Time-Trends of U.S. Occupational Noise Standard Violations by OSHA Region and Industry Type *1972 to 2019*

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Objective: We examined time-trends in Occupational Noise Standard violations by OSHA region and industry type over 48 years. **Methods:** Along with descriptive analysis of original data, negative binomial regression and Poisson regression were applied to the analysis of 1972 to 2019 and 1972 to 2012 data, respectively. **Results:** A small annual decrease in violation units over the periods was revealed. The three analyses produced differing time-trends. The manufacturing industry had more violations, and Region 4 had the most violations. Regarding numbers of units, the 10 regions and 2 industries were jointly significant. Some interaction between regions and industry types appeared in both regressions. **Conclusions:** OSHA should specify how many regions report noise violations each year to ensure accurate identification of noise-related health risks to American workers. Further time-trend studies are needed for specific regions and industry types.

Keywords: industry, occupational noise, region, time-trend, United States Occupational Safety and Health Administration

According to the National Institute for Occupational Safety and Health (NIOSH), about 25% of U.S. workers have been exposed to hazardous noise.[1,2] Noise-induced hearing loss (NIHL) is a critical health problem in itself[3] and can exacerbate the risk for developing chronic health conditions such as hypertension and hyperlipidemia.[1,4] To prevent NIHL and related complications, the Occupational Safety and Health Administration (OSHA) established occupational noise exposure limits and related initiatives. About 50 years ago, OSHA promulgated four Occupational Noise Exposure Standards: (a) 29 CFR 1910.95, Occupational noise exposure; (b) 29 CFR 1926.52, Occupational noise exposure; (c) 29 CFR 1926.101, Hearing protection; and (d) 29 CFR 1904.10, Recording criteria for cases involving occupational hearing loss. OSHA has also employed various approaches to manage NIHL at the individual company level.[5] Strong evidence exists for the effectiveness of a number of occupational health and safety regulations with respect to reducing injuries and occupational health disparities as well as improving compliance with applicable laws.[6,7] However, uncertainties remain regarding how effective and efficient occupational safety and health regulations and legislation have been in terms of enforcement action.[8] Moreover, studies evaluating enforcement tools have been insufficient, and only two studies have proposed the need for OSHA noise-related enforcement actions.[9,10] In an extensive literature review, we identified only one study that investigated the extent of violations of the above four OSHA Noise Standards to reveal violation trends between 1972 and 2019.[5]

The prevalence rates of occupational NIHL have differed by industrial type over time.[1] In particular, industrial change has strongly affected the prevalence of NIHL cases in American workplaces.[1] Zhou et al.s[11] study supported this fact by showing that workplace noise exposure cases increased as states shifted from agriculture-based to industry-based economies. In addition, major industrial sectors have varied according to states' regional characteristics, and their policies may have impacted changes in noise levels.[12] In other words, given that the structure of various industries has changed over time, it is reasonable to assume that the number of noise violations in each industry changed as well. However, we found no study that evaluated the time-trends of OSHA Noise Standard violation cases. Thus, the purposes of this study were to examine the time-trends of violation cases over time and the difference in trends by industry type as well as by OSHA region.

METHODS

The original data for OSHA Noise Standard violation cases were obtained from two sources: the Integrated Management Information System (IMIS) and the Occupational Safety and Health Information System (OIS).[13] Because OSHA's initial information management system, IMIS, has a limited capability to integrate information on workplace hazards from various sources, the authors decided to use combined data from the two systems.[13] Specifically, the authors employed data from a master file in IMIS, which contains records of violation cases opened through 2012, and more recent data were obtained from OIS. Ultimately, data for all OSHA noise violation cases from March 8, 1972, through April 30, 2019, were obtained. The original data covered violations issued by federal OSHA and under OSHA-approved State Plans in 50 states, the District of Columbia, and five U.S. protectorates (Guam, Puerto Rico, American Samoa, U.S. Virgin Islands, and Northern Mariana Islands). All data had been de-identified when they were obtained. More information about these datasets and data extraction methods was provided in an earlier publication.[5] The study protocol was approved by the Institutional Review Board at the University of Illinois at Chicago (Protocol # 2019-0764).

For the purposes of data analysis, Noise Standard violations were classified according to the 10 OSHA regions.[14] Figure 1 illustrates the locations and regional offices of the 10 regions. The original data included industrial codes from the North American Industry Classification System (NAICS) and Standard Industrial Classification (SIC). However, for consistent presentation of industry data, NAICS codes were converted into SIC codes because more data originally contained SIC codes[15]; where this conversion was not possible, the data were excluded. Finally, data for 112,867 noise

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Ethical considerations: The deidentified data from OSHA was analyzed after determination by the Institutional Review Board at the University of Illinois at Chicago (Protocol # 2019-0764).

The authors report no conflicts of interest.

Clinical significance: Our findings indicate that OSHA should implement regulatory mechanisms to improve regions' compliance with Noise Standard violation reporting. Researchers should examine whether violation timetrends align with changes in OSHA noise reduction policies in particular regions and/or industry sectors. Both efforts will support OSHA's mission of safeguarding workers from noise hazards.

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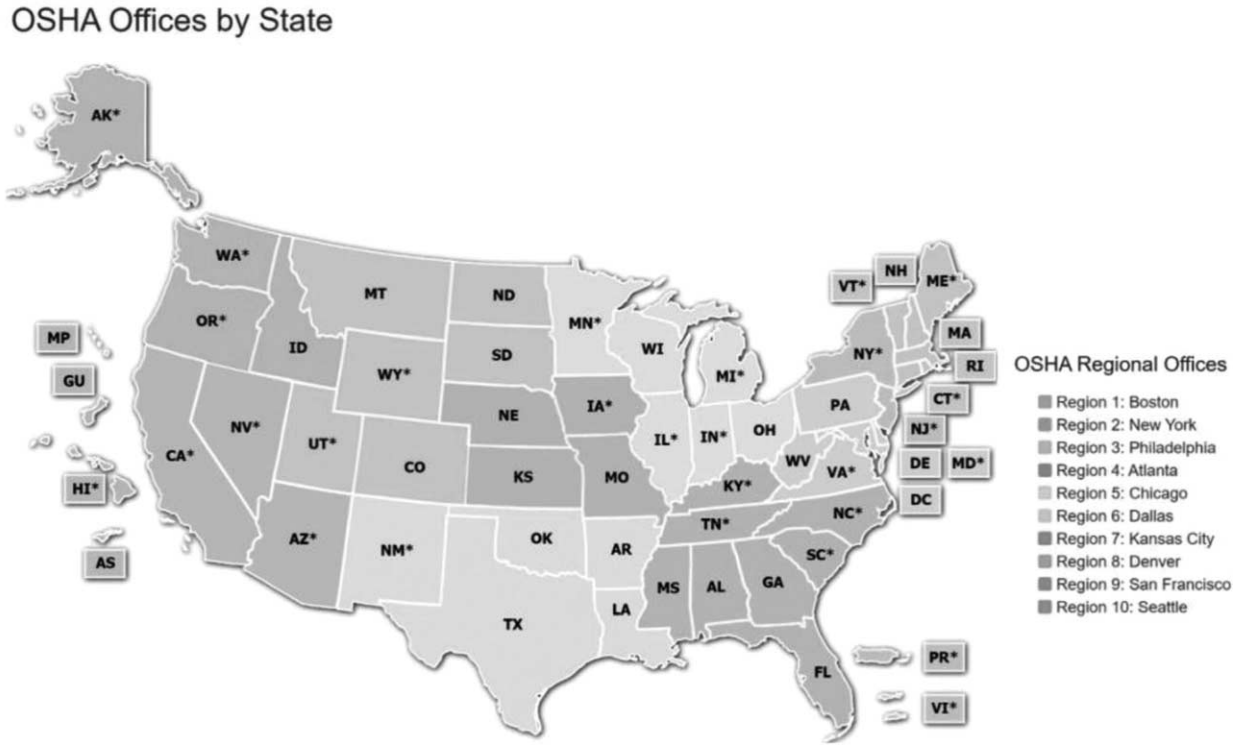

FIGURE 1. OSHA regions.

violation cases were extracted. SIC codes extend from 110 to 9,999,[15] and in this study, data for noise violations containing 878 SIC codes were extracted. Also, industry types were dichotomized as manufacturing and nonmanufacturing because manufacturing— SIC code D—accounted for about 87% of all the cases; for coding purposes, we combined the other nine SIC codes as nonmanufacturing. Using Stata 16.0, descriptive statistics were used to analyze cases by SIC code, industry (manufacturing vs. nonmanufacturing), and 10 OSHA regions.

To perform the time-trend analysis, the 112,867 noise violation cases were aggregated at the unit level by OSHA region, industry, and year. To support accurate trend analysis, the study regression shows unit time-trends adjusted by region as well as by industry, not actual violation cases. A total of 2451 aggregated units constituted the study sample. A negative binomial regression with Wald tests was used to reveal time-trends based on extremely skewed count data, which arise when the conditional variance is greater than the conditional mean.[16] To determine whether industrial time-trends differed by region, the interaction terms included a negative binomial regression model.

Unexpectedly, we obtained different time-trend analysis results for the original data and the 2451 units. The reason for these differences was not known to us, so we examined all the data and found that the number of regions reporting violation cases gradually decreased starting in 2013. Therefore, we also explored the data generated from 1972 to 2012 only. While 1551 violation cases were reported from 2013 to 2019, we found that 111,316 cases were reported in the previous years. These cases were also aggregated at the unit level by OSHA region, industry, and year. Finally, 807 aggregated units were identified and used in Poisson Regression with interaction terms. This regression method is suitable for modeling count data, and conditional variance did not exceed the conditional mean in the 807 units' data. Although we originally planned to explore overall time-trends in violation cases from 1972 to 2019, we considered how different the two time-trend patterns might be for the 1972 to 2019 and 1972 to 2012 periods. Specifically, we performed separate time-trend analyses for 2451 aggregated units from 1972 to 2019 and for 807 aggregated units from 1972 to 2012.

RESULTS

Descriptive statistics for the original data covering 112,868 cases showed that OSHA Noise related Standard violation cases increased steadily after 1972 until they peaked in 1983 ($n = 6734$). Subsequently, the number of annual cases steadily dropped (Fig. 2A). Furthermore, between 1973 and 2013, the number of annual cases was in the thousands, but after2013, the numberwas in the hundreds. Since 2015, only 100 to 200 cases per year have been recorded, a considerably low number for the country's size. Over about 50 years, OSHA Region 4 had the greatest number of Noise Standard violations, followed by Regions 5, 3, and 6 (Table 1). Of the 112,868 total cases, most—97,848 (87%)—were in the manufacturing industry (SIC code D). Non-manufacturing accounted for the remaining 15,019 cases; these cases included 4192 (0.04%) in construction (SIC code C) (Table 1). Also, in all 10 regions, violation cases in the manufacturing industry dominated (Table 1). Given the fact that Region 4 and the manufacturing industry had the greatest number of violation cases, they were chosen to serve as reference groups for both negative binomial regression and Poisson Regression.

The negative binomial regression results for 2451 units were statistically significant ($P < 0.001$). Regarding the 48-year time-trends, the regression showed only a small annual decrease in units over the entire period (Table 2). As shown in Figure 2B, the number

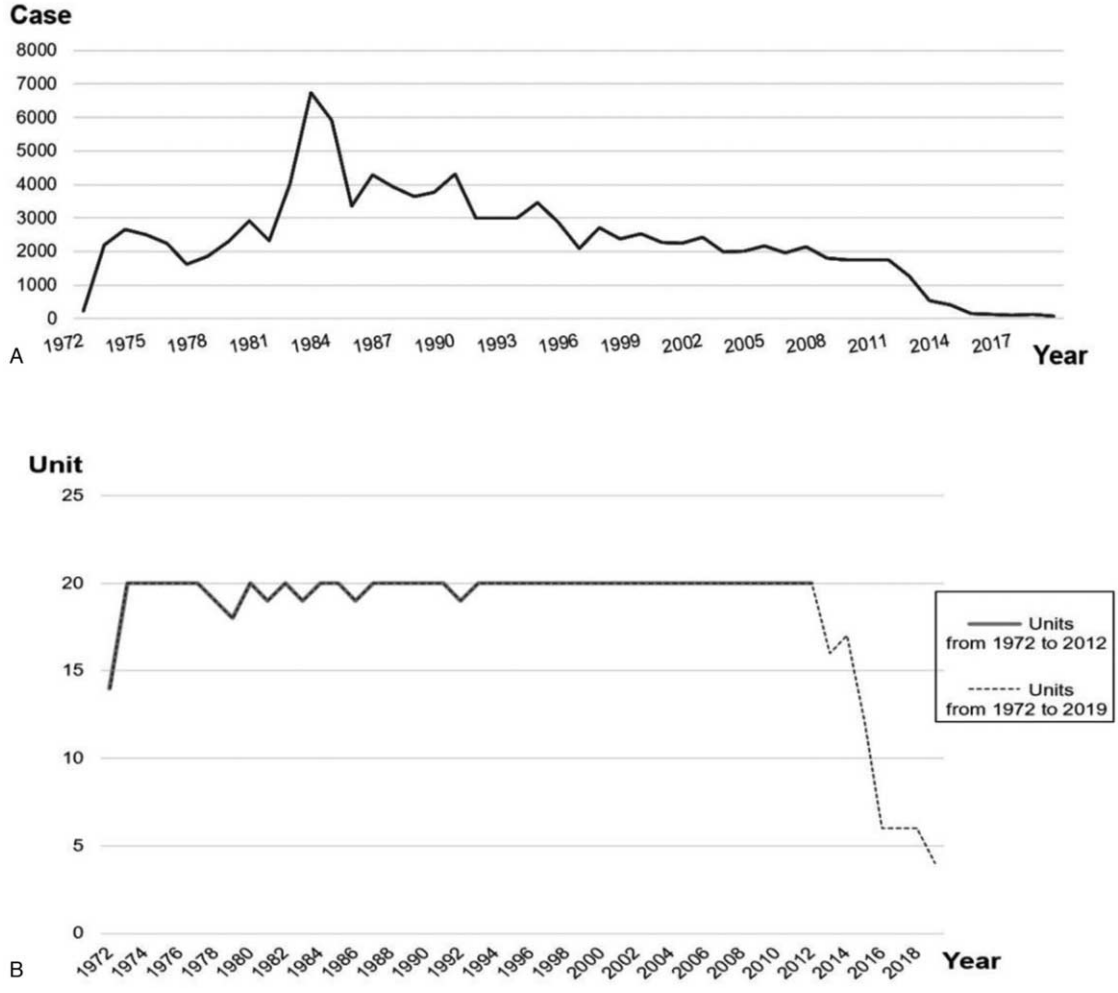

FIGURE 2. Comparison of (A) time-trend of OSHA Noise Standard violation cases based on original data and (B) violation units aggregated by year, region, and industry.

TABLE 1. OSHA Noise Standard Violation Cases by OSHA Region and SIC Code

		SIC Code										
		D	A	B	C	E	F	G	H	I	J	Total
		Manufacturing					Nonmanufacturing					–
OSHA region	1	8,189	44	2	551	108	188	23	7	163	17	**9,292**
	2	9,473	29	6	845	413	367	43	25	616	207	**12,024**
	3	13,872	18	7	555	201	454	38	0	374	96	**15,616**
	4	22,446	146	13	584	237	894	195	9	642	160	**25,326**
	5	20,159	39	13	659	251	504	74	3	406	54	**22,162**
	6	12,464	23	131	297	173	537	28	5	352	214	**14,224**
	7	4,328	11	13	121	69	124	14	0	96	52	**4,828**
	8	2,232	14	14	149	85	85	19	1	80	37	**2,716**
	9	2,369	16	2	191	101	84	75	1	493	67	**3,399**
	10	2,316	117	11	240	119	139	59	9	181	90	**3,281**
	Total	97,848	457	212	4,192	1,757	3,376	568	60	3,403	994	**112,867**

Note. A, agriculture, forestry, and fishing; B, mining; C, construction; D, manufacturing; E, transportation, communications, electric, gas, and sanitary services; F, wholesale trade; G, retail trade; H, finance, insurance, and real estate; I, services; J, public administration; SIC code, Standard Industrial Classification. Bold number indicates a total number of Noise Standard violations by each region.

TABLE 2. A Binominal Panel Regression Result of Time-Trend of OSHA Noise Standard Violation Units (N = 2451)

				95% Confidence Interval	
	b	Standard Error	*z*	Lower	Upper
Time	−0.009	0.002	**−5.31**	−0.012	−0.005
OSHA region 1	−0.694	0.298	**−2.33**	−1.278	−0.110
2	−0.177	0.292	−0.60	−0.749	0.396
3	−0.289	0.300	−0.96	−0.877	0.299
5	−0.422	0.293	−1.44	−0.996	0.153
6	−0.206	0.294	−0.70	−0.781	0.369
7	−1.012	0.303	**−3.34**	−1.606	−0.419
8	−1.063	0.300	**−3.54**	−1.651	−0.475
9	−0.733	0.302	**−2.43**	−1.324	−0.143
10	−0.620	0.293	**−2.11**	−1.194	−0.045
Industry: nonmanufacturing	−3.563	0.211	**−16.89**	−3.976	−3.149

				95% Confidence Interval	
Interaction among OSHA Regions and Industry	***b***	**Standard Error**	***z***	**Lower**	**Upper**
Region 1 × nonmanufacturing	0.265	0.870	0.30	−1.439	1.969
Region 2 × nonmanufacturing	0.716	0.867	0.83	−0.983	2.415
Region 3 × nonmanufacturing	0.101	0.870	0.12	−1.604	1.806
Region 5 × nonmanufacturing	−0.326	0.867	−0.38	−2.025	1.373
Region 6 × nonmanufacturing	0.348	0.868	0.40	−1.352	2.049
Region 7 × nonmanufacturing	0.619	0.871	0.71	−1.089	2.326
Region 8 × nonmanufacturing	1.266	0.871	1.45	−0.440	2.973
Region 9 × nonmanufacturing	1.650	0.871	1.89	−0.058	3.356
Region 10 × nonmanufacturing	1.817	0.867	**2.10**	0.118	3.516

Note. Bold number indicates *P*-value < 0.05.

of units sharply increased from 1972 to 1974 and then remained similar until 2012, although the number fluctuated upward and downward over the years. Starting in 2013, the number of units abruptly decreased through 2019. As to region-specific findings, OSHA Regions 1, 7, 8, 9, and 10 had fewer units annually than Region 4. In addition, the non-manufacturing industry showed annual four-unit reductions (Table 2). As shown in Figure 3, time-trends by region showed a similar pattern for all 10 regions. An abrupt decrease in number of units was observed between 1972 and 1973, and the number steadily decreased from 1973 through 2012. Again, a sudden increase in units was observed from 2012 to 2016 in addition to a subsequent decrease starting in 2017 (Fig. 3). Moreover, as Figure 5A reveals, the non-manufacturing industry displayed a very flat pattern over time. For the manufacturing industry, the number of units fluctuated somewhat from 1972 to 1984 and then decreased overall until 2014. The number of units increased from 2015 through 2018 but then went into another decline starting in 2019 (Fig. 5A). For the 10 OSHA regions and two industry types, regression results with the interaction term were jointly significant with respect to the violation units among regions and between industries ($P < 0.05$). Unlike the joint significance results, no interaction was observed between OSHA regions and industries except for Region 10 (Table 2); the insignificant result of a subsequent Wald test supported a finding of no overall interaction. Given that a parallel pattern was found in the Wald test, the lack of overall interaction between regions and industries was confirmed.

Poisson regression results for 807 units were statistically significant ($P < 0.001$). Regarding the 41-year time-trends, the regression also showed a small annual decrease in units from 1972 to 2012, as did the data for 1972 to 2019 (Table 3). As to region-specific findings, except for Region 5, other OSHA regions had fewer units annually than Region 4. For example, OSHA Regions 8, 9, and 10 showed a more than two-unit per year decrease compared to Region 4. All 10 regions showed similar time-trends. Furthermore, compared to the manufacturing industry, the non-manufacturing industry showed an annual two-unit reduction (Table 3). Time trends by industry displayed patterns for all 10 regions that were similar to the regional trends. An abrupt pattern of decreasing units was observed between 1972 and 1973. Subsequently, numbers of units exhibited small ups and downs, but a nearly flat pattern was observed from 1992 to 2012 (Fig. 4). As to industry differences over the 41 years, the non-manufacturing industry showed a pattern nearly parallel to that observed from 1972 to 2019 (Fig. 5A and B). The manufacturing industry showed small ups and downs five times until 1993, after which the pattern was nearly flat. Compared to the time-trend pattern in the manufacturing industry from 1972 to 2019, the pattern observed in the Poisson regression was more static with minor variations in units over time (Fig. 5A and B). As for the data from 1972 to 2019, regression analysis showed jointly significant interactions for the units among regions and between industries ($P < 0.05$; see Table 3). Unlike the time-trends from 1972 to 2019, some OSHA regions and the two industry types showed more interactions between regions and industries. Specifically, with OSHA Region 4 and the manufacturing industry as the reference groups, OSHA Regions 2, 8, 9, and 10 showed interactions with the nonmanufacturing industry (Table 3).

DISCUSSION

The purposes of this study were to examine the time-trends of OSHA Noise Standard violation cases over time and the difference in trends by industry type and region. The results of the analysis of the original data and negative binomial and Poisson regression revealed inconsistent patterns among them. That is, patterns that appeared in the two regression models could not be found in the

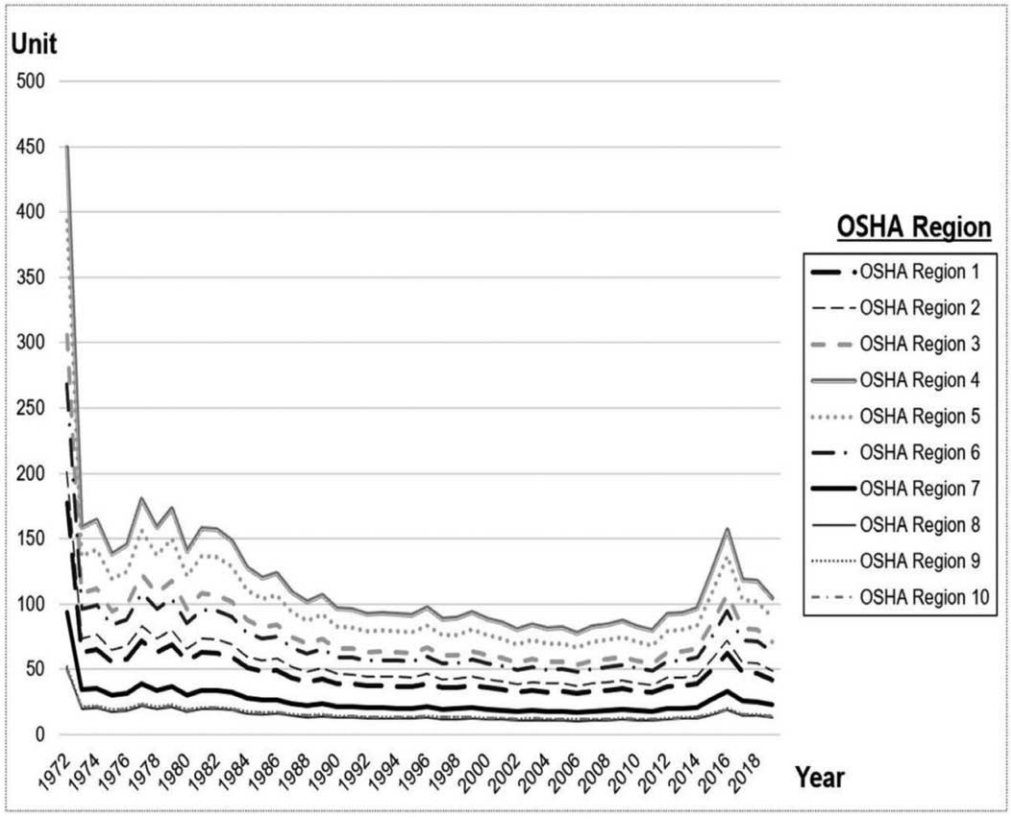

FIGURE 3. Time-trend of OSHA Noise Standard violation units by OSHA region using the data from 1972 to 2019.

TABLE 3. A Poisson Regression Result of Time-Trend of OSHA Noise Standard Violation Units ($N = 807$)

				95% Confidence Interval	
	b	**Standard Error**	***z***	**Lower**	**Upper**
Time	−0.010	0.003	**−3.97**	−0.0151	−0.005
OSHA region					
1	−0.983	0.125	**−7.88**	−1.227	−0.738
2	−0.838	0.125	**−6.69**	−1.084	−0.593
3	−0.458	0.129	**−3.54**	−0.712	−0.205
5	−0.091	0.111	**−0.82**	−0.309	0.127
6	−0.562	0.148	**−3.79**	−0.853	−0.272
7	−1.625	0.113	**−14.33**	−1.848	−1.403
8	−2.285	0.115	**−19.87**	−2.510	−2.060
9	−2.240	0.169	**−13.20**	−2.569	−1.905
10	−2.345	0.125	**−18.71**	−2.590	−2.099
Industry: nonmanufacturing	−2.043	0.126	**−16.28**	−2.289	−1.797
				95% Confidence Interval	
Interaction Among OSHA Regions and Industry	***b***	**Standard Error**	***z***	**Lower**	**Upper**
Region 1 × nonmanufacturing	0.052	0.184	0.28	−0.308	0.412
Region 2 × nonmanufacturing	0.707	0.188	3.77	0.339	1.075
Region 3 × nonmanufacturing	−0.005	0.191	−0.02	−0.379	0.370
Region 5 × nonmanufacturing	−0.281	0.162	−1.73	−0.600	0.037
Region 6 × nonmanufacturing	0.085	0.206	0.42	−0.317	0.488
Region 7 × nonmanufacturing	−0.082	0.168	−0.49	−0.412	0.248
Region 8 × nonmanufacturing	0.539	0.191	**2.82**	0.164	0.914
Region 9 × nonmanufacturing	1.278	0.223	**5.73**	0.841	1.715
Region 10 × nonmanufacturing	1.250	0.247	**5.06**	0.766	1.734

Note. Bold number indicates P-value < 0.05.

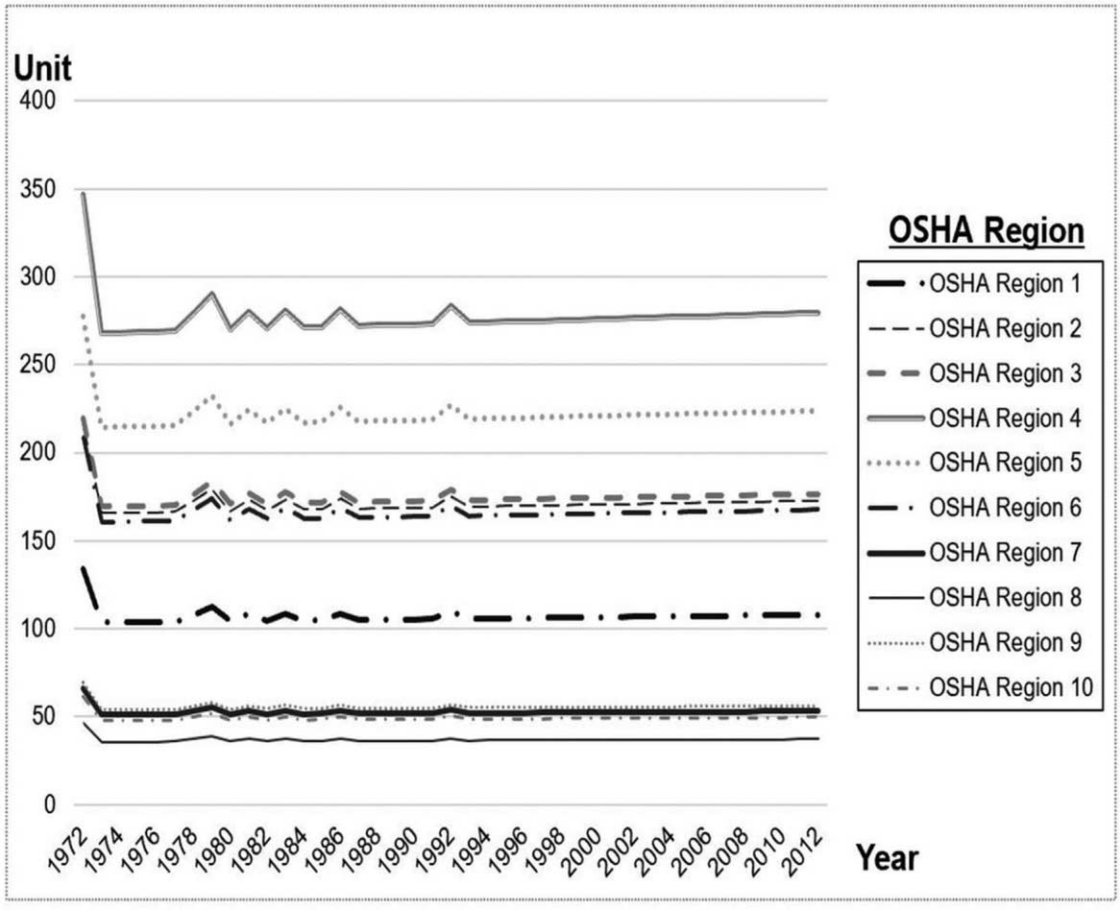

FIGURE 4. Time-trend of OSHA Noise Standard violation units by OSHA region using the data from 1972 to 2012.

original data. Specifically, the original data indicated that violation case numbers increased through 1983 and then decreased, but results of the two regressions showed a gradual increase in units between 1972 and 1974, followed by a flat pattern through 2012 (see Fig. 2B). Moreover, binomial regression results showed an abrupt decrease in units from 2013 to 2019. The primary reason for this discrepancy may involve the number of regions that reported violation cases. Through additional mining of the original data, the authors discovered that all 10 OSHA regions reported cases on an annual basis from 1972 through 2012. For unknown reasons, the number of regions that reported cases gradually decreased from 2013 onward. Specifically, in 2013 and 2014, nine regions reported cases; in 2015, seven regions did so; from 2016 to 2018, only three regions—4, 5, and 10—reported cases; and in 2019, only two regions—4 and 10—did so. The authors assumed that the decreasing number of regions reporting violation cases was due to (1) under-reporting or missing reports from some or all regions, (2) potential issues in converting from IMIS to OIS, and (3) data quality issues. Although OSHA has described how its data collection system operates,[17] it has not clearly explained its means of verifying data quality or managing the data. Thus, OSHA should make efforts to improve the accuracy of its accumulated Noise Standard violation data in order to support meaningful data analyses. As one example, OSHA should direct each region to report its violation cases every year. Also, additional studies are needed to evaluate OSHA's noise-related enforcement actions and tools.

In the negative binomial and Poisson regression results, timetrends of units showed similar patterns from 1972 to 2012 (Fig. 2B). In addition, although analysis of units from 1972 to 2019 and from 1972 and 2012 showed different time patterns, numbers of units in the 10 regions showed similar patterns (Figs. 3 and 4). Although the binomial negative regression excluded data from some regions, we thought it critical to explore what the time-trends showed through the endpoint of the available data in order to identify current problem areas. This approach had pros and cons. On the one hand, we generated foundational knowledge that could be used to help resolve the issues; on the other hand, our data exploration might be misleading if it was not sufficiently thorough. Given the fact that time-trends for all 10 regions showed similar patterns in each regression, it appears that OSHA Noise Standard violation policy and initiatives were consistently communicated to regional offices, regardless of how many violation cases were reported by each region. Further research is needed to determine whether actual time-trends of Noise Standard violation cases align with changes in OSHA noise reduction policy and initiatives.

Historically, OSHA has focused its compliance efforts on entire industries, but that does not mean that OSHA has targeted entire industries for monitoring, evaluation, corrective action, or other interventions.[13] Along with this limitation on our ability to generalize our findings to all sectors of U.S. industry, we encountered challenges in investigating regional and/or industry

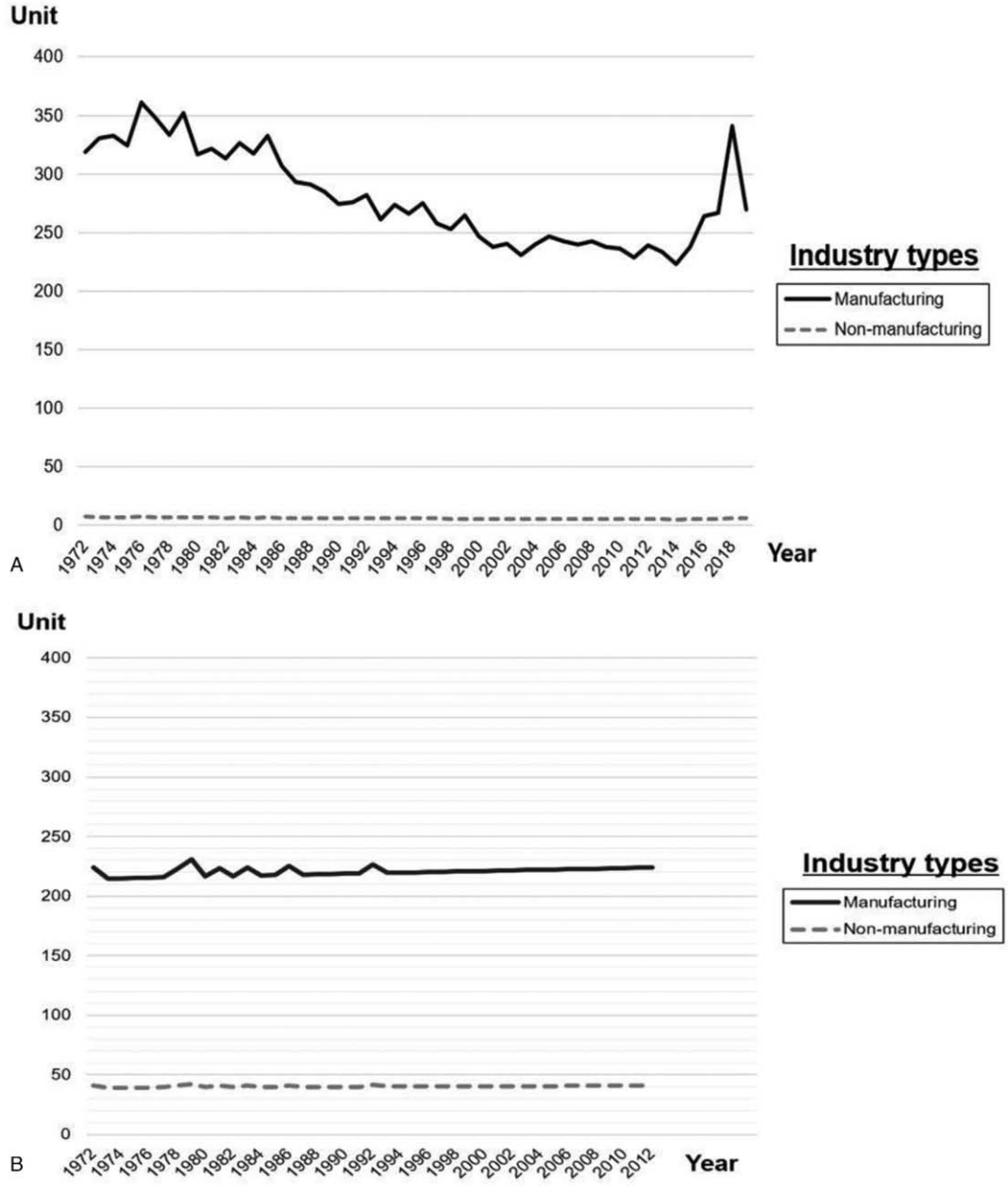

FIGURE 5. Comparison between (A) Time-trend of OSHA Noise Standard violation units by industry types using the data from 1972 to 2019 and (B) from 1972 to 2012.

differences in violation cases. No official reports could be found regarding the major industries operating in each state or state-specific industry changes over time. For the 10 OSHA regions and the manufacturing and non-manufacturing industries, both regression analyses showed jointly significant interactions for the numbers of units among regions and between industries. As the Poisson regression with units from 1972 to 2012 showed interactions for some regions and the two industry types, additional research is warranted to identify occupational noise hazards presenting NIHL risks in particular regions and industry types. Also, researchers should continue to investigate time patterns of Noise Standard violations by region and industry type to determine whether actual interactions occur over time. Furthermore, OSHA's accumulated noise violation data should be evaluated to identify factors, including industry types and regions, influencing violations and NIHL risk. Such evaluation is necessary to design and implement industry- and/or region-specific interventions for reducing NIHL.

The manufacturing industry remains the fifth-largest employer in the United States with 11.9 million workers, according to the U.S. Census report, *Manufacturing in America 2020.*[18] Based on another U.S. Census report, *County Business Patterns, OSHA* Region 4 accounted for 17% of the country's manufacturing facilities (578,982 of a total of 3,480,038)[19]; however, our study results showed that 23% of manufacturing noise violations occurred in Region 4. The reason for this discrepancy is unclear,

but it may be due to a greater number of inspections being performed in Region 4 compared to other regions. Also, the study results showed that more violations were observed in the manufacturing industry, but industries known to pose high risk of NIHL such as Construction and Mining[1] were found to have relatively few reported violations. In fact, the results of our two regressions showed surprisingly few units for the nonmanufacturing industry, especially considering that noise violation data were collected across the United States. Also, we noted a large gap in the number of units between the nonmanufacturing and manufacturing industries (Fig. 5). As to why this study's results showed more Noise Standard violations in the manufacturing industry than in the Construction and Mining sectors, OSHA has stated that ''following the Seventh Circuit Court of Appeals decision in Kropp Forge Company in 1981, the 1910.95 standard in general industry was changed to include the requirements of what would be considered an adequate hearing conservation program. Unfortunately, the construction standard was not changed.'' OSHA's interpretations of the Noise Citation Policy for Construction (Standard 1926.52) raised questions about the adequacy of its citations for lack of a hearing conservation program,[20] but the agency has not litigated the issue or amended the standard. These circumstances imply that in the absence of well-defined citation criteria, OSHA faces challenges in citing companies in the Construction sector for violations.[13] Also, application of different criteria under Standards 1910.95 for General Industry and 1926.52for Construction poses another challenge in investigating violation cases in each industry sector.[13] Future research should examine the descriptions and requirements in each standard to determine whether it applies to particular industries. For instance, it is not clearly questioned whether Standard 1910.95 for General Industry is appropriate to apply to non-manufacturing sectors such as Mining and Service industries.

STRENGTHS AND LIMITATIONS

A strength of the study is that it is one of the first studies to explore the time trends in OSHA Noise Standard violations by specific region and industry type over 48 years. Another strength of the study is to apply three different types of analytical approaches for better understanding of the violation trends: descriptive data analysis using original data, negative binomial regression with violation units from 1972 to 2019, and Poisson regression with units from 1972 to 2012. Our findings indicate a need to put regulatory mechanisms in place to verify the accuracy of each region's reporting of noise violations. On the other hand, similar time-trends were observed among the regions regardless of which data were used, indicating consistent policy adherence among the regions over time. Thus, requiring each region to report all noise violations annually would eliminate most missing values from the accumulated data. In addition, our regressions revealed interactions between some regions and industry types. While further time-trend studies regarding these interactions will be needed, identification and mitigation of occupational hazards presenting NIHL risks in particular regions and industry sectors would reduce noise hazards in the American workplace.

The study findings are subject to a number of limitations. First, the limited OSHA data available restricted this study's ability to explore industry and regional differences in Noise Standard violation cases. Second, the data for violation cases were not representative of noise violations in all U.S. workplaces. Because no official reports could be found regarding the major industries operating in each state or state-specific industrial changes over time, it is difficult to confirm our findings. Third, our data did not include information that specifically addressed repeat violations or post-violation actions. Finally, due to limited noise violation reporting by the regions, the descriptive and regression analyses produced different time-trend results. Thus, the time-trends presented herein should be interpreted with caution.

CONCLUSION

Our study showed a small annual decrease in OSHA Noise Standard violation cases over the entire 48-year period examined. However, the study revealed inconsistent patterns among the original data and the results of the two regressions. These inconsistencies are likely attributable to the limited reporting of cases by OSHA regions after 2012, which gradually decreased to the point where only three regions reported violations from 2016 to 2018. Therefore, we suggest that OSHA monitor and publish how many regions report violation cases each year to allow more accurate identification of noise-related health risks to workers across the country. Although our two regression models showed that violation units decreased over time, further collection and analysis of evidence are called for. Especially because our findings indicate interactions between regions and industry types, such research is necessary to determine whether the actual time-trends of Noise Standard violation cases align with changes in OSHA noise reduction policies and initiatives by region and industry type.

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REFERENCES

1. Masterson EA, Deddens JA, Themann CL, Bertke S, Calvert GM. Trends in worker hearing loss by industry sector, 1981–2010. *Am J Ind Med*. 2015;58:392–401.
2. The National Institute for Occupational Safety and Health (NIOSH). Occupational hearing loss (OHL) surveillance [NIOSH web site]. August 27, 2019. Available at: https://www.cdc.gov/niosh/topics/ohl/overall.html. Accessed March 12, 2021.
3. Occupational noise exposure. Occupational Safety and Health Administration (OSHA). Available at: https://www.osha.gov/noise/health-effects. Accessed March 12, 2021.
4. Kerns E, Masterson EA, Themann CL, Calvert GM. Cardiovascular conditions, hearing difficulty, and occupational noise exposure within US industries and occupations. *Am J Ind Med*. 2018;61:477–491. doi:10.1002/ajim.22833.
5. Park S, Johnson MD, Hong O. Analysis of Occupational Safety and Health Administration (OSHA) noise standard violations over 50 years: 1972 to 2019. *Am J Ind Med*. 2020;63:616–623.
6. Tompa E, Kalcevich C, Foley M, et al. A systematic literature review of the effectiveness of occupational health and safety regulatory enforcement. *Am J Ind Med*. 2016;59:919–933.
7. Siqueira CE, Gaydos M, Monforton C, et al. Effects of social, economic, and labor policies on occupational health disparities. *Am J Ind Med*. 2014;57:557–572.
8. Mischke C, Verbeek JH, Job J, et al. Occupational safety and health enforcement tools for preventing occupational diseases and injuries. *Cochrane Database Syst Rev*. 2013;8:CD010183.
9. Sayler SK, Roberts BJ, Manning MA, et al. Patterns and trends in OSHA occupational noise exposure measurements from 1979 to 2013. *Occup Environ Med*. 2019;76:118–124.
10. Sriwattanatamma P, Breysse P. Comparison of NIOSH noise criteria and OSHA hearing conservation criteria. *Am J ind Med*. 2000;37:334–338.
11. Zhou H, Zhou Y, Zhang H, et al. Socio-economic disparity in the global burden of occupational noise-induced hearing loss: An analysis for 2017 and the trend since 1990. *Occup Environ Med*. 2021;78:125–128.
12. Stebbins S. These are the largest in dustries in ever ystate. USATODAY. August31, 2018. Available at: https://www.usatoday.com/story/money/economy/2018/08/27/largest-industry-in-each-state/37585051/. Accessed May 17, 2021.

13. Privacy impact assessment - OSHA - Information system. U.S. Department of Labor (DOL). Available at: https://www.dol.gov/agencies/oasam/centers-offices/ocio/privacy/osha/ois. Accessed March 12, 2021.
14. OSHA offices by state. OSHA. Available at: https://www.osha.gov/contactus/bystate. Accessed February 20, 2021.
15. Counts by SIC industry sectors. NAICS Association. Available at: https://www.naics.com/business-lists/counts-by-sic-code/. Published 2018. Accessed January 10, 2021.
16. Negative binomial regression. UCLA: Statistical Consulting Group. Available at: https://stats.idre.ucla.edu/stata/dae/negative-binomial-regression/. Published August 22, 2016. Accessed January 10, 2021.
17. OSHA data collection system. OSHA. Available at: https://www.osha.gov/Reduction_Act/SS2091999.html. Published 1999. Accessed June 16, 2021.
18. Manufacturing in America. United Census Bureau. Available at: https://www.census.gov/library/visualizations/2020/comm/manufacturing-in-amer-ica-2020.html.PublishedSeptember28,2020.UpdatedSeptember29,2020.Accessed September 21, 2021.
19. All Sectors: County Business Patterns, including ZIP Code Business Patterns, by Legal Form of Organization and Employment Size Class for the U.S., States, and Selected Geographies: 2018. United Census Bureau. Available at: https://data.census.gov/cedsci/table?q=CBP2018.CB1800CBP&g=0400000US01,12,13,21,28,37,45,47_04000S0US01, 12,13,21,28,37,45,47&n=31-33%3AN0300.31%3AN0400.31&tid= CBP2018.CB1800CBP&hidePreview=true. Accessed September 21, 2021.
20. Noise citation policy for construction. OSHA. Available at: https://www.osh-a.gov/laws-regs/standardinterpretations/1994-05-02-0. Published May 2,1994. Accessed June 7, 2021.

