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RESEARCH ARTICLE

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Assessing the accuracy of the death certificate injury at work box for identifying fatal occupational injuries in Michigan

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Abstract

Background: Death certificates contain a box labeled "Injury at Work" which is to be marked "Yes" for all fatal occupational injuries. The accuracy of this box in Michigan is not fully characterized.

Methods: The accuracy of the Injury at Work box on the Michigan death certificate was compared to deaths identified from 2001 through 2016 by the Michigan Fatality Assessment and Control Evaluation multi-source surveillance system. The sensitivity was calculated across this time period, while specificity and positive and negative predictive values were derived for 2011-2016. Univariate and multivariate regression were used to examine differences in the sensitivity over time and across demographic variables, industry, and the type of death.

Results: We found a sensitivity for the Injury at Work box of 73.1% among 2156 deaths. The sensitivity showed a significant declining trend over the 17 years, from 79.8% to 63.1%. Sensitivity varied significantly across incident type (aircraft, animal-related, drug overdose, motor vehicle, and suicides having particularly lower sensitivities, and electrocutions, falls, and machine-related incidents having higher sensitivities), and industry sector (construction, manufacturing, public safety, transportation, and trade sectors having higher sensitivities, and agriculture and services sectors showing lower sensitivities). Across nearly all categories the sensitivity was significantly below 1.

Conclusions: The Injury at Work box on the Michigan death certificate was often incorrectly completed and has become less accurate with time, though the degree of this inaccuracy varies by the industry of the victim and the type of incident.

KEYWORDS

death certificate, occupational fatalities, sensitivity, surveillance

1 | INTRODUCTION

Death certificates are important sources of information for public health surveillance systems and epidemiological studies. In occupational health, the use of death certificates for surveillance of deaths from occupational injuries has been reported to be one of the most comprehensive single sources of information for fatal occupational injuries.[1,2] Death certificates in the United States contain a box that indicates whether a fatal injury occurred while at work, labeled "Injury at Work". This box is included on the standard certificate of death developed by the Centers for Disease Control (CDC),[3] and in Michigan, the state public health code requires that the CDC's guidelines for completing the death certificate, including the Injury at Work box, be followed whenever possible.[4]

The Michigan Fatality Assessment and Control Evaluation (MIFACE) program is a state-based program funded by the National Institute for Occupational Safety and Health (NIOSH) that utilizes a multi-source surveillance system to track fatal work-related injuries. Information on these fatalities is taken from death certificates as well as media reports, police and first-responder reports, hospital records, medical examiner and autopsy reports, workers' compensation records, and records from

Michigan and Federal Occupational Safety and Health Administrations (MIOSHA and OSHA, respectively). MIFACE, alongside the national NIOSH-based program and other state-based FACE programs, follows an approach for work-related fatality surveillance that largely adopts the case inclusion criteria of the Census of Fatal Occupational Injuries (CFOI), operated by the Bureau of Labor Statistics (BLS).[5] CFOI (and by extension the FACE programs that follow its multisource surveillance model) is considered one of the most comprehensive surveillance systems for fatal work-related injuries across industrialized nations.[6]

The instructions are given for completing the death certificate Injury at Work box by the CDC largely match the criteria for considering a fatality work-related by MIFACE, the FACE program broadly, and the BLS CFOI program from which the FACE criteria were derived. Namely, an injury at work includes any injury sustained while working on job premises, while on break or lunch or in the parking lot on job premises, while working for pay or compensation regardless of location, or while traveling on business, including to/from business sites. An injury is *not* considered to have occurred at work if due to personal recreational activity on the job premises, if while a visitor to job premises, while commuting to or from the job premises, or if the work is done for oneself for no profit.[3,5] We would, therefore, expect the Injury at Work box to identify most if not all work-related deaths when compared to the CFOI or FACE programs.

However, previous work suggests that this is not the case. Other studies examining the accuracy of death certificates in identifying traumatic work-related fatalities compared to more comprehensive surveillance systems have found sensitivities in the range of 60% to 90%.[1,2,7,8] From 2001 -2016, MIFACE has calculated the sensitivity of the Injury at Work box, with sensitivities ranging annually from 55% to 87%.[9] This previous work broadly suggests that the Injury at Work box is inaccurate in identifying at-work fatalities in Michigan and other states. However, other metrics describing the accuracy of the Injury at Work box (specificity and positive and negative predictive value) have not previously been calculated for Michigan, nor have they been examined across time, industries, and incident types. Furthermore, no study has performed a comprehensive evaluation of the Injury at Work box as compared to a FACE program (one study limited to motor vehicle-related deaths was done using the Kentucky FACE program as a referent).[10]

This paper assesses the sensitivity, specificity, and positive and negative predictive value of the Injury at Work box in Michigan, and examines whether the sensitivity varies across demographics, time, industry of the deceased worker, and/or the fatal incident type, using the records of the MIFACE surveillance system as a reference record of work-related deaths.

2 | METHODS

2.1 | Case ascertainment and coding

MIFACE is a multi-source surveillance system for identifying acute, traumatic work-related fatalities. It is the Michigan state-based FACE program operated as part of a cooperative agreement with the National Institute for Occupational Safety and Health (NIOSH) FACE program. For the purposes of this system, work was defined as all legal duties, activities, or tasks that produce a product as a result and that are done in exchange for money, goods, services, profit, or benefit. In order for a death to be included in the MIFACE system, it must have resulted from a traumatic injury, defined as any unintentional or intentional wound or damage to the body resulting from acute exposure to energy or from the absence of such essentials as heat or oxygen caused by a specific event, incident, or series of events within a single workday or shift. There must have also been a relationship between the work, the individual, and the injury event such that the event either occurred (a) on the employer's premises while the individual was there to work, (b) off the employer's premises and the individual was at the location to work, or (c) the event or acute exposure was related to the individual's work or status as an employee. The death itself may have occurred at any time and place following the incident.

MIFACE was alerted to work-related fatalities and received further information concerning them through numerous sources, including news reports, police reports, hospital records, medical examiner reports/autopsies, death certificates, and MIOSHA investigations. Death was considered in-scope for MIFACE according to the NIOSH FACE (and therefore CFOI) criteria for the definitions of “traumatic injury” and “work-related”.[5] For each death identified during the years 2001-2016, demographic information on the individual were collected and recorded. Additionally, the industry in which each individual was employed was determined based on these sources of information and was coded according to the North American Industry Classification System (NAICS), and subsequently aggregated into the National Occupational Research Agenda (NORA) industry sectors delineated by NIOSH.[11] Each case was also coded for the type of incident/fatality.

We reviewed all death certificates included in the MIFACE system. We recorded whether the “Injury at Work?” box on the death certificate is marked “Yes”, “No”, “Unknown”, or whether it was left blank. If the death was determined to fall within the scope of the MIFACE system (ie, the incident was deemed to have occurred at work), the death certificate was recorded as being accurate if this box was marked “Yes” (true positives), and inaccurate in all other cases (false negatives). We defined false positive cases as those in which the Injury at Work box was marked Yes on the death certificate but where the fatal incident was determined not to have occurred at work. The review of all death certificates with the Injury at Box marked “Yes” regardless of their inclusion in the MIFACE system for false positives was only available for the years 2011-2016. True negatives (wherein a death is neither included in MIFACE nor had the Injury at Work box marked “Yes”) were computed by subtracting the combined number of true positives, false positives, and false negatives from the total number of deaths occurring in Michigan during this period among individuals 15 to 84 years old.[12]

2.2 | Data analysis

Descriptive statistics regarding year, worker sex, worker race, worker ethnicity, NORA sector, and incident type were generated

for all MIFACE cases. Point estimates and 95% confidence intervals were calculated for the specificity, positive predictive value (PPV) and negative predictive value (NPV) of the Injury at Work box compared to the MIFACE multi-source system for each year from 2011-2016 (the only years for which information regarding all potential false positive death certificates was available), and for the sensitivity for each year from 2001-2016, using univariate logistic regression models for each measure with categorical year variables included as a fixed effect. The presence of a temporal trend in sensitivity was tested using linear regression of the sensitivity on year. The effect of the year on the sensitivity was also examined using autoregressive integrated moving average (ARIMA) regression. Dickey-Fuller tests were used to test the stationarity in ARIMA model. A p-value of less than 0.05 from Dickey Fuller test indicates nonstationarity.

Univariate and multivariate logistic regression was used to generate point estimates and 95% confidence intervals of the sensitivity of the Injury at Work box across each category of the remaining variables (worker sex, worker race, worker ethnicity, NORA industry sector, and incident type) separately and in combination, with each variable included as a categorical fixed effect.

Predicted sensitivities across the categories of each variable were considered to differ statistically from each other, the overall sensitivity or a sensitivity of 1 (ie, perfect agreement between the Injury at Work box and MIFACE inclusion across each variable) if their 95% confidence intervals (CI) did not overlap each other's, that of the overall sensitivity, or 1, respectively. This is approximately equivalent to setting the type I error rate at 0.05. Analyses were completed using SAS 9.4 (SAS, Cary, NC).

3 | RESULTS

3.1 | MIFACE case characteristics

There were 2213 deaths in the MIFACE system during the study period. Death certificates were unavailable for 57 of these cases. Of the remaining 2156 deaths, the Injury at Work box was marked "Yes" on the death certificate for 1576 of these deaths, giving an overall sensitivity of 73.1% (Table 1).

The distribution of demographic characteristics, industries, and incident types among the remaining 2,156 MIFACE deaths are shown in Table 1. Decedents included in the MIFACE system during this period were predominantly male, white, and Non-Hispanic. The NORA sectors with the largest number of fatalities include the Services (552 deaths, 25.6%) and Construction (446 deaths, 20.7%) sectors. Motor vehicle collisions comprised the largest share of fatal incidents (451 deaths, 20.9%), followed by falls (331 deaths, 15.4%), homicides (303 deaths, 14.1%), struck-by incidents (280 deaths, 13.0%), and machine-related incidents (278 deaths,12.9%).

TABLE 1 Michigan Fatality Assessment and Control Evaluation case characteristics 2001-2016

	Number	%
"Injury at Work" box		
Yes	1576	73.1
No	580	26.9
Sex		
Male	1967	91.2
Female	189	8.8
Race		
White	1796	83.3
Black	83	3.9
Asian	6	0.3
Other	271	16.7
Ethnicity		
Hispanic	105	4.9
Non-Hispanic	2044	95.1
Industry sector		
Agriculture, forestry & fishing	293	13.6
Construction	446	20.7
Healthcare & social assistance	75	3.5
Manufacturing	219	10.2
Mining	17	0.8
Public Safety	69	3.2
Services	552	25.6
Transportation, warehousing & utilities	261	12.1
Wholesale and resale trade	224	10.4
Incident type		
Aircraft	49	2.3
Animal-related	20	0.9
Asphyxiation	19	0.9
Drowning	19	0.9
Drug overdose	37	1.7
Electrocution	87	4
Fall-related	331	15.4
Fire/explosion	45	2.1
Heat/cold-related	11	0.5
Homicide	303	14.1
Machine-related	278	12.9
Motor vehicle	451	20.9
Other	19	0.9
Struck-by	280	13
Suicide	158	7.3
Toxic exposure	49	2.3

3.2 | Sensitivity, specificity, PPV, and NPV

We used univariate regression to model the sensitivity by year for 2001-2016 and compared this to the observed sensitivity (Figure 1). The sensitivity of the Injury at Work box was

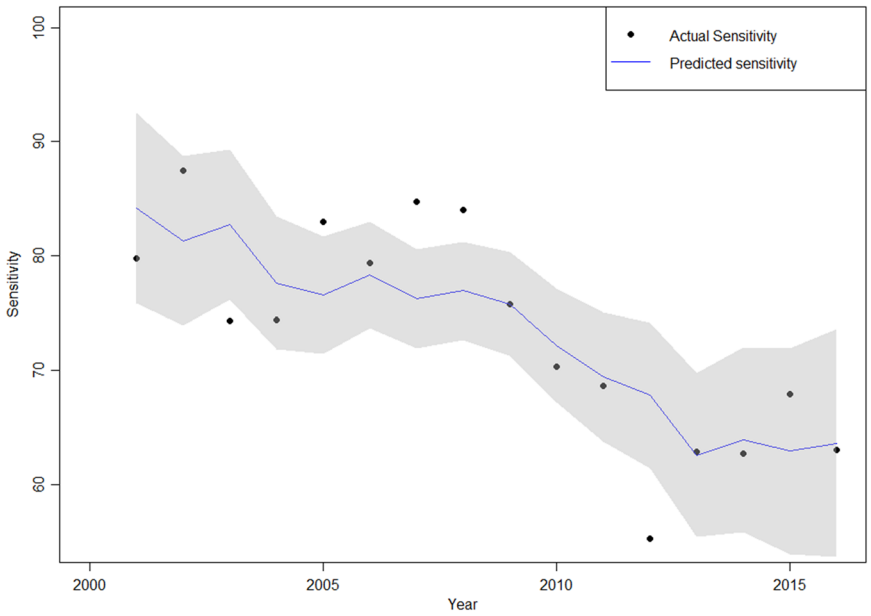

FIGURE 1 Sensitivity of Injury at Work box by year. Data points represent calculated sensitivity for that year. Blue trend line represents the yearly sensitivity predicted by the univariate regression model, with shaded area representing the 95% confidence interval for the predicted sensitivity [Color figure can be viewed at wileyonlinelibrary.com]

significantly lower than 1 during each year of the period studied and declined across the years. This trend was verified via regression ($F(1,14) = 20.03$, $P < .001$) showing a significant ($P < .005$) decrease in sensitivity of 1.52% per year. ARIMA regression was used to test for autoregression within this trend, though the result was nonsignificant ($P = .32$).

For the years 2011-2016, all death certificates with the Injury at Box work marked "Yes" were available for analysis, allowing for parallel analysis of specificity, positive predictive value (PPV) and negative predictive value (NPV) alongside sensitivity for those years. While specificity and NPV were each over 99.9% every year from 2011-2016, NPV was significantly lower than 1 each year while specificity was not (data not shown). PPV varied from 89.0% (95% CI, 82.9-95.1%) to 95.0% (95% CI, 90.7-99.3%) and was significantly lower than 1 each year (Table 2). No differences between years or other temporal trends were observed in the 7 years where these three measures could be calculated.

TABLE 2 Sensitivity and positive predictive value of the Injury at Work box

Year	Sensitivity (95% CI)	Positive predictive value (95% CI)
2011	68.6 (60.8-76.4)	95.0 (90.7-99.3)
2012	55.2 (46.8-63.6)	91.4 (85.9-96.9)
2013	62.9 (54.6-71.1)	95.4 (91.0-99.8)
2014	62.7 (54.7-70.6)	89.0 (92.9-95.1)
2015	67.9 (59.9-75.9)	94.7 (90.1-99.2)
2016	63.0 (55.5-70.6)	93.4 (88.7-98.1)
Total	73.1 (71.3-74.9)*	93.1 (91.0-95.2)

*Total sensitivity incorporating data for all years available, 2001-2016.

3.3 | Univariate analysis

Univariate regression was used to evaluate the effects of demographic variables, industry, and type of fatality on sensitivity for 2001-2016. All race categories except for Asian (67.7%, 95% CI, 28.9%-104.4%) showed sensitivities that were significantly lower than 1, and the Other race category (65.3%, 95% CI, 59.6%-71.0%) was significantly lower than the overall sensitivity and the White category (74.1%, 95% CI, 72.0%-76.1%). The sensitivity for the Hispanic ethnicity (82.9%, 95% CI, 75.6%-90.1%) was significantly higher than the overall sensitivity and that of Non-Hispanics (72.3%, 95% CI, 70.7%-74.6%), although the sensitivities of both categories were significantly lower than 1. While the sensitivity of both sexes differed significantly from 1, neither differed significantly from the overall sensitivity or from each other (data not shown).

The sensitivities for each industry sector except mining (88.2%, 95% CI, 72.9-103.6%) were significantly lower than 1 (Figure 3). The sensitivities for the agriculture, forestry, and fishing (47.8%, 95% CI, 42.1-53.5%) and services (65.8%, 95% CI, 61.8-69.7%) sectors were significantly lower than the overall sensitivity, while the construction (85.6%, 95% CI, 82.4-88.9%), manufacturing (87.7%, 95% CI, 83.3%-92.0%), and public safety (84.1%, 95% CI, 75.4-92.7%) were all significantly higher than the overall sensitivity (Figure 2).

The predicted sensitivity of the Injury at Work box varied widely across types of fatal incidents (Figure 3). The sensitivity for each type of death was significantly lower than 1. The sensitivities for animal-related (40.0%, 95% CI, 18.5-61.5%) and aircraft-related (53.1%, 95% CI, 39.1-67.0%) incidents, drug overdoses (54.1%, 95% CI, 38.0-70.1%), motor vehicle collisions (64.3%, 95% CI, 59.9-68.7%), suicides (62.7%, 95% CI, 55.1-70.2%), and toxic exposures (55.1%, 95% CI, 41.2-69.0%) were all significantly lower than the overall sensitivity, while those of electrocutions (89.7%, 95% CI, 83.4-96.1%), falls

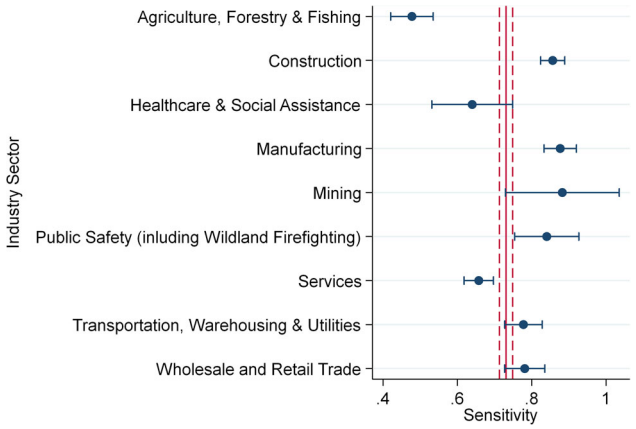

FIGURE 2 Sensitivity of Injury at Work box by industry sector. Data points represent sensitivity predicted by the univariate model with 95% confidence intervals. The solid red line represents the predicted overall sensitivity under the model, with the 95% confidence interval [Color figure can be viewed at wileyonlinelibrary.com]

(88.8%, 95% CI, 85.4-92.2%), and fires/explosions (86.7%, 95% CI, 76.7-96.6%) were all significantly higher than the overall sensitivity.

3.4 | Multivariate analysis

A multivariate model incorporating sex, race, ethnicity, industry sector, and type of fatal incident was used to analyze all variables simultaneously (Table 3). The predicted overall sensitivity under this model was 73.2% (95% CI, 71.4-74.9%).

These results across demographic variables were comparable under the univariate and multivariate models. The sensitivities for all race categories, including Asian (59.0%, 95% CI, 23.3-94.7%), were significantly lower than 1 but not significantly different from the overall sensitivity. Both ethnicity categories produced sensitivities

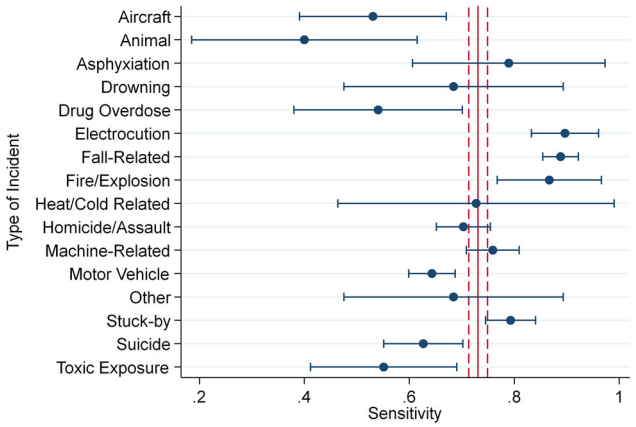

FIGURE 3 The sensitivity of Injury at Work box by incident type. Data points represent sensitivity predicted by the univariate model with 95% confidence intervals. The solid red line represents the predicted overall sensitivity under the model, with the 95% confidence interval [Color figure can be viewed at wileyonlinelibrary.com]

that remained significantly lower than 1, although that of the Hispanic category (82.8%, 95% CI, 74.6-91.0%) was not significantly higher than the overall sensitivity as it was under the univariate model.

Trends in sensitivity across industries and types of incidents under the multivariate model largely mirrored those produced under the univariate models. For industry sectors, the sole difference in significance was that the sensitivity for the services sector (69.4%, 95% CI, 65.8-73.0%) was no longer significantly lower than the overall sensitivity. Examining sensitivity by incident type, the predicted sensitivity for animal-related incidents (67.5%, 95% CI, 48.7-86.4%) became notably higher under the multivariate model and was no longer significantly lower than the overall sensitivity, nor was that for toxic exposures (59.7%, 95% CI, 46.8-72.6%). The sensitivity for fires/explosions (82.6%, 95% CI, 71.1-94.0%) was no longer significantly higher than the overall sensitivity under this model, while that for struck-by incidents (80.8%, 95% CI, 76.4-85.2%) was. As under their respective univariate models, the sensitivities predicted for all industry sectors except for Mining (82.5%, 95% CI, 62.3-102.8%) and all incident types were significantly lower than 1.

4 | DISCUSSION

We found that the Injury at Work box on the Michigan death certificate showed a sensitivity of 73.1% in identifying work-related deaths from traumatic incidents as compared to the multi-source surveillance system MIFACE from 2001-2016. The sensitivity showed a significant declining trend over the period studied, from 79.8% in 2001 to 63.1% in 2016, and varied across demographic groups (victims falling into the "Other" race category having a lower sensitivity than the overall and that of white decedents), types of fatal incidents (aircraft, animal-related, drug overdose, motor vehicle, and suicides having particularly lower sensitivities, and electrocutions, falls, and machine-related incidents having higher sensitivities), and industry sectors (construction, manufacturing, public safety, transportation, and trade sectors having higher sensitivities, and agriculture and services sectors showing lower sensitivities). Across the majority of these categories, the sensitivity was significantly below 1, the sensitivity that would be expected if the Injury at Work box captured traumatic work-related deaths as well as a multisource surveillance system. This data is consistent with the decision by NIOSH to drop its National Occupational Traumatic Fatality (NOTF) system in 1993, which used the at-work box on death certificates when BLS initiated the multi-source surveillance system CFOI for work-related fatalities.

Our overall sensitivity of 73.1% falls within the range generated by older studies,[1,2,7,8] though our data also show that the sensitivity has decreased even further into the 60% range from 2011 -2016. The most likely explanation for the overall low sensitivity lies in the misevaluation or misinterpretation of the Injury at Work box criteria. This may be due in part to the quantity and detail of the information provided by police or other reports to the funeral director, medical

TABLE 3 Predicted sensitivity of Injury at Work box using multivariate analysis

	Sensitivity (95% CI)
Overall	73.2 (71.4-74.9)
Sex	
Male	73.4 (71.6-75.3)
Female	70.7 (64.7-76.7)
Race	
White	74.5 (72.6-76.4)
Black	75.5 (65.1-85.9)
Asian	59.0 (23.3-94.7)
Other	64.2 (58.7-69.6)
Ethnicity	
Hispanic	82.8 (74.6-91.0)
Non-Hispanic	72.7 (70.9-74.5)
Industry Sector	
Agriculture, forestry & fishing	40.1 (34.3-45.9)
Construction	80.6 (76.4-84.8)
Healthcare & social assistance	72.8 (63.4-82.2)
Manufacturing	86.7 (82.0-91.4)
Mining	82.5 (62.3-1.03)
Public safety	87.1 (80.1-94.1)
Services	69.4 (65.8-73.0)
Transportation, warehousing & utilities	82.9 (78.8-87.1)
Wholesale and resale trade	80.8 (76.0-85.6)
Incident type	
Aircraft	45.8 (32.5-59.1)
Animal-related	67.5 (48.7-86.4)
Asphyxiation	83.9 (69.8-98.0)
Drowning	76.8 (60.3-93.3)
Drug overdose	52.1 (37.3-66.9)
Electrocution	87.5 (80.4-94.7)
Fall-related	85.7 (81.7-89.7)
Fire/explosion	82.6 (71.1-94.0)
Heat/cold-related	65.3 (38.8-91.9)
Homicide	70.3 (65.1-75.5)
Machine-related	84.0 (79.9-88.0)
Motor vehicle	61.4 (57.1-65.8)
Other	66.9 (47.1-86.7)
Struck-by	80.8 (76.4-85.2)
Suicide	61.9 (54.7-69.1)
Toxic exposure	59.7 (46.8-72.6)

examiner or physician completing or certifying the death certificate, or to variability in how the information is interpreted and how the criteria for marking the box "Yes" are applied. One study conducted among coroners in California supports this notion; coroners largely agreed that vignettes presenting paid work at a worksite during normal work hours should be classified as "at work" fatalities, but there was substantial disagreement if payment of the individual was unclear or untraceable, if the worker was traveling for work, or if the work occurred outside of normal working hours.[13]

Many incident types (electrocutions, falls, fires/explosions, machine-related incidents, struck-by incidents) with predicted sensitivities significantly higher than the overall sensitivity, or otherwise on the upper end of the confidence interval for the overall sensitivity, are those which may be easily identifiable as work-related fatalities. likely due to some combination of their wide recognition as leading and prototypical causes of workplace injuries and deaths and their occurrence at fixed and/or easily-identifiable job sites. A similar reason is the likely explanation why construction, manufacturing, public safety, mining also had sensitivities higher than the overall. Other studies also report these incident types and industries as ones with particularly high sensitivities.[2,7,8]

The inverse is the likely explanation of why certain incident types and industries tended to produce lower-than-overall sensitivities. The agriculture, forestry, and fishing industry sector, for example, had a sensitivity significantly lower than the overall, even after accounting for other variables in the multivariate model. Previous studies have also identified the Agriculture industry as that with the lowest sensitivity of using death certificates to identify work-related fatalities.[2,7] This sector contains many farmers who own and operate their own farmland, which is often colocated with their residential property, often making it difficult to determine if a fatal injury occurred while performing "work" or while performing labor for themselves for no profit. A further complication is that farming is not the exclusive, or even primary, occupation for many farmers. However, previous work has found that whether or not an individual was performing their "usual" occupation was not an important factor in whether coroners agreed on the "at work" classification of death.[13] The other industry sector with a sensitivity significantly lower than the overall in the univariate model, the services sector, did not have a significantly lower sensitivity under the multivariate model, suggesting this was being driven at least in part by other variables, such as its overrepresentation among suicides (a low-sensitivity incident type). While some previous work suggests the Service industry may have particularly low sensitivity,[7] others do not.[2]

Incident types with sensitivities significantly lower than the overall sensitivity included aircraft- and motor vehicle-related deaths, drug overdoses, and suicides. Aircraft- and particularly motor vehicle-related deaths are likely to display lower-than-overall sensitives due to their frequent failure to occur at a definite or fixed-job site. Multiple previous studies also reported that motor vehicle incidents show very low sensitives usually lower than the respective overall sensitivities,[2,7] with some exceptions.[8] Animal-related incidents and toxic exposures showed significantly lower sensitivities in the univariate model but had higher and nonsignificant sensitivities under the multivariate model, suggesting that the univariate effects may have been driven instead because many of these cases occurred within particular industry sectors, namely agriculture. Drug overdoses and suicides may not frequently be considered work-related and therefore may fail to be marked as at-work whether they occurred at an obvious job site or not, although CDC guidelines should still lead to their inclusion. The type of injury, the industry sector of the worker, or a combination of the two, play an important role in

whether death is recorded as work-related on the death certificate. Further examination of the type of incident within each industry sector would help clarify which types and industries are the most influential factors in this regard. Given the small number of deaths in certain industry sectors (eg, healthcare and social assistance, public safety) and incident types (animal-related, drug overdoses) in the data set utilized here, examining these interactions would require a larger, potentially nationwide set of data.

We identified several trends in the sensitivity across demographic variables, although none differed significantly from the overall sensitivity in the multivariate model, suggesting the differences in the univariate model were driven by disproportionate involvement in certain industries and incident types as well as small sample numbers. We found no differences in sensitivity across sexes, whereas previous work suggested death certificates to have a much lower sensitivity for females,[8] although this is complicated by the overwhelming number of cases being male in both this and previous work, leading to imprecise estimates for females. Certain race categories, such as the Asian category, suffer from similarly imprecise estimates due to the small number of deaths involving Asian workers, rendering it difficult to draw conclusions from our data set.

The decline in sensitivity over time may be due to several factors. One potential explanation is that many of the industries and incident types with comparatively high sensitivities are well-recognized as those related to common workplace deaths. They are also potentially those most likely to be targeted by occupational safety and health enforcement activities. This, in turn, might lead to a relatively steeper decline in these deaths as a proportion of total deaths. This, if coupled with slower decreases, plateauing, or even increases in the other, lower-sensitivity deaths such as motor vehicle incidents and suicides, would mean the lower-sensitivity deaths would make up a larger proportion of all deaths as time went on, producing a decreasing overall sensitivity. Alternatively, or in addition, high-sensitivity industries may have declining annual numbers of fatalities due to declines in their respective workforces, again, in turn, leaving lower-sensitivity industries to make up a larger share of total deaths. Evidence for this can be seen in employment statistics for MI from 2001 to 2016: high-sensitivity industry sectors saw declining employment, such as in construction (from 206 300 employed in 2001 to 155 100 employed in 2016) and manufacturing (811 800-605 700), while lower-sensitivity industry sectors saw increases in employment, including healthcare and social assistance (456 700 to 590 900) and leisure and hospitality (from 394 900 to 425 200, part of the Services NORA Sector used here).[14] Preliminary analyses of MIFACE data partially support these hypotheses with, for example, deaths in the high-sensitivity manufacturing sector decreasing as a proportion of the total number of deaths from 15.5% in 2001 to 8.9% in 2016 (data not shown). Further research is needed to quantify the contribution of individual industries and incident types in the downward trend in overall sensitivity identified here. It may also be the case that the MIFACE program has become more comprehensive over time (due in part to its use of a growing number of sources apart from death certificates), identifying a greater proportion of the true number of work-related deaths. This would result in the accuracy of death certificates compared to the FACE program to decline. That said, even if MIFACE and related multi-source surveillance systems such as CFOI have improved over their lifetimes, it is likely that these programs are still missing a small number of acute traumatic fatalities. If true, the actual sensitivity of the Injury at Work box compared to the true number of work-related deaths would be lower.

We found no notable deficits in specificity or negative predictive value in the use of the Injury at Work box for identifying fatal work-related incidents, with both over 99.9%. We found an overall positive predictive value of 93.1%. These trends are generally in line with other studies,[2,8] although both positive and negative predictive values were higher than in previous studies.

Taken together, these results suggest caution when using death certificates as the sole source of information for surveillance programs or epidemiological studies focused on fatal occupational injuries. This mirrors other well-known issues with using death certificates for this purpose, such as the frequent misclassification of the industry and/or occupation of the decedent.[15-20] Death certificates are still useful sources of information as part of a comprehensive multi-source surveillance system. The most recent data set from BLS CFOI, for 2017, reports that death certificates contributed information for 96.9% of all fatal occupational injuries nationwide.[21]

This study has identified a deficit in the sensitivity of the Injury at Work box on Michigan death certificates in identifying fatal work-related injuries compared to the MIFACE program, mirroring findings from other states and in comparison to other sources. We have also shown that this deficit became worse in the last 30 years. Public health or individual liability decisions should not be solely based on whether the workbox is checked. Our work stresses the importance of applying uniformly the criteria for labeling a death "at work" if death certificates are to continue being a primary source of information for occupational health surveillance programs and epidemiological studies. Future work should focus on continuing to characterize this deficit and its temporal trends, the characteristics and circumstances of work-related deaths that contribute most to these errors, and the development and dissemination of guidelines meant to ensure the consistent and accurate completion of death certificates for occupational fatalities.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John D. Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTIONS

ANO was responsible for the conception and execution of this work, the acquisition, analysis, and interpretation of the data, the drafting of the manuscript and its final approval. LW was responsible for the

analysis and interpretation of the data, the critical revision of the manuscript and its final approval. KDR is the Principal Investigator of the encompassing study and was responsible for critical revisions of the manuscript and its final approval.

ETHICS APPROVAL AND INFORMED CONSENT

All work was approved by its institutional review board. No consent was required as all utilized data were publicly available and did not require the direct participation of or disclosure by subjects.

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