Support Services and Waste Management & Remediation Services (56)	13	8.7
Educational Services (61)	6	1.5
Health Care & Social Assistance (62)	5	*
Arts, Entertainment & Recreation (71)	3	*
Accommodation & Food Services (72)	42	13.7
Food Services & Drinking Places (722)	*41*	*14.1*
Other Services (81)	7	3.2
Public Administration (92)	10	7.4
Unknown Industry	78	
Total	491	11.6

* 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 workers' compensation claims data, so the table is limited to the 442 cases for which a medical record was available.) Sharp objects were identified in nearly one-third (30.1%) of the cases. Power saws (e.g., table saws, miter saws) comprised nearly one-half of sharp object injuries. Presses caused one in nine (11.3%) amputations. Medical records generally did not specify the type of press.

TABLE 7
Number of work-related amputations, by cause of injury
Michigan residents, 2012

Cause of Injury	Number	%
Sharp object	133	30.1
Power saw	*61*	*13.8*
Knife	*25*	*5.7*
Food slicer (including "meat saw")	*24*	*5.4*
Lawn mower	*5*	*1.1*
Other sharp object	*18*	*4.1*
Press	50	11.3
Mechanical	*3*	*0.7*
Other type of press	*15*	*3.4*
Unspecified type of press	*32*	*7.2*
Pinched between objects	41	9.3
In door	*9*	*2.0*
Struck by falling object	21	4.8
Struck by object - other	11	2.5
Caught in chain/pulley/gears/belt	37	8.4
Grinder	8	1.8
Meat grinder	*3*	*0.7*
Machine - other specified type	38	8.6
Machine - unspecified type	37	8.4
Other specified cause	39	8.8
Unspecified cause	27	6.1
Total	442	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 one in six (17.0%) 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 for 6.1% of cases.

Source of Payment

As shown in Table 8, workers' compensation was the expected payer in 287 (64.9%) of the 442 cases for which there was a medical record. For 56 cases payment source could not be identified. Note that of the 155 cases for which workers' compensation was not listed as a payment source in medical records, 45 were linked to workers' compensation claims data. Workers' compensation was the expected payer for 67.5% of the 425 patients that were not self-employed.

TABLE 8
Work-related amputations
by payment source overall and for non-self-employed workers
Michigan residents, 2012

Expected Source of Payment	Total		Non-self-employed	
	Number	%	Number	%
Workers' compensation	287	64.9	287	67.5
Commercial insurance	45	10.2	39	9.2
Other	54	12.2	47	11.1
Not specified	56	12.7	52	12.2
Total	442	100.0	425	100.0

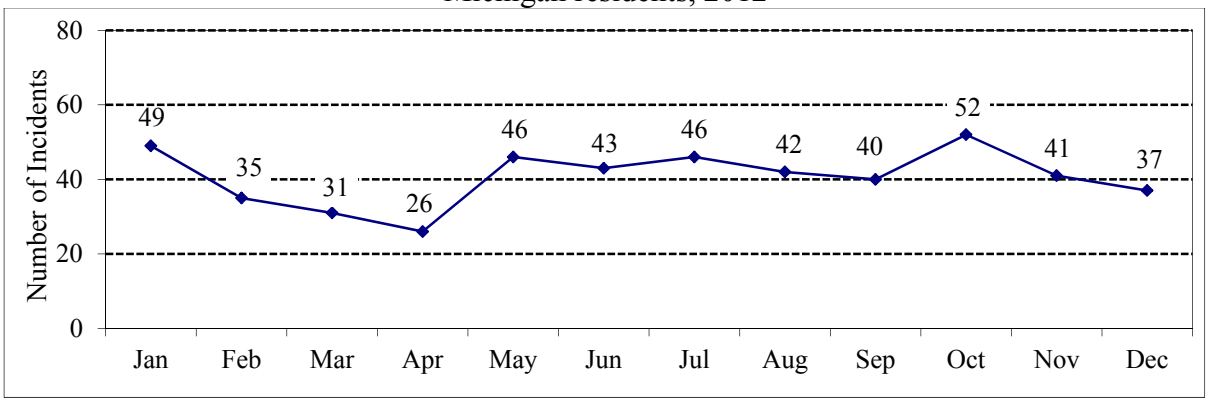
Data Source: Michigan hospital/ED medical records

Temporal Characteristics

Incidents by Month

No seasonal trend was apparent. The fewest number of cases occurred between February and April (Figure 3).

FIGURE 3
Work-related amputations
by incident month
Michigan residents, 2012

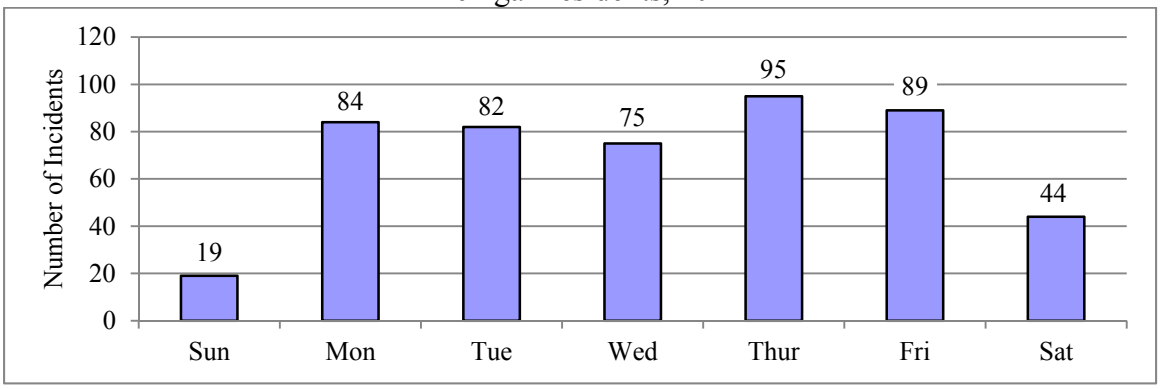


Month of incident was unknown for three cases.
Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Workers' Compensation Agency

Incidents by Day of Week

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

FIGURE 4
Work-related amputations
by day of incident
Michigan residents, 2012

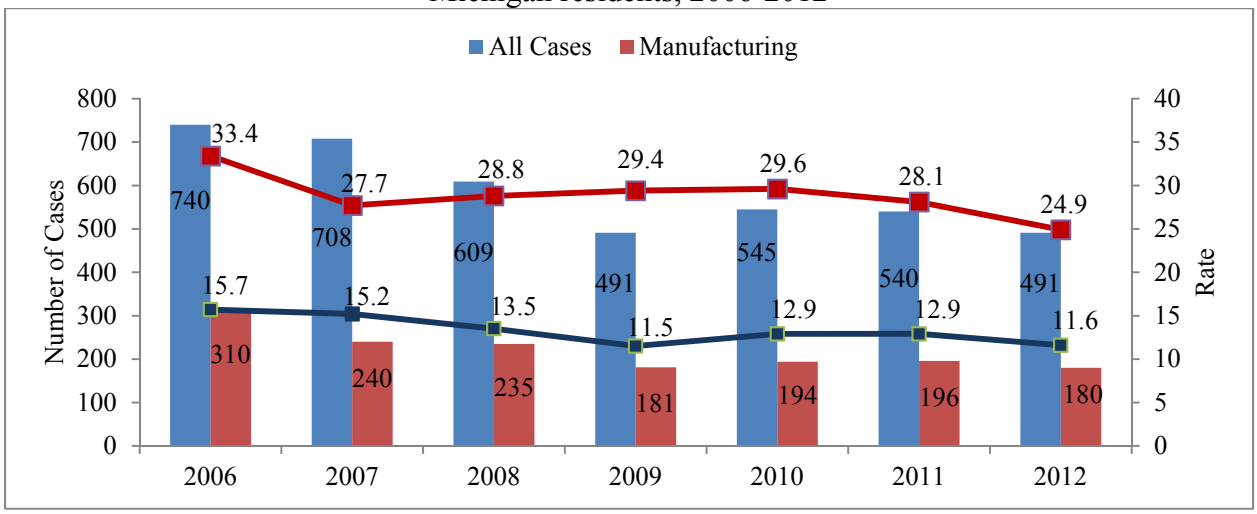


Day of incident was unknown for three cases.
Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Growth Workers' Compensation Agency

Incidents by Year

During the seven years that the surveillance system has been in place, the annual number of cases has decreased – from 740 in 2006 to 491 in 2012, a 33.6% change (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 decreased 26.1% (15.7 to 11.6 per 100,000 workers), a slightly smaller percentage decrease 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. The annual number of amputations in manufacturing also decreased. The rate was highest in 2006, but leveled off in subsequent years.

FIGURE 5
Annual numbers and rates of work-related amputations
by year of incident
Michigan residents, 2006-2012



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

Seventeen (17) of the 453 work-related amputations for which there was a hospital/ED medical record met the MIOSHA referral criteria.[*] MSU referred these 17 worksites to MIOSHA.

MIOSHA inspected thirteen worksites subsequent to a referral based on a hospital/ED medical record (Table 9). All thirteen inspections occurred within 120 days of MSU referrals (in fact, all thirteen occurred within 60 days of MSU referrals).

TABLE 9
Outcome of work-related amputation referrals to MIOSHA
Michigan residents, 2012

Outcome of Referral	Number of Worksites	%
Worksite inspected subsequent to referral	13	76.5
Inspected within 120 days of referral	*13*	*76.5*
Unknown if company on MIOSHA priority list	*13*	*76.5*
Worksite not inspected subsequent to referral	4	23.5
Worksite inspected prior to referral	*0*	*0.0*
Worksite not inspected	*4*	*23.5*
Inspection attempted or initiated, but not completed	*0*	*0.0*
Total	17	100.0

The following analyses examine the outcome of the 13 MIOSHA inspections. Table 10 summarizes the number of violations identified in these inspections. The number of violations ranged from zero to four with a median of one. Table 11 illustrates the

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

distribution of assessed penalties. For one case, there was no penalty. The maximum penalty was $20,000 and the median was $2,400. MIOSHA cited two companies for hydraulic press violations, but none for mechanical power press violations.

TABLE 10
Violations identified in worksite inspections
conducted following an MSU referral
Michigan residents, 2012

Number of Violations	Number of Inspections	%
0	1	7.7
1-5	12	92.3
6-9	0	0.0
10+	0	0.0
Total	13	100.0

Data Source: MIOSHA inspection reports

TABLE 11
Penalties assessed in worksite inspections
conducted following an MSU referral
Michigan residents, 2012

Penalty Assessed	Number of Inspections	%
$0	1	7.7
$1-$999	1	7.7
$1,000-$9,999	10	76.9
$10,000+	1	7.7
Total	13	100.0

Data Source: MIOSHA inspection reports

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 2012, there were 13 such cases. This identification and referral system directly provides support to MIOSHA in addressing Objective 1.1 of their 2009-2013 Strategic Plan[7]:

> *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.[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 2012:

1) *Incomplete submission of cases by hospitals* – Twenty-six hospitals reported treating no patients with work-related amputations in 2012 and consequently submitted no medical records to MSU. An analysis of Michigan inpatient and outpatient visits (MIDB-MODB)* in 2012 identified

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

six Michigan residents treated at six of these 26 hospitals that had an amputation diagnosis and workers' compensation listed as a source of payment. Two of these six were found in the workers' compensation database, one as an amputation and one as a crush/contusion. A third case was a match to a case reported by another hospital. In other words, had hospitals reported all amputations, at least another four work-related amputation cases would have been identified by our surveillance system. This represents 0.8% of the total number reported.

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 30 amputations, work-relatedness could not be determined as 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.

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 2012, twelve Michigan residents were treated for an amputation at an out-of-state hospital although none had workers' compensation listed as a primary or secondary payer. None of these twelve individuals was identified by the surveillance system. Our experience has shown that some work-related cases do not have workers' compensation as a payment source, so some of these twelve may have been work-related. Based on this information, it is estimated that in 2012, the surveillance system missed less than 1% of work-related amputations occurring in Michigan 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 200 work-related amputations in Michigan in 2012 – 59% fewer than our system (N=491). 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=17) and individuals without lost work time. The BLS figure is not 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. In 13 cases (2.9% of the 442 for which there was a medical record), the injury was described as a laceration or an avulsion, involved tissue only, and either there was no surgery or treatment involved suturing or providing a splint. Although each of these was coded as an amputation, it is unclear why given the injury and surgery descriptions. 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.

[†] 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 2012 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).

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 submitted a statement stating they had no cases and it appears that few cases were lost due to those latter 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 3.8% of the 442 Michigan resident work-related amputation cases for which there was a medical record, they comprised 40.0% of the 30 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 2012 were initially received in May 2012 and the last records for 2012 were received in October 2013. In December 2013, 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. At this point, data from workers' compensation claims were obtained and record matching was performed. The improved timeliness of the system has allowed more cases to be referred to MIOSHA within six months of the incident.

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. For example, information on the type of injury sustained, the involvement of bone, and

subsequent surgery was added to the data collected for 2011 and has provided valuable information without having a negative impact on the surveillance system. Crush injuries, which can overlap with amputations, were placed under surveillance in 2013.

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 71 of 1,609 (4.4%) 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). The Workers' Compensation Agency provides their claims database in a timely manner 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 items are identifying NAICS codes for employers and ascertaining info on injury type, involvement of bone and surgery). 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 73% 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." Either a power press was incorrectly listed as the cause, or a power press was in fact the cause, but not explicitly noted. For 32 of 50 (64%) amputations recorded as having been caused by a press, the type of press was unspecified (see Table 7).
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., there was minimal finger loss, 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 hand/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 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 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. The ultimate objective is to significantly reduce the incidence of this serious injury.

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APPENDIX A

Additional Data Tables

TABLE A-1
Number and rate of work-related amputations
by age and sex
Michigan Residents, 2012

Age Group	Male		Female		Total	
	Number	Rate	Number	Rate	Number	Rate
16-19	17	18.9	3	*	20	10.9
20-24	61	29.2	10	5.6	71	18.3
25-34	92	21.6	14	3.5	106	12.8
35-44	78	16.0	11	2.5	89	9.6
45-54	107	19.6	13	2.7	120	11.6
55-64	62	17.1	9	2.8	71	10.3
65+	12	10.0	2	*	14	7.0
Total	429	19.2	62	3.1	491	11.6

* Statistically stable rate could not be calculated.
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, 2012

Race	Hispanic Ethnicity			Total
	Yes	No	Unknown	
White	0	0	222	222
Black	0	0	37	37
Other	0	0	10	10
Unknown	21	0	152	173
Total	21	0	421	442

Data Sources: Michigan hospital/ED medical records and Michigan Department of Licensing and Regulatory Affairs Workers' Compensation Agency

TABLE A-3
Work-related single-finger amputation incidents (N=369)
by injured hand and amount of finger lost
Michigan residents, 2012

Hand	Finger	Section Lost				Total
		Distal Phalanx	Middle Phalanx	Proximal Phalanx	Unknown	
Right	Thumb	28		2	0	30
	Index	43	12	3	1	59
	Middle	37	1	1	1	40
	Ring	31	2	0	0	33
	Little	12	3	1	0	16
Left	Thumb	38		2	1	41
	Index	56	5	3	2	66
	Middle	40	2	0	0	42
	Ring	18	1	3	0	22
	Little	12	4	2	0	18
Unknown	Thumb	1		0	0	1
	Unknown	0	0	0	1	1
Total		316	30	17	6	369

Data Source: Michigan hospital/ED medical records

TABLE A-4
Work-related multiple-finger amputation incidents (N=55)
by injured hand and amount of finger lost
Michigan residents, 2012

Hand	Finger	Section Lost				Total
		Distal Phalanx	Middle Phalanx	Proximal Phalanx	Unknown	
Right	Thumb	0		0	0	0
	Index	10	5	2	0	17
	Middle	12	7	2	0	21
	Ring	8	3	2	0	13
	Little	3	1	0	0	4
Left	Thumb	1		1	0	2
	Index	10	2	7	0	19
	Middle	15	6	4	0	25
	Ring	16	1	1	0	18
	Little	6	3	0	0	9
Total		81	28	19	0	128

Data Source: Michigan hospital/ED medical records