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The Impact of Law No. 6331 on Work-related Incidents in Türkiye (2007-2023): Standardization Analysis of City-Level Data for Compulsory Insured Workers

Türkiye'de 6331 Sayılı Kanun'un İş Sağlığı Olaylarına Etkisi (2007-2023): İl Düzeyinde Zorunlu Sigortalı Çalışan Verilerinin Standardizasyon Analizi

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ABSTRACT

Objective: This study examined the effects of the occupational health and safety (OHS) Law No. 6331, enacted in Türkiye in 2013. It analyzed the rates of work-related accidents (WrAs), occupational diseases (ODs), and work-related mortalities (WrMs) among compulsory insured workers from 2007 to 2023. Additionally, it aimed to reveal the situation prior to the introduction of compulsory OHS services for public institutions and low-risk workplaces with fewer than 50 workers in 2025.

Methods: Using data from Türkiye's Social Security Institution (SSI), trends across 81 cities were examined through an epidemiological, observational, and descriptive design. Indirect standardization was applied to adjust for variations in the number of "4-1/a compulsory insured" workers, allowing for comparisons of standardized (s) WrA, sOD, and $_{s}$WrM ratios between cities.

Results: The number of insured workers in Türkiye nearly doubled during the study period. Regional disparities became evident, with $_{s}$WrA ratios higher in western provinces and $_{s}$WrM ratios elevated in the east. Zonguldak, Bilecik, Kütahya, Manisa, Bartın, Karabük, and Kocaeli consistently showed the highest standardized ratios. After the law's implementation, $_{s}$WrA rose in the Black Sea region, while a modest rise in sOD was detected in Marmara. Peaks in $_{s}$WrM occurred in various cities, with clustering observed in the Eastern Black Sea.

Conclusion: This study highlights systemic weaknesses and regional inequalities in Türkiye's OHS landscape. The upcoming 2025 expansion of Law No. 6331 provides an opportunity for improvement; however,

ÖZ

Amaç: Bu çalışma, 2013 yılında Türkiye'de yürürlüğe giren iş sağlığı ve güvenliği (İSG) Kanunu No. 6331'in etkilerini incelemiştir. 2007–2023 yılları arasında zorunlu sigortalı çalışanlar arasında iş kazası (WrA), meslek hastalığı (OD) ve işle ilişkili ölüm (WrM) oranlarını analiz etmiştir. Ayrıca, kamu kurumları ve 50'den az çalışanı bulunan düşük riskli iş yerleri için İSG hizmetlerinin 2025 yılında zorunlu hale gelmesinden önceki durumu ortaya koymayı amaçlamıştır.

Yöntemler: Türkiye Sosyal Güvenlik Kurumu'ndan (SGK) elde edilen veriler kullanılarak, 81 ildeki eğilimler epidemiyolojik, gözlemsel ve tanımlayıcı bir yöntemle değerlendirilmiştir. "4-1/a zorunlu sigortalı" çalışan sayısındaki değişiklikleri dengelemek amacıyla dolaylı standardizasyon uygulanmış; böylece iller arasında standardize edilmiş (s) $_{s}$WrA, sOD ve $_{s}$WrM oranlarının karşılaştırılması sağlanmıştır.

Bulgular: Çalışma döneminde Türkiye'deki sigortalı çalışan sayısı neredeyse iki katına çıkmıştır. Bölgesel eşitsizlikler belirginleşmiş; batı illerinde $_{s}$WrA oranları daha yüksek, doğu illerinde ise $_{s}$WrM oranları daha fazla gözlenmiştir. Zonguldak, Bilecik, Kütahya, Manisa, Bartın, Karabük ve Kocaeli, dönem boyunca en yüksek standardize oranlara sahip iller arasında yer almıştır. Kanunun yürürlüğe girmesinin ardından $_{s}$WrA oranları Karadeniz bölgesinde artış göstermiş, Marmara bölgesinde ise sOD oranlarında sınırlı bir artış gözlenmiştir. $_{s}$WrM oranlarında ise farklı illerde zirveler görülmüş olup, bu artışların Doğu Karadeniz bölgesinde kümelendiği izlenmiştir.

Sonuç: Bu çalışma, Türkiye'deki iş sağlığı ve güvenliği sistemine ilişkin yapısal zayıflıkları ve bölgesel eşitsizlikleri ortaya koymaktadır. 2025

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ABSTRACT

persistent underreporting, limited diagnostic capacity for occupational diseases, and uneven implementation across regions suggest that significant structural gaps remain.

Keywords: Work-related accident, occupational disease, work-related mortality, occupational health and safety, OHS, Türkiye, city, province, region, standardization, 6331

ÖZ

yılında Kanun No. 6331'in kapsamının genişletilmesi iyileştirme için bir fırsat sunmaktadır; ancak OD tanılamasındaki yetersizlikler, WrA raporlamasındaki eksiklikler ve bölgesel uygulamalardaki eşitsizlikler dikkate alındığında, önemli yapısal açıkların sürdüğü görülmektedir.

Anahtar Sözcükler: İş kazası, meslek hastalığı, işle ilişkili ölüm, iş sağlığı ve güvenliği, İSG, Türkiye, şehir, iller, bölge, standardizasyon, 6331

INTRODUCTION

In Türkiye's recent history, significant reforms in occupational health and safety (OHS) have been initiated, initially the social security reform of 2006. This reform unified previously separate social security institutions (SSI), including those for self-employed individuals and civil servants, under a single framework. As part of this reform, social security Law No. 5510 was enacted, mandating the reporting of all work-related accidents (WrA) to the SSI. Since 2007, the Ministry of Labor and Social Security has made annual statistical data publicly accessible (1,2), compiled in accordance with International Labor Organization (ILO) definitions and European Union (EU) sustainability criteria, and shared with relevant stakeholders (2).

Despite these advancements, the ILO reported in 2009 that OHS practices remained inadequate in 33 countries, including Türkiye (3). The Ministry also acknowledged deficiencies in the reporting of OHS issues during the same period (4). In response, OHS Law No. 6331 was introduced in 2013 (5), which requires employers to appoint occupational safety experts and workplace physicians, conduct risk assessments, provide OHS training, and designate worker representatives. This law also imposes penalties for non-compliance and mandates the preparation of emergency response plans. Following its implementation, reported WrAs tripled in 2013 (6,7), indicating increased awareness and reporting of workplace incidents. In the National OHS Policy Document-III (8,9), published immediately after this law, OD set a target for a significant increase in diagnosis rates. However, these targets were not achieved (9).

The law intended to require OHS services compulsory for public institutions and low-risk workplaces with fewer than 50 workers since its inception. However, due to infrastructural deficiencies, its implementation was postponed until 2025 (10). With the publication of the 2023 SSI annual statistical data, a comprehensive dataset covering 17 years (2007-2023) is now available online (2), allowing for an in-depth analysis of long-term trends in OHS.

The purpose of this study is to evaluate the effects of the OHS Law No. 6331, which entered into force in Türkiye in 2013, by analyzing the standardized (s) ratios of work-related accidents (WrAs), occupational diseases (ODs), and work-related mortalities (WrMs). Additionally, it seeks to elucidate the conditions preceding 2025, when OHS services will become compulsory for public institutions and low-risk workplaces with fewer than 50 workers, thereby providing insights for potential future interventions by the Ministry of Labor and Social Security.

MATERIALS AND METHODS

Research Method

This study was designed as an epidemiological, observational, and descriptive research project. By standardizing the incidence rates of WrAs, ODs, and WrMs, these data were utilized for targeted evaluations.

Inclusion and Exclusion Criteria

This study included workers classified under the "4-1/a insurance" status, as defined by Article 4, Paragraph 1(a) of the Law No. 5510 (1,11). This category specifically refers to individuals "worked by one or more workers under a service contract", for whom social security contributions are paid by their employers. This group was selected because of its comprehensive and reliable data set, as well as its regular workup and higher risks of WrAs and ODs (11,12).

• Excluded groups include; interns, trainees, apprentices, partially insured workers, voluntary insured workers due to their lower exposure to hazardous tasks, and the groups mentioned below.

• Insured in agricultural sector: High levels of informal employment and seasonal work.

• Collective insured: Data unrelated to workplaces in Türkiye.

Furthermore, ODs diagnosed after insurance coverage were not reported prior to Law No. 6331. Therefore, those reported after the law were also excluded to ensure consistency. Moreover, these data lacked city-specific information and were excluded from the standardization analysis to maintain comparability and consistency in the results.

Data Sources

Data were obtained from all statistical yearbooks publicly published by Türkiye's SSI to date. The analysis covers a 17-year period (2007–2023) and includes data from 81 cities, allowing for a detailed examination of trends (2). Since the data for 2024 has not yet been published, it could not be included in the analysis.

Statistical Analysis

Indirect standardization technique was chosen because it does not require detailed age-specific rates or other confounding factors, making it appropriate for datasets where such information is unavailable (13–15). This method is particularly advantageous for adjusting variations in the number of insured workers and ensuring comparability of incidence rates across cities (16,17). This approach adjusted for city-level differences in the number of insured workers,

accounting for regional variations and enabling more accurate comparisons of WrAs, ODs, and WrM incidence rates.

The analysis utilized the "standardized ratio formula", offering a reliable method for comparing observed and expected rates. The following formulas were applied to calculate standardized ratios for WrAs, ODs, and WrMs:

• National WrA or OD or WrM (incidence) Rate (only for WrA x1,000)

= Türkiye's Observed WrAs / Türkiye's Number of Workers x 100,000

• Expected Incident

= City's Number of Workers × National WrA or OD or WrM Rate

• Standardized ($_s$) City's WrA or OD or WrM incidence [$_s$WrA or $_s$OD or $_s$WrM] Ratio

= (City's Observed / Expected Incident) × 100

Statistical analyses were performed using SPSS 25 (IBM Corp., Armonk, NY, USA), and visualizations were generated via Excel and Flourish Studio (available at https://flourish.studio).

Interpretation of Standardized Ratios

A normal incidence rate is expressed as, for example, the "WrA rate", while a standardized incidence rate is referred to as the "$_s$WrA ratio" and is typically expressed as a percentage. A "$_s$WrA ratio" of 100% represents the national average. For instance, in 2015, "Şırnak's $_s$WrM ratio" was 1,080%, indicating a 9.8-fold increase compared to the national average. This indicates that while 17 fatalities were "observed" in Şırnak that year, only 2 fatalities were "expected" based on the national WrM rate and the number of insured workers in the city.

In other words, large standardized ratios highlight unexpected developments in specific cities during certain years. Identifying and analyzing these deviations can provide critical insights into underlying causes and help develop targeted solutions to address them.

Presentation Method - Tables

The results of the standardization analyses for WrAs, ODs, and work-related mortality (WrM) are presented in three supplementary tables (Supplementary Tables 1-4), which provide a comprehensive list of all cities and their respective ratios. The effective date of OHS Law No. 6331 is highlighted. Due to the extensive length of these tables, a summary is provided for clarity and emphasis:

• Cities that ranked in the top six for WrAs in any year during the 17-year period are included in Table 1.

• Cities ranked in the top three for ODs in any year were included in Table 2.

• Cities ranked first for WrMs in any year were shown in Table 3.

This approach allows for limiting each table to 14 cities, ensuring a concise presentation while effectively representing key patterns and trends in the data.

Presentation Method - Figures

The interpretation of OHS statistics largely depends on the methodological approach adopted. In our study, these approaches can be observed in a hierarchical progression from simpler to more complex analyses.

Figure 1 presents the annual numbers of WrA, OD, and WrM in Türkiye as raw values, offering a general overview of the country's OHS status. However, this approach is limited in several respects, primarily because it does not account for changes in the number of workers over time. In other words, it cannot determine whether the observed increase in work-related incidents truly reflects a rise in occupational risk or simply results from workforce expansion. To overcome this limitation, it is necessary to examine rates rather than raw numbers, as shown in Figure 2. By presenting these two perspectives together, we aimed to draw the reader's attention to this crucial distinction.

Table 1. Cities appearing in the top six for standardized work-related accident (sWrA) ratios in any year from 2007 to 2023.

City (%)*	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Zonguldak	565	587	974	970	788	774	340	295	278	252	212	174	221	239	225	211	216
Bilecik	527	416	387	506	514	244	360	350	316	287	293	267	291	283	289	271	258
Karabük	576	614	635	616	607	454	267	252	252	216	198	165	184	183	201	159	149
Manisa	376	532	446	549	501	593	339	312	233	223	208	213	201	196	207	204	205
Karaman	122	94	155	132	153	173	205	217	198	277	354	277	229	243	203	189	146
Kütahya	167	244	288	179	301	262	158	179	155	150	159	156	137	147	148	157	134
Kocaeli	272	145	119	152	207	122	193	202	215	193	185	175	176	183	183	183	178
Eskişehir	201	252	210	270	291	93	203	179	180	172	149	145	145	148	143	140	141
Kayseri	226	243	184	20	227	215	213	204	184	174	165	149	158	171	176	162	159
Bartın	157	146	239	367	362	177	175	145	143	138	125	131	119	126	139	136	133
Denizli	169	216	210	245	248	251	175	161	156	147	136	125	123	125	128	127	115
Bolu	136	121	179	205	194	165	151	149	138	149	135	143	164	176	192	187	173
Yalova	90	106	154	63	97	138	98	114	136	156	164	160	230	253	266	241	251
Bursa	198	197	188	249	162	262	158	154	157	142	125	117	115	112	112	119	118
*Standardized ratio percentage			1st		2nd		3rd		4th		5th		6th		OHS Law No. 6331		

Table 2. Cities appearing in the top three for standardized occupational disease (sOD) ratios in any year from 2007 to 2023.

City (%)*	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Zonguldak	9900	7615	5316	2201	3158	8279	4921	1246	3737	3355	1269	1883	872	706	458	704	302
Kütahya	26	28	0	0	5788	267	231	381	364	434	1508	1601	1334	340	131	511	147
Bilecik	22	52	0	56	169	77	1347	3764	176	625	612	1138	1798	900	334	728	48
Kocaeli	39	5	207	129	9	83	218	366	447	198	384	339	420	330	657	535	0
Çankırı	146	334	1060	102	0	271	1303	0	146	0	104	144	124	69	152	62	0
Bartın	42	0	0	0	0	494	0	189	519	478	272	762	349	0	50	0	0
Yalova	0	0	0	0	0	0	0	0	71	62	307	410	619	384	486	728	0
İzmir	128	242	110	458	31	80	35	61	52	128	116	55	204	91	86	82	612
Sakarya	35	477	100	0	99	0	0	125	85	91	211	205	264	372	299	197	0
Çorum	0	0	0	0	0	0	0	0	251	913	138	297	0	129	49	235	63
Ankara	17	26	199	414	260	187	53	40	140	81	127	102	76	53	39	38	7
Samsun	0	52	0	17	0	0	0	0	23	20	32	0	0	22	8	19	1016
Artvin	0	0	0	0	0	131	0	0	0	0	0	0	61	410	262	292	30
Erzincan	0	195	559	0	0	0	0	0	0	0	261	0	0	0	0	0	0
*Standardized ratio percentage					1st		2nd			3rd					OHS Law No. 6331		

Table 3. Cities ranked first for standardized work-related mortality (sWrM) Ratios in any year from 2007 to 2023.

City (%)*	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Şırnak	168	305	93	517	457	124	344	440	1080	331	441	135	201	527	335	403	131
Hakkâri	131	267	255	383	209	444	0	156	153	474	507	347	352	204	0	229	70
Artvin	208	131	86	252	214	348	347	253	134	260	208	257	338	126	422	82	137
Bartın	0	118	211	103	146	196	106	184	116	144	201	168	138	84	147	1622	23
Zonguldak	115	269	122	626	267	278	229	116	211	151	231	147	144	162	192	146	128
Siirt	155	157	220	176	419	344	182	43	190	870	151	28	122	78	35	67	209
Gümüşhane	0	785	277	68	55	240	210	66	223	73	223	122	259	232	149	68	90
Manisa	86	66	80	153	86	107	125	1232	63	105	110	99	68	133	109	122	165
Tunceli	468	0	302	376	110	0	0	138	144	479	111	0	0	132	248	0	365
Karabük	140	131	157	50	128	147	312	202	86	185	138	347	68	67	180	194	113
Batman	36	112	129	185	468	304	139	158	89	101	60	142	179	124	127	118	130
Nevşehir	202	177	90	338	124	47	394	86	55	55	115	161	118	252	73	130	116
Bingöl	110	0	354	99	341	359	95	0	220	130	63	166	239	82	187	0	77
Bayburt	388	0	0	0	125	223	0	0	0	144	98	111	462	0	247	119	113
*Standardized ratio percentage							1st								OHS Law No. 6331		

To further explore these national trends at the subnational level, Figures 3–5 visualize city-level standardized ratios and their spatial clustering. In Figures 3–5, the analysis was extended to the city level. However, city-level analyses are inherently complex, as the number of workers varies substantially both across cities and over time. Therefore, a more advanced approach beyond Figure 2 was required, and standardization, the core analytical method of this study, was applied. Through this approach, city-level variations were mapped to enhance interpretability, regional clustering patterns were clearly visualized, and, to identify the cities most influenced by Law No. 6331, correlation analyses across years were conducted to reveal those with the most notable increases.

Finally, we focused on the cities with the highest deviations from expected values, documenting their trajectories in Figures 6–8.

RESULTS

The results and figures were presented in a hierarchical structure progressing from general to specific to ensure clarity and ease of interpretation. The analyses were conducted at three levels—national, regional, and city—and within each level, WrA, OD, and WrM were evaluated separately.

National Level

Between 2007 and 2023, the number of 4-1/a compulsory insured workers in Türkiye nearly doubled (from 8.5 to 16.4 million),

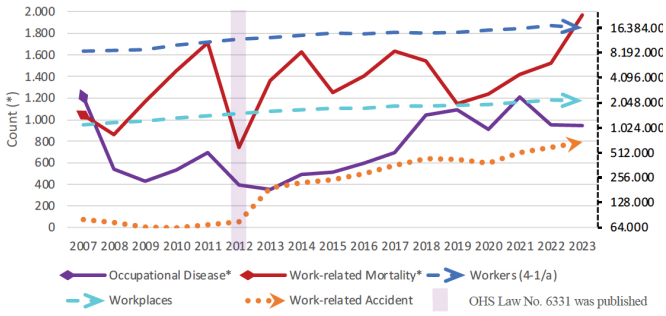

Figure 1. The count of workers, workplaces and work-related incidents in Türkiye (2007–2023).

This figure illustrates the annual changes in the number of workers, workplaces, WrAs, ODs, and WrMs across Türkiye. It emphasizes trends at the national level and highlights the effective date of OHS Law No. 6331. This figure is particularly significant as it visualizes the five key work-related risk parameters in a single graph. Two Y-axes were used: parameters marked with an asterisk (*) correspond to the left axis, while those shown with dashed lines correspond to the right axis (logarithmic scale).

workplaces increased from 1.1 to 2.2 million, WrA cases rose from 80,602 to 681,401, OD diagnoses slightly declined from 1,208 to 945, and WrM cases increased from 1,043 to 1,966 (Figure 1)

The number of WrAs had nearly tripled within a year following the implementation of Law No. 6331, and this increase continued steadily in the subsequent years. OD diagnoses exhibited a delayed response, demonstrating a consistent upward trend one year after the law's enactment. This trend persisted until the onset of the COVID-19 pandemic, during which the ratios experienced fluctuations. Conversely, the number of WrM cases followed a fluctuating and irregular pattern; however, when averaged over time, it can be stated that they demonstrated a stable trajectory (Figure 1).

Upon examining the National Incidence Rates (Figure 2), which are more reliable than the numbers in Figure 1, it was found that although no difference in the WrA trajectory could be detected that would change the interpretation, the increase observed in OD rates in Figure 1 was, in fact, minimal. Furthermore, while no significant difference in WrM rates was observed before and after the implementation of the law in Figure 1, a notable decrease in these rates was recorded in the period following the law's enactment, in Figure 2. Overall, after the implementation of Law No. 6331, the reporting WrA and OD rates increased, while WrM rates gradually decreased over the study period.

Region Level

WrA reports were predominantly concentrated in the western half of the country. However, an analysis of the 14 cities showing the greatest post-law increase in $_s$WrAs (range: 70%–96.4%) revealed a distinct clustering pattern in the Black Sea region (Figure 3).

Regarding $_s$ODs, cities such as Zonguldak, Kütahya, and Bilecik consistently ranked among the highest. The 14 cities with the largest increase in OD diagnoses (range: 61.5%–96.1%) formed a marked concentration within the Marmara Region, reflecting region-specific differences in diagnostic activity (Figure 4).

In contrast to ODs, elevated $_s$WrM ratios were more geographically dispersed across Türkiye. Yet, when mapped, the 14 cities with the highest $_s$WrM levels (range: 35.5%–58.2%) showed a clear tendency to cluster in the Eastern Black Sea region (Figure 5).

City-Level

The top 7 cities with the highest overall ratios of $_s$WrA, $_s$OD, and $_s$WrM were as follows: Zonguldak, Bilecik, Kütahya, Manisa, Bartın, Karabük, and Kocaeli, respectively. Notably, the top six cities consistently ranked at the forefront both before and after the implementation of Law No. 6331. When examined their locations on the map, it can be observed that they were aligned almost in a consecutive line on the north-south axis. In the cities at the top of the rankings, a noticeable decline pattern in $_s$WrA was observed following the implementation of Law No. 6331. While irregularities and a wide range of fluctuations dominate the trends of $_s$OD, a slight downward trend is evident in the maximum rates observed after the enactment of Law No. 6331. In contrast, $_s$WrMs exhibit more frequent peaks and troughs, showing no discernible pattern associated with Law No. 6331 (Figures 6—8).

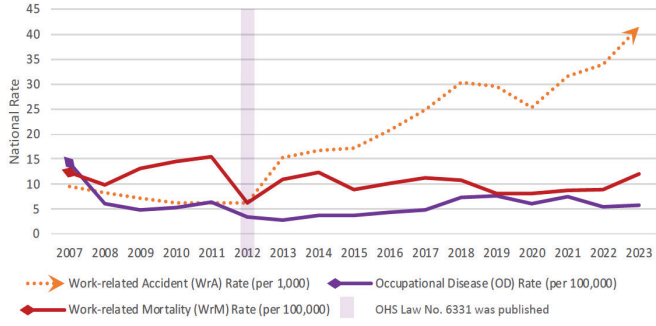

Figure 2. National work-related incidence rates in Türkiye (2007–2023).

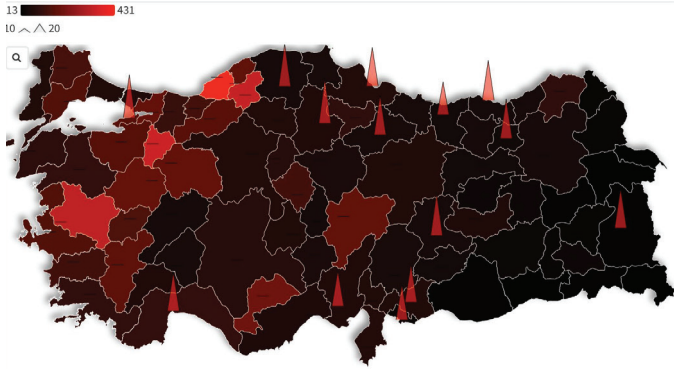

Figure 3. Heatmap of standardized work-related accident ($_s$WrA) ratios (%) by city (2007–2023).

Figures 3–5 are heatmaps of Türkiye created to visualize the 17-year standardization analyses, illustrating the average standardized ratio percentages for 81 cities. The top left corner includes a scale for standardized incidence ratios (%) and a second scale showing percentage increases (upward arrows). These arrows highlight cities that exhibited an increasing trend following the implementation of Law No. 6331, effectively representing both the magnitude and direction of the correlation (Spearman). This approach was limited to the 14 cities with the highest ratios in order to focus attention.

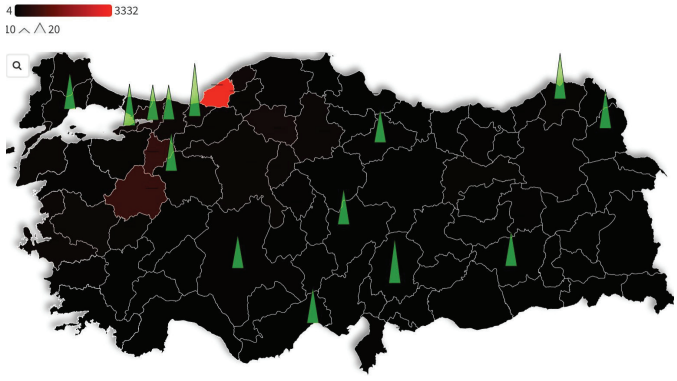

Figure 4. Heatmap of standardized occupational disease (sOD) ratios (%) by city (2007–2023).

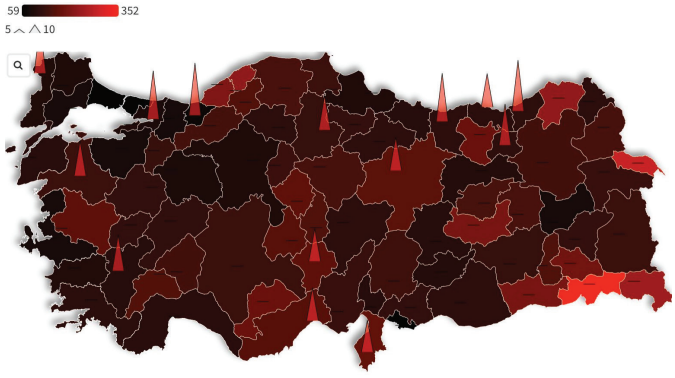

Figure 5. Heatmap of standardized work-related mortality (sWrM) ratios (%) by city (2007–2023).

Work-Related Accidents

Before the implementation of Law No. 6331, $_{s}$WrA reached as high as 900% in some cities; however, no city recorded a rate exceeding 500% in any subsequent period.

Specifically: $_{s}$WrA ratios declined from 565% to 216% in Zonguldak, from 527% to 258% in Bilecik, and from 576% to 149% in Karabük. Similar downward trends were observed in Manisa (593% → 205%) and Bartın (367% → 133%) (Table 1, Figure 6).

Occupational Diseases

Prior to the implementation of Law No. 6331, some cities reported extremely high $_{s}$OD values—up to 10,000% in Zonguldak in 2007. Following the enactment of the law, maximum ratios declined markedly to around 4,000% by 2016 and continued to decrease to approximately 1,000% between 2017 and 2019. After 2020, ratios above 500% became rare, except for isolated spikes such as 1,016 % in Samsun (2023).

Specifically: $_{s}$OD ratios declined in Zonguldak (9,900% → 302%), in Bilecik (3,764% → 48%), and in Kütahya (5,788% → 147%), while Bartın's rate decreased (519% → 0%) by 2023 (Table 2, Figure 7).

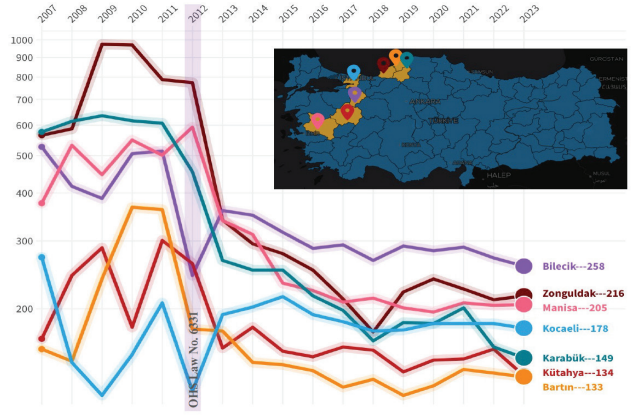

Figure 6. Trends in standardized ratios (%) of work-related accidents (WrA) in the top 7 cities (2007–2023).

Figures 6–8 provide detailed analyses of the top seven cities with the highest standardized ratios of WrAs, ODs, and WrMs over the 17-year period, particularly in relation to the implementation of Law No. 6331. This approach allows a closer examination of specific cities while preserving the general-to-specific flow of the study. These figures use a logarithmic Y-axis while retaining original values, allowing both small and large ratios to be displayed for clearer comparison.

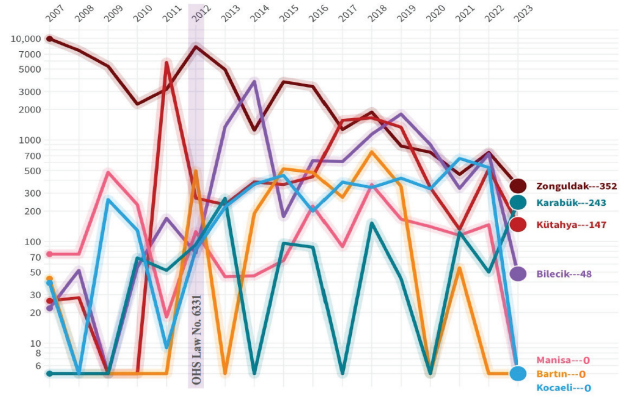

Figure 7. Trends in standardized ratios (%) of occupational diseases (OD) in the top 7 cities (2007–2023).

Work-Related Mortalities

In terms of WrMs, no consistent pattern associated with Law No. 6331 was observed, and the cities with the highest ratios varied considerably over the years. Unlike WrA and OD (Tables 1, 2), $_{s}$WrM ratios displayed abrupt spikes rather than stable rankings. Cities showing recurrent peaks often exceeded 200–300%, whereas others such as Manisa (2014) and Bartın (2022) exhibited isolated, extreme surges. Specifically:

- Bartın showed an extraordinary increase in 2022 with a $_{s}$WrM ratio of 1,622%, but this ratio dropped to 23% in 2023.
- Manisa experienced a notable spike in 2014, reaching a $_{s}$WrM ratio of 1,232%.
- Şırnak had one of the highest $_{s}$WrM ratios in 2015 at 1,080%, but this ratio decreased to 131% in 2023.

• Zonguldak had a high $_s$WrM ratio of 626% in 2010, which dropped to 128% in 2023.

• Karabük reached a $_s$WrM ratio of 312% in 2013, but this ratio fell to 113% in 2023.

These data indicate significant variations in $_s$WrM ratios across cities and reveal that sudden spikes occurred in certain years (Table 3, Figure 8).

DISCUSSION

This study examined the effects of the OHS Law No. 6331, which came into force in Türkiye in 2013, through the standardization (s) of data related to WrAs, ODs, and WrM. Utilizing data published by the SSI for all available years, the analysis revealed a significant increase in $_s$WrAs following the implementation of Law No. 6331, a slight increase in $_s$OD ratios, and no significant change in $_s$WrMs. The analyses also revealed that occupational health indicators were concentrated in certain regions; however, the highest standardized rates in these regions showed a declining trend over the years.

Beyond this, our study is the first to evaluate all these dimensions simultaneously and uniquely investigates the impact of the law on these data. To improve interpretability, our study used rates instead of raw counts and extended the analysis from national to city level through standardization, which allowed meaningful spatial comparison. Previously, Bayramlar et al. (9) illustrated these regional clusters based on a limited five-year period (2010–2015) and highlighted only the top ten cities with the highest standardized WrA, OD, and WrM ratios. İşsever et al. (18), similarly, analyzed the 2008–2017 period from an occupational perspective and demonstrated that mining-intensive cities consistently exhibited high WrA and OD rates. Our study not only corroborates these earlier findings but also goes beyond them by analyzing a longer period (2007–2023) and providing a broader spatial perspective on regional clustering.

This broader temporal and spatial scope not only enhances the representativeness of our findings but also provides a stronger basis for cross-national comparison. Typically, even in countries with the most advanced OHS systems, it is estimated that there

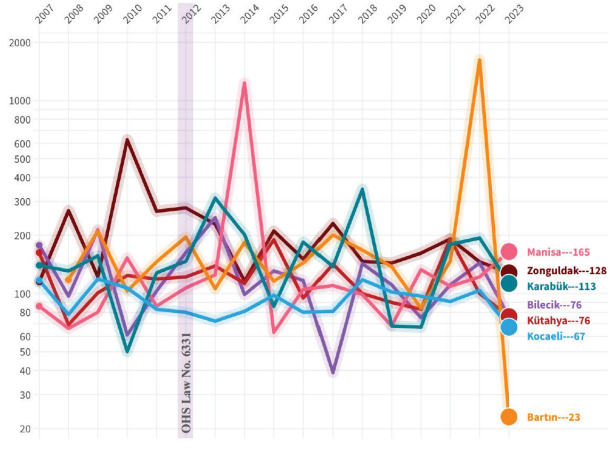

Figure 8. Trends in standardized ratios (%) of work-related mortality (WrM) in the top 7 cities (2007–2023).

are reporting deficiencies (including WrM) (19,20). To contextualize these deficiencies, we believe that the most effective assessment can be achieved through a comparison with German Statutory Accident Insurance statistics, a country with a similar population and a strong OHS system. In terms of WrAs, while 870,000 WrAs were reported in Germany in 2019 (21), this number was below 430,000 in Türkiye (Figure 1). The seemingly large gap observed here was considerably wider in previous years, particularly before 2013, when the absence of a comprehensive OHS framework led to severe underreporting. The Ministry became aware of this situation at the time and concluded that the major problem lay in the structural deficiencies of the national OHS system; accordingly, it enacted Law No. 6331 in 2013 to establish a comprehensive legal framework. As part of this legal framework, the forthcoming implementation of compulsory OHS services in 2025 for public institutions and low-risk workplaces with fewer than 50 workers is also expected to further strengthen this progress (5). However, the continued discrepancy with Germany after 2013 also suggests that other major structural factors—such as informal employment, enforcement limitations, and the absence of a mature safety culture—have remained influential. This interpretation is supported by Çalış and Küçükali (22), who argued that the lack of a well-established work safety culture in Türkiye contributes significantly to underreporting. Normally, the prevention of WrAs reflects an effective OHS system; however, due to the aforementioned reasons underlying Türkiye's much lower WrA reporting rates compared to Germany, any increase in WrAs should be interpreted positively as an indication that the OHS system is beginning to take hold. This increase does not indicate a rise in actual incidents but rather reflects improved reporting practices and growing compliance with OHS regulations. In particular, regional increases in WrA reporting can be regarded as early evidence of a developing safety culture at the local level. Consistent with this interpretation, our study found that the provinces with the highest rise in standardized WrA were concentrated in the Black Sea region following the enactment of the law, suggesting that this area may have been among the first to internalize the emerging safety culture (Figure 3).

Having examined WrA as indicators of reporting behavior and enforcement, it is also important to evaluate OD, which reflect the diagnostic and recognition capacity of the OHS system. Following the enactment of Law No. 6331, the expected increase in OD diagnoses began only in 2014, one year after the law's enactment. This rise showed a steady upward trend until the fluctuations in the COVID-19 pandemic period (Figure 2). As of 2022, the number of OD diagnoses in Türkiye has reached only around 1,000 (Figure 1). Yuvka and Zorlu (6) also demonstrated that the number of OD diagnoses in Türkiye remained consistently low, highlighting a chronic underreporting problem (6). Likewise, Ucuncu (7) showed that OD diagnosis rates in the SGK statistics were far below expectations. In contrast, during the same period, this number was 200,000 in Germany (21,23). Nienhaus et al. (23) reported that the recognition of COVID-19 as an OD in Germany dramatically increased OD notifications. In contrast, the fact that COVID-19 was not recognized as an OD in Türkiye led to a marked difference between the two countries in this regard. Türkiye's disparity in this regard exists not only with Germany but also with many other countries (6). The seriousness of missed diagnoses in OD is clearly observed in the complex trends

depicted in the relevant graphs and the differences in the heat map (Figures 4 and 7). Authorities acknowledge that the number of OD diagnoses in Türkiye remains quite low (7,8,24). Following the enactment of Law No. 6331, the cities experiencing the highest increase in OD diagnoses were concentrated in the Marmara region, the most developed area of Türkiye. This situation suggests that the infrastructure and awareness for identifying OD may be stronger in more industrialized and economically developed regions. As can be inferred from our interpretive perspective on these findings, a high reporting rate of OHS incidents in a region of Türkiye does not indicate poor workplace management; rather, it reflects the functionality of the system and the emergence of a developing safety culture, serving as a positive indicator.

Following the assessment of OD as an indicator of diagnostic capacity, we next evaluated WrM, which represents the final and most severe outcome in the spectrum of occupational health indicators. In Eurostat data for 2014, the rate of WrM per 100,000 workers was recorded as 1.27 in EU countries (25), while in Türkiye, our study found this ratio to be 12.2 (Figure 2). Contrary to the issues of underreporting in WrAs and ODs, the problem concerning WrMs lies in the very high rates themselves, which is understandably concerning. Even if some underreporting exists, it appears to be at much lower levels compared to WrAs and ODs, since a concrete and extremely serious outcome such as fatality is less likely to be overlooked. Since WrAs and ODs ultimately lead to WrM, fatalities represent the most tangible and predictable endpoint, whereas WrA and OD data are more dependent on reporting practices and therefore would be expected to be less reliable. Studies such as Hämäläinen et al. (26) have provided global estimates of both work accidents and fatal work-related diseases, demonstrating that fatalities constitute a substantial and measurable burden. While these analyses do not directly evaluate reporting reliability, the fact that fatal outcomes can be estimated globally indirectly supports our assumption that WrM data are less prone to underreporting compared to other occupational health indicators. en et al. (27) associated the ten-fold higher WrM rates in Türkiye with insufficient preventive measures and weak implementation of OHS legislation, and Ceylan (28) highlighted that fatal work accidents in Türkiye remain substantially higher than in EU countries. Moreover, Yuvka and Zorlu (6) and Ucuncu (7) reported that occupational incidents in Türkiye often result in more severe outcomes compared to other countries. Taken together, these findings reinforce our view that WrM data can be considered a gold standard when evaluating occupational health indicators in Türkiye. In our study, despite many developments following the enactment of Law No. 6331, the average WrM rate has not changed (Figure 2). In our study, despite many developments following the enactment of Law No. 6331, the average WrM rate has remained unchanged, and these rates were found to be higher in the relatively less developed regions of Türkiye (Figure 5). Overall, while legislative progress has provided a framework for improvement, the persistently high WrM rates highlight the need for stronger policy enforcement and region-specific preventive strategies to reduce fatal outcomes.

According to the ILO accident hierarchy pyramid, expected fatalities can typically be predicted based on the quantity and quality of WrA (29). However, in the Turkish context, widespread underreporting of WrAs prevents such predictions from being reliable. When we examine the 14 cities with the highest $_s$WrM ratios, we find that, with the exception of two cities, these locations had already reached $_s$WrMs of 200-300 prior to major incidents (Table 3 and Figure 8). This indicates that these cities exhibited significant risks for major accidents and displayed clear warning signs even before such catastrophic events occurred. Consequently, in the case of Türkiye, this situation may suggest the potential for prevention of catastrophic events if focused interventions are implemented in these high-risk cities.

The consistency of $_s$WrM data can also be observed in its clear reflection of well-known disasters (30), such as the 2010 mining accident in Kilimli (Zonguldak), during which the city's $_s$WrM rose to 626%. Similarly, the 2014 Soma mining disaster in Manisa, which resulted in the fatalities of 301 workers, caused the city's $_s$WrM ratio to spike to 1,232%. Another notable incident was the 2014 Ermenek mining accident in Karaman, which also contributed to elevated $_s$WrM. More recently, the 2022 Amasra mining disaster in Bartın led to an extraordinary increase in the city's $_s$WrM, reaching 1,622% (Table 3 and Figure 8).

The vast majority of major mining disasters in Türkiye have occurred in the western and northwestern regions (30). However, despite this geographic concentration of large-scale accidents, $_s$WrA reporting rates are markedly lower in the eastern provinces, whereas standardized $_s$WrM rates are substantially higher (Figures 3 and 5). This apparent paradox can be explained by the fact that in the west, fatal events are concentrated in isolated industrial centers with intensive production activity, rather than forming a regional cluster. In contrast, in the east, limited industrial activity combined with severe underreporting and weaker preventive mechanisms leads to proportionally higher fatality rates. This pattern demonstrates that the inadequacy of Türkiye's OHS system is even more pronounced in the eastern regions, where structural weaknesses manifest as persistently elevated mortality despite lower reported accident frequencies.

Generally, the cities with the highest ratios of $_s$WrA, $_s$OD, and $_s$WrM included Zonguldak, Bilecik, Kütahya, Manisa, Bartın, Karabük, and Kocaeli (Tables 1-3). Mining activities were predominant in all of these cities except for Kocaeli, which was an industrial center. Furthermore, these mining cities consistently ranked at the top both before and after the enactment of Law No. 6331. This is also evident in İssever's et al. (18) research on industrial sectors. However, the pattern of decreasing peak values observed in previous years for $_s$WrA and $_s$OD was also evident in these cities over time (Figures 6 and 7). The underlying reason for this may be the improvements in OHS practices in other cities following the enactment of Law No. 6331 and the resulting increase in work-related incidence rates, which has led to the growth of the denominator in the standardization formula. No direct or clear impact of COVID-19 had been observed in these cities.

Study Limitations

This study has several limitations that should be acknowledged. While the SSI reports include all individuals under the 4-1/a category collectively, our analysis focused specifically on compulsory insured workers, who represent the main risk group for occupational incidents. This scope may have led to a slight overestimation in standardized rates but ensured a consistent and homogeneous

comparison across years. Another limitation involves potential reporting and detection bias, particularly in WrA and OD data, which depend heavily on institutional awareness and diagnostic capacity. Intercity variations in economic structure and enforcement intensity may also have acted as uncontrolled confounders. Although standardization was applied to mitigate these effects, residual bias cannot be fully excluded. Furthermore, the study did not account for the severity of WrAs, which could have provided a more detailed understanding of the outcomes (31). The lack of sector-specific data, international benchmarks, and workplace hazard profiles limits broader generalizability. Finally, region-specific academic research on occupational health indicators in Türkiye remains scarce, constraining the contextual interpretation of spatial disparities. Despite these limitations, the study offers a comprehensive national and regional overview that can guide future, more granular research and policy design.

CONCLUSION

This study provides valuable insight into Türkiye's OHS system in the period preceding the planned 2025 expansion of Law No. 6331. Cities with the highest standardized ratios of workplace incidents—particularly WrAs, ODs, and WrMs—were concentrated in mining-intensive provinces such as Zonguldak, Bilecik, and Manisa. Marked regional disparities were identified: eastern provinces showed lower WrA reporting but higher WrM rates, indicating underreporting except in fatal cases. Although $_s$ODs remained low nationwide, a relative rise in the Marmara Region likely reflects improved infrastructure and awareness. The overall decline in extreme peak values suggests gradual progress in reporting and compliance. To strengthen the system, we recommend targeted OHS training in high-risk regions, enhanced OD diagnosis and reporting, and improved surveillance of WrM. Future national monitoring frameworks should integrate standardized indicators such as $_s$WrA, $_s$OD, and $_s$WrM to enable comparability, data-driven evaluation, and early detection of regional disparities. Region-specific research should be encouraged to guide evidence-based interventions.

Ethics

Ethics Committee Approval: Ethical approval was not required, as the study utilized publicly available, anonymized data in compliance with the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all participants or their legal representatives and is available from the corresponding author upon reasonable request.

Footnotes

Authorship Contributions

Surgical and Medical Practices: O.F.B., H.İ., Concept: O.F.B., H.İ., Design: O.F.B., H.İ., Data Collection or Processing: O.F.B., Analysis or Interpretation: O.F.B., Literature Search: O.F.B., Writing: O.F.B.

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Supplementary Tables 1–4:

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