

ORIGINAL ARTICLE

Surveillance of work-related amputations in Michigan using multiple data sources: results for 2006–2012

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ABSTRACT

Objectives An amputation is one of the most serious injuries an employee can sustain and may result in lost time from work and permanent limitations that restrict future activity. A multidata source system has been shown to identify twice as many acute traumatic fatalities as one relying only on employer reporting. This study demonstrates the value of a multidata source approach for non-fatal occupational injuries.

Methods Data were abstracted from medical records of patients treated for work-related amputations at Michigan hospitals and emergency departments and were linked to workers' compensation claims data. Safety inspections were conducted by the Michigan Occupational Safety and Health Administration for selected cases.

Results From 2006 through 2012, 4140 Michigan residents had a work-related amputation. In contrast, the Survey of Occupational Injury and Illness conducted by the Bureau of Labor Statistics (BLS) estimated that there were 1770 cases during this period. During the 7-year period, work-related amputation rates decreased by 26%. The work-related amputation rate for men was more than six times that for women. Industries with the highest work-related amputation rates were Wood Product Manufacturing and Paper Manufacturing. Power saws and presses were the leading causes of injury. One hundred and seventy-three safety inspections were conducted as a result of referrals from the system. These inspections identified 1566 violations and assessed \$652 755 in penalties.

Conclusions The system was fairly simple to maintain, identified more than twice as many cases than either BLS or workers' compensation alone, and was useful for initiating inspection of high-risk worksites.

BACKGROUND

An amputation is one of the most serious injuries an employee can sustain at work. A worker who has had an amputation may lose time from work, have permanent impairment that limits activity at home as well as at work, or be unable to return to their original job.

Data on the incidence of work-related amputations is essential for targeting prevention activities. In its Survey of Occupational Injuries and Illnesses (SOII), the Bureau of Labor Statistics (BLS) collects data in nearly all states on work-related injuries from a sample of employers. For 2012, they estimated that 5280 amputations resulting in days away from work occurred nationally with 26

What this paper adds

- Amputations are among the most serious injuries that occur at work. Many of these may be prevented via Occupational Safety and Health Administration (OSHA) inspections.
- A multisource surveillance system for work-related acute traumatic fatalities doubles the number of fatalities identified.
- By referring worksites to OSHA in a timely manner, a surveillance system can have a direct impact on identifying and remediating hazardous working conditions.
- A multisource surveillance system based on medical records and workers' compensation claims results in much greater sensitivity than a single data source.

median lost workdays for amputation cases compared to 8 days for all work-related injuries.¹

Reducing the incidence of work-related amputations is a priority, nationally and in Michigan. In 2011, the federal Occupational Safety and Health Administration (OSHA) proposed amending rules requiring employers to report hospitalised and fatal work-related injuries to them, which would include reporting of hospitalised work-related amputations.² The Michigan OSHA (MIOSHA) strategic plan for 2004–2008 included an objective to reduce amputations by 20%.³ Michigan's surveillance data on work-related amputations is used in targeting MIOSHA worksite inspections in specific facilities.⁴

Preliminary work with data from 1997 showed the feasibility of performing multisource surveillance.⁵ This report describes Michigan's work-related amputation surveillance system, summarises cases identified by the system since its inception (2006–2012), and describes how the data are used to prevent additional amputations in worksites identified from case reports. Data from 1 year (2008) of the system were previously published.⁶

METHODS

Sources of data were Michigan hospitals, including inpatient and emergency departments, and the Workers' Compensation Agency (WCA) within the Michigan Department of Licensing and Regulatory Affairs. Under Michigan's Public Health Code, hospitals were required to report injuries as requested



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by the Michigan Department of Community Health (MDCH).⁷ Michigan State University (MSU) has been designated as the bona fide agent of the state to carry out surveillance for work-related conditions. Michigan acute care hospitals including Veterans' Administration hospitals (between 130 and 135 hospitals during 2006–2012) were required to provide face sheets and discharge summaries for hospitalised patients and face sheets and the history and physical notes for outpatient and emergency department patients diagnosed with an amputation. From 2006 through 2010, each hospital received a request to provide these records on an annual basis. Beginning in 2011, the request was made on a quarterly basis. The hospitals received frequent reminders until they had submitted the records or indicated they had not treated any work-related amputations. The WCA provided data for claims for wage replacement due to lost work time. To be eligible for wage replacement in Michigan, an individual must have been out of work more than seven consecutive days (ie, five weekdays and two weekend days) or have sustained 'specific losses.' These specific losses included amputations in which at least a full phalanx was lost.

A case identified using hospital medical records was defined as a Michigan resident aged 16 years or older at the time of injury who received medical treatment at a Michigan hospital for whom: (1) an amputation diagnosis had been assigned *International Classification of Diseases, 9th Revision, Clinical Modification (ICD9CM)*⁸ codes 885.0-1, 886.0-1, 887.0-7, 895.0-1, 896.0-3, or 897.0-7; and (2) the incident had been documented as having occurred at work. In cases in which submitted medical records did not specify work-relatedness or patient employer, telephone interviews were performed to ascertain the missing information. A case identified using the workers' compensation system was defined as a Michigan resident aged 16 years or older with an accepted claim for an amputation resulting in lost work time wage replacement or 'specific loss.'

Based on medical record review and patient interviews, cases were categorised as 'work-related,' 'non-work-related,' or 'undetermined.' For all work-related cases, worker demographics, employer industry, injury characteristics, and cause and date of injury were abstracted from medical records; for undetermined cases, a subset of these variables were collected. Records in the resulting database were then linked to records in the workers' compensation claims database using date of birth, first

and last name, date of injury and employer. This process was performed using the entire (ie, all health conditions) workers' compensation claims database. This allowed for linkage to workers' compensation cases for which the health condition was coded as something other than amputation.

Work-related amputation rates were calculated by gender, age group 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. Employment figures were based on the Current Population Survey, conducted by the US Census Bureau for the BLS.⁹

Data linkage and analysis were performed using SAS software, V.9.2 of the SAS System for Windows (copyright 2002–2003 by SAS Institute Inc).

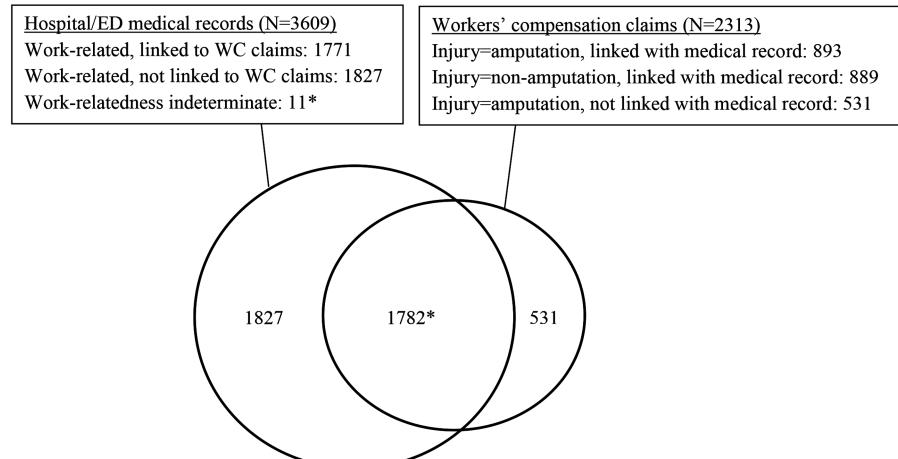
Worksites of cases identified via medical records that met the following criteria were referred to MIOSHA: (1) the worksite was located in Michigan; and either (2) the company was within an industry identified by MIOSHA as having a high injury rate or (3) the amputation potentially was caused by a mechanical power press. MIOSHA staff reviewed referred cases to determine if a worksite inspection would be conducted. MIOSHA provided inspection reports for worksites referred to them by the amputation surveillance system for inspection. These reports were the source of information on the number of violations cited and total penalties assessed. MIOSHA requires proof via visual inspection or from pictures taken by employers that all safety hazards have been corrected.

Both authors were certified as having completed the required training on human subjects and the project was approved by the Human Subject's Review Board at MSU.

RESULTS

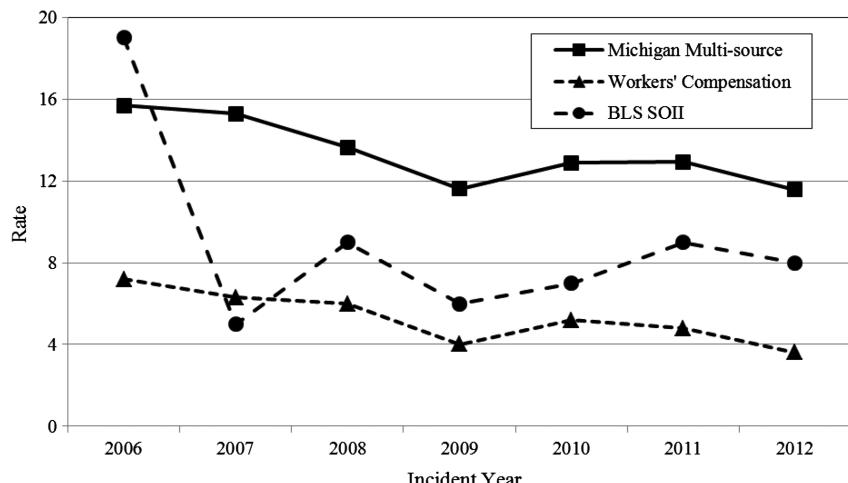
Between 2006 and 2012, Michigan hospitals submitted 11 966 medical records for patients treated with an amputation. From these, 3598 Michigan residents were identified whose amputations were work-related. For an additional 279 cases, it could not be determined if the amputations were work-related and an interview with the individuals could not be completed. Eleven of these 279 cases were considered work-related after they were linked to cases in the workers' compensation claims database (six to injuries coded as amputations, and five to injuries coded as non-amputations). Thus, the total number of cases for which there was a medical record was 3609 (figure 1). Among the work-related cases identified through medical records, 1771

Figure 1 Results of linking Michigan resident work-related amputation cases ascertained from hospital/emergency department (hospital/ED) records and workers' compensation (WC) wage replacement claims, 2006–2012 (total number of work-related amputations: 4140).



*For 11 cases, work-relatedness could not be determined from medical records. Six were matched to WC as an amputation and five were matched to WC as a non-amputation.

Figure 2 Work-related amputation rates by year, Michigan residents, 2006–2012, by data source. BLS, Bureau of Labor Statistics; SOII, Survey of Occupational Injuries and Illnesses.



Rates for Michigan Multi-source and Workers' Compensation are the number of amputations per 100,000 workers.
Rate for BLS SOII are the number of amputations per 100,000 full time equivalents for private sector employees only.

linked to the workers' compensation claims database, 887 for which the injury was listed as an amputation, and 884 as a non-amputation. The workers' compensation database identified another 531 amputations for which no medical records were received from a hospital.

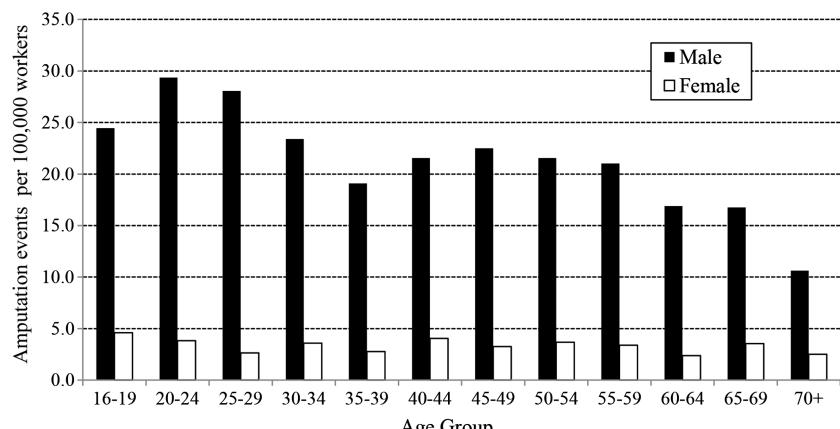
The total number of work-related amputations identified by the two data sources combined was 4140. This corresponds to an average annual rate of 13.4 amputations per 100 000 workers. The online supplementary figure shows the number of annual cases per our multisource system and those corresponding to BLS and workers' compensation claims alone. With the exception of the BLS SOII estimate in 2006, Michigan's multisource system annually identified more than twice as many work-related amputations as either source alone. Figure 2 illustrates annual rates for the three sources. (Note that the BLS rates are per 100 000 full time equivalents and could be generated for private sector employees only.) The annual rate for the multisource system decreased from 15.7/100 000 in 2006 to 11.6/100 000 in 2012. A test for trend using Poisson regression found the rate decreased an average of 4.7% annually and was statistically significant ($p<0.0001$).

Descriptive summary of work-related amputation cases

Age and gender

Men comprised 88% of workers who sustained an amputation. Figure 3 displays amputation rates by age group and gender.

Figure 3 Average annual amputation rates by age group and gender, Michigan residents, 2006–2012.



Among men, the highest rates were for those in their 20s, while among women, those aged 16–19 had the highest rates.

Industry

Table 1 illustrates the average annual number and rate of work-related amputations by industry. For 13.4% of cases, there was insufficient information in medical records, patient interviews, or workers' compensation claims data to make an industry classification. Two hundred and thirty-nine workers (5.8%) were described in the medical records as self-employed. Industry could be ascertained for 103 of these self-employed workers; the remaining 136 were included in Unknown Industry. Among two-digit North American Industry Classification System (NAICS¹⁰) industry sectors, Agriculture/Forestry/Fishing/Hunting had the highest rate (38.7/100 000 workers). However, in absolute numbers there were more than 10 times as many amputations within Manufacturing as in Agriculture (1606 vs 156). Although the overall rate in Manufacturing (30.3/100 000) was lower than that in Agriculture, certain three-digit NAICS subsectors within Manufacturing had rates greater than Agriculture, notably Wood Product Manufacturing (127/100 000) and Paper Manufacturing (105/100 000).

Causes of amputations

Causes of work-related amputations are illustrated in table 2. (This information was unavailable in workers' compensation

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Table 1 Average annual number and rate of work-related amputations by worker industry, Michigan residents, 2006–2012

Industry classification (NAICS industry sector code)	Average annual number	Average annual rate
Agriculture, forestry, fishing, hunting (11)	22.3	38.7
Mining (21)	1.9	*
Utilities (22)	2.6	*
Construction (23)	59.0	24.8
Manufacturing (31–33)	229.4	30.3
Food manufacturing (311)	18.1	55.7
Wood product manufacturing (321)	13.0	127.3
Paper manufacturing (322)	9.9	105.0
Plastics and rubber products manufacturing (326)	17.9	56.2
Primary metal manufacturing (331)	19.4	69.1
Fabricated metal product manufacturing (332)	52.4	98.5
Machinery manufacturing (333)	23.6	36.8
Transportation equipment manufacturing (336)	38.0	11.6
Furniture and related product manufacturing (337)	8.7	29.6
Wholesale trade (42)	29.9	26.8
Retail trade (44–45)	36.6	7.4
Transportation and warehousing (48–49)	13.6	9.2
Information (51)	1.4	*
Finance and insurance (52)	1.7	*
Real estate and rental, and leasing (53)	5.4	8.0
Professional, scientific and technical services (54)	5.3	2.2
Management of companies and enterprises (55)	0.3	*
Administration and support services, waste management and remediation services (56)	16.7	10.4
Educational services (61)	9.9	2.4
Health care and social assistance (62)	6.9	1.1
Arts, entertainment and recreation (71)	5.9	7.7
Accommodation and food services (72)	43.3	14.1
Food services and drinking places (722)	41.0	14.7
Other services (81)	12.6	5.5
Public administration (92)	7.7	5.1
Unknown industry	79.3	
Total	591.4	13.4

*Rate not calculated when based on fewer than 20 cases due to statistical instability.

NAICS, North American Industry Classification System.

claims data, so the table is limited to the 3609 cases for which a medical record was available.) Sharp objects were the leading cause of injury (29.5%). Power saws (eg, table saws, mitre saws) comprised one-half of sharp object injuries. Presses caused slightly more than 1 in 10 (10.6%) amputations. Medical records generally did not specify the type of press. Another frequent cause of amputations was workers getting pinched or crushed between objects, such as doors. Medical records provided no information on cause for 325 cases (9%).

Source of payment

Workers' compensation was listed in medical records as the expected payer in 2390 (66%) of 3609 cases. It was the expected payer for 71% of the 3370 patients who were not self-employed. For 423 cases, payment source could not be identified. Note that of the 1219 cases for which workers' compensation was not listed as a payment source in medical records, 376 (31%) were linked to workers' compensation claims data. Conversely, of the 2390 cases for which workers' compensation was listed as a payment source, 984 (41%) were not linked to a workers' compensation claim. Many of these latter cases were presumably

Table 2 Number of work-related amputations by cause, Michigan residents, 2006–2012

Cause of injury	Total number	Per cent
Sharp object	1064	29.5
Saw	526	14.6
Meat saw/food slicer	175	4.8
Knife	176	4.9
Lawn mower blade	28	0.8
Other sharp object	159	4.4
Press	384	10.6
Mechanical press	35	1.0
Hydraulic press	16	0.4
Press brake	4	0.1
Rolling press	8	0.2
Printing press	6	0.2
Drill press	20	0.6
Other specified type of press	32	0.9
Unspecified type of press	263	7.3
Pinched between objects	364	10.1
In door (eg, car, safe)	75	2.1
Caught in chain/pulley/gears/belt	261	7.2
Struck by falling object	200	5.5
Struck by object, other	78	2.2
Grinder (excluding food grinders)	74	2.1
Fan blade	24	0.7
Auger	20	0.6
Snow blower	15	0.4
Wood splitter	15	0.4
Router	13	0.4
Hi-Lo/forklift	12	0.3
Drill (excluding drill press)	9	0.2
Hedge trimmer	8	0.2
Wood chipper	6	0.2
Machine, other and unspecified	447	12.4
Other specified	290	8.0
Unknown/unspecified	325	9.0
Total	3609	100.0

Michigan workers' compensation claims data do not contain cause of injury information and thus are excluded from the table.

medical only since they were not in the workers' compensation database, which only contains wage replacement cases. However, at least 101 of the 984 workers (10.3%) had lost at least one full phalanx and qualified for time loss claims via 'specific losses,' so severity of the injury only partially explains why 41% of the amputations with workers' compensation as the payer were not found in the workers' compensation database.

Worksite inspections

There were 172 MIOSHA inspections performed to follow-up a work-related amputation. The maximum number of violations cited in a single inspection was 44 and the median was 7. In 12 inspections, no violations were identified. The maximum penalty assessed in a single inspection was \$134 310, with a median penalty of \$1800. There were 23 investigations that resulted in no penalties. MIOSHA cited 25 companies for mechanical power press violations.

DISCUSSION

Michigan's multisource surveillance system for amputations identified that 4140 Michigan residents had a work-related amputation from 2006–2012, an average of 591 per year. In

comparison, the BLS estimate based on the extrapolation of results from a sample of employers identified 1770 amputations, an average of 253 per year. Thus, the BLS estimate was 57% lower than our count. If only the worker compensation database for wage replacement had been used, then only 1424 amputations, an average of 203 per year or 66% lower than our multi-source system, would have been identified. Amputation rates decreased from 2006 in all three systems (figure 2). Michigan's multisource system and workers' compensation claims showed a decrease in the amputation rate from 2006 to 2009 and then a relatively stable rate from 2010 to 2012. The BLS SOII rate (available for private sector only) decreased from 2006 to 2007 and then had a slight upward trend. The increase in 2011 in the BLS rate may have been secondary to BLS dropping the requirement for bone loss for an injury to be classified as an amputation, as this increase was not seen in the workers' compensation or medical record data, which never required bone loss for an injury to be classified as an amputation. Given that the rate and not just the number of amputations decreased, we cannot explain the decrease to fewer individuals working during the recession that occurred during this time period. We will continue to monitor the rate of amputations in future years.

BLS's much lower estimate of work-related amputations can be explained in part by the fact that BLS included in its statistics only amputations with one or more days away from work or with altered work hours. Michigan's surveillance system counted all work-related amputations admitted or treated as an outpatient at a Michigan hospital, since we cannot determine number of days away from work or if there were altered work hours. Second, BLS excluded the self-employed, independent contractors and farm workers who work on farms with fewer than 11 employees. Michigan's surveillance system identified 239 self-employed workers and another 91 farm workers, although some of the farm workers would have been employed by agricultural establishments covered by the BLS survey. Our results of the BLS undercount for this 7-year period are similar to the 59% undercount we previously reported for the year 2008.⁶ Since the number of amputations is relatively small in any given year, we were concerned that perhaps 2008 was an unusual year. This proved not to be true. Our finding related to the BLS undercount of work-related amputations was also consistent with our previous reports from Michigan, stating that BLS undercounted work-related skull fractures by 54%¹¹ and work-related burns by 69%.¹² The consistency found in under-reporting by the BLS system is inherent in a system that: (1) is dependent on reporting from a single source, that is, employers; (2) has disincentives for workers to inform their employers of workplace injuries; and (3) has at least perceived disincentives for employers to be fully forthcoming when compiling their injury counts.

Another possible reason for the difference between our numbers and those estimated by BLS are differences in classifying injuries as amputations. We defined an amputation as either a medical encounter in which the diagnosis was coded as an amputation or a workers' compensation claim in which the nature of injury was designated as an amputation. BLS relied on employer representatives from the employers in their sample to code the injury based on the information in any of the following sources: the OSHA Form 301; a workers' compensation report; an accident report; or an insurance form. In addition, prior to 2011, for an injury to be categorised as an amputation by BLS, bone loss was required, either in the initial injury or from subsequent surgery. This would not be a factor contributing to the difference in the years 2011 and 2012 when BLS no longer

required bone loss to classify an injury as an amputation. In a comparison of injury coding in a workers' compensation database and the BLS employer survey, Wuellner and Bonauto¹³ found that among 119 cases coded as amputations in workers' compensation, only 60% were classified as amputations in the BLS employer survey. Our system allowed us to examine injury coding agreement between medical records and workers' compensation claims data. There were 884 amputations identified in medical records that were coded as something other than an amputation in the workers' compensation database. It is also possible that there were 531 injuries coded as amputations in the worker compensation databases that were coded as some other type of injury in the hospital records. We cannot be sure about the latter comparison because some of those 531 amputations were probably treated at locations that did not report, such as an urgent care centre or an out-of-state healthcare facility or from hospitals that provided incomplete reports. Other possible explanations for the BLS undercount may be that their statistical sampling procedure was not adequate or employers did not provide complete reporting on the survey. Since each company's results are weighted, under ascertainment of even a few amputations at each company can have a major effect on BLS's overall estimate.

Previous activities at the state level to enumerate work-related amputations have been limited to: using workers compensation as the sole data source,^{14 15} conducting one-time studies^{16 17} and collecting data on bone loss injuries only using administrative databases that had a long lag time between time of injury and access to the data and where the name of the injured individual and/or company where the injury occurred were not available to allow for workplace follow-up.¹⁸

Michigan's surveillance system for work-related amputations, which is based on multiple data sources and reporting with personal identifiers, provides a more robust estimate of the true number of work-related amputations. Further, receipt of the reports in an ongoing timely manner with actual company names allows Michigan to initiate workplace investigations. BLS data can be used only to target industry sectors since the reports from individual companies are kept confidential, even from other groups in the US Department of Labor (eg, OSHA).

In 93% of the companies inspected as a result of our referral system, a citation was issued by Michigan OSHA. Most (88%) of these citations were for the absence of guards on machines or other safety issues directly related to the injury and 61% of these were not corrected at the time of the inspection. This indicates that despite a serious injury, more than half of the companies did not initiate a change to correct the hazardous situation. We have found these follow back investigations to be equally productive for other workplace injuries such as burns.¹²

Although this paper reports on amputations only through 2012, we continue to track these injuries and initiate workplace inspections. Preliminary data from 2013 to 2014 show an additional 360 amputations and 12 workplace inspections. Also, beginning in 2013, we began requesting work-related crush injuries. We anticipate finding additional amputation cases from this broader scope since some crush injuries result in revision amputation surgery.

We are aware of certain limitations with our surveillance system. It does not capture 100% of Michigan resident work-related amputations. Michigan residents who sustained work-related amputations but were treated in an out-of-state medical facility or worked for an out-of-state employer would be missed in our system. Some hospitals may have under-reported cases and we were unable to check on their reporting completeness.

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Without the availability of a gold standard, there is no way to quantify the sensitivity of our system. This lack of a gold standard also hinders a sensitivity comparison to BLS estimates. However, medical records-based identification of amputations is as close to a gold standard as possible in the absence of having an independent, experienced healthcare provider evaluating each patient's injury. The 531 amputations identified in the workers' compensation database that were not identified by medical records could be cases in which the claimant was treated somewhere other than one of the reporting hospitals, were cases coded as amputations by hospitals, but not reported to us, or were coded by hospitals as something other than an amputation and therefore not reported. Another major limitation was that key information, such as extent of the injury, employer name and cause of injury, was often missing or incomplete in hospital/ED as well as WCA reports.

CONCLUSIONS

Despite its limitations, Michigan's surveillance system, which used multiple reporting sources, provided a more accurate estimate of the true number of work-related amputations than the BLS or workers' compensation estimates. This is an important finding for agencies that rely on these other two sources for estimates of work-related amputations. Michigan's system also was used to successfully target inspections at the individual facilities where people were injured. For these reasons, we encourage other states to develop similar systems. This could be achieved by accessing medical records, and developing relationships with staff from state OSHA and workers' compensation systems. The Council of State and Territorial Epidemiologists has developed guidance documents to assist states in making referrals to OSHA.¹⁹

The Michigan system has been maintained now for 7 years and will be continued. It has already been expanded to include work-related burns, crush injuries and skull fractures. Plans are to put all work-related fractures requiring hospitalisation under surveillance.

Contributors TWL was responsible for collection, analysis and interpretation of the data, and for principally developing the manuscript. KDR was responsible for the design of the system for data collection, for assisting in the interpretation of data and for providing substantial input in the manuscript. Both authors provided final approval of the report and are accountable for all aspects of the manuscript.

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Competing interests None.

Ethics approval Michigan State University Institutional Review Board.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Data used in this report may be made available following a signed Data Use Agreement. The data set will be stripped of identifiers.

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