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Clinical diagnosis groups developed to bridge the ICD-9-CM to ICD-10-CM coding transition and monitor trends in workers' compensation claims — Ohio, 2011–2018

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ABSTRACT

Introduction: This study aimed to develop a set of broad clinical diagnosis (ClinDx) groups relevant to occupational safety and health. The ClinDx groups are necessary for analysis and interpretation of longitudinal health data that include injury and disease codes from the Ninth and Tenth Revision of the International Classification of Disease, Clinical Modification (ICD-9-CM, ICD-10-CM). *Methods:* Claims data were analyzed for Ohio Bureau of Workers' Compensation insured employers from 2011 to 2018. We used interrupted time series regression models to estimate level (frequency) and slope (trend) changes to the percentage of each ClinDx group in October 2015. We created ClinDx groups aligned with ICD-10-CM structure and coding principles. Each ClinDx group was counted once per claim (distinct groups). Monthly percentages were calculated based on the injury date. When present, seasonality was assessed separately for each outcome using an autoregressive-moving average model. *Results:* The final set of ClinDx groups included 57 mutually exclusive and exhaustive groups. The study population included 661,684 claims, with 959,322 distinct ClinDx groups. Among all claims, 96.27% included injury code(s) and 11.77% included disease(s) codes. At the transition to ICD-10-CM, 33 ClinDx groups lacked any statistically significant ($P < 0.05$) changes between periods. We observed level changes for 17 ClinDx groups and slope changes for nine groups. Eight ClinDx groups had $\geq$ 20% (+/-) level changes. *Conclusion:* While the transition to ICD-10-CM is a break in series, about two-thirds of disease groups and half of injury groups were relatively stable across the transition. These findings also underscore the need for characterizing both injury and disease outcomes when analyzing workers' compensation data. *Practical Applications:* The 57 ClinDx groups created in this study may be a practical starting point for other occupational epidemiologic analyses that include a mixture of ICD-9-CM and ICD-10-CM data.

1. Background

According to the National Academy of Social Insurance (Welch, Murphy, Wolfe, & Manley, 2024) in the U.S. $60 billion were paid for workers' compensation (WC) indemnity and medical payments in 2021. WC insurance pays for medical expenses and provides partial wage replacement to employees who experience work-related injuries or illnesses. Analyzing large administrative WC databases for research and tracking work-related injury and illness patterns has become a valuable tool for occupational safety and health research and surveillance (Evoy, Syron, Case, & Lucas, 2023; Howard, Adams, Marcum, & Cole, 2022; Konda et al., 2020; Masterson, Wurzelbacher, Bushnell, & Tseng, 2023; Meyers et al., 2018; Shraim, Cifuentes, Willetts, Marucci-Wellman, & Pransky, 2015). WC data are used by U.S. state-based occupational health surveillance programs as part of a comprehensive approach to improving population health (CSTE, 2024). For example, since 2013, the

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Center for Workers' Compensation Studies (CWCS) at the National Institute for Occupational Safety and Health (NIOSH) has published over 30 peer-reviewed articles (Centers for Disease Control and Prevention, 2023a). Since 2013, collaborations between state health departments and their WC bureaus have yielded over 100 publications (Centers for Disease Control and Prevention, 2023b).

WC insurer's data include the International Classification of Diseases, Clinical Modification diagnosis billing codes Version 9 (ICD-9-CM), 1979–2015, and Version 10 (ICD-10-CM), 2015–present. In the United States, the 2015 transition to ICD-10-CM, referred to hereafter as 'the transition,' led to a different structure (e.g., longer codes, first character changed from numeric to alpha) and nearly five times as many diagnosis codes compared to ICD-9-CM (National Center for Health Statistics, 2015). Directly forward or backward mapping between Version 9 and Version 10 is complex because, "multiple ICD-9-CM and ICD-10-CM codes share complex, entangled, and non-reciprocal mappings," especially for the injury and poisoning codes (Boyd et al., 2013).

In practice, to use over 80,000 diagnosis codes [~13,000 billable ICD-9-CM codes to ~ 64,000 billable ICD-10-CM codes] for occupational safety and health analyses, a set of broad, meaningful clinical diagnosis (ClinDx) groups for injury and illness codes are needed. Standardized classification systems promote consistency for monitoring public health trends. From an occupational safety and health perspective, three important characteristics are currently missing from existing diagnosis code classification systems. First, the system would categorize both injury and disease diagnoses. WC claims from work-related diseases/illnesses (such as some musculoskeletal diseases, respiratory diseases, cancer) are compensable, costly, and disabling (Leigh, 2011; Leigh, Marcin, & Miller, 2004). Although laws vary by state, WC insurers pay for medical treatment for diagnoses caused by or aggravated by work, including some chronic diseases (such as diabetes, mental health outcomes) that impact treatment, recovery, and disability outcomes (Utterback, Meyers, & Wurzelbacher, 2014). Separate nature-of-injury matrices exist for ICD-9-CM and ICD-10-CM (ICD-9-CM codes 800–999 and ICD-10-CM codes beginning with S and T) (Fingerhut et al., 2002; Hedegaard, Garnett, Johnson, & Thomas, 2021); however, those matrices exclude disease diagnosis chapters (ICD-9-CM 001–799, ICD-10-CM Chapters A-R and U). Second, the system would be capable of analyzing WC claims pre- and post-transition. WC records from one injured worker's medical journey may include both ICD-9-CM and ICD-10-CM codes. WC systems include all diagnosis codes for injured and ill workers over the life of the claim. Typically, analyses of WC claims data are delayed until the claims have had at least one year to 'mature' on these medical journeys; therefore, some claims that occurred before October 2015 include ICD-10-CM codes. Third, the system would contain a manageable number of categories, in contrast to some existing classification systems for clinical outcomes that include too many categories (> 200) and lack utility for some occupational safety and health surveillance and research (Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP), 2020; AHRQ, 2024; Centers for Medicare & Medicaid Services). Alternatively, while Meyers and colleagues (2018) assigned all injury and disease ICD-9-CM codes to a manageable number of 57 work-related groupings suitable for occupational health research and surveillance needs, those ClinDx groups (called 'Diagnosis categories') only apply to ICD-9-CM codes (Meyers et al., 2018).

To improve the utility of WC data as an occupational health surveillance system, it is important to understand the impact of the transition on diagnosis trends for WC claims. The goal of this study was to develop and assign ClinDx groups for both ICD versions to facilitate longitudinal analysis and interpretation of occupational safety and health trends across the transition. Specifically, our aim was to evaluate the effect of the transition on slopes and levels of monthly percentages by ClinDx group immediately following the transition. The hope is that results from this study can be used to analyze and interpret longitudinal data for projects that include a mixture of ICD-9-CM and ICD-10-CM codes.

2. Methods

2.1. Development of ICD-10-CM ClinDx groups

Developing the ICD-10-CM crosswalk and definitions was an iterative process. First, we adapted the set of broad 57 ICD-9-CM ClinDx groups (Meyers et al., 2018) to create a concordance table, similar to the broad, aggregate ICD mortality groups that Janssen and Kunst (2004) used to evaluate mortality trends across ICD versions. In short, we identified the best match for each ICD-9-CM ClinDx group among the ICD-10-CM chapter(s) (such as Neoplasms), categories or sub-categories. Each ClinDx group name was edited to improve consistency and align with ICD-10-CM descriptions. After developing the ICD-10-CM ClinDx groups, we aligned ICD-9-CM codes with the updated ClinDx group case definitions. Both backward and forward mapping techniques were used to improve the accuracy of the mappings to each ClinDx group. This strategy reduced challenges with one-to-many or many-to-one mappings. For example, "Hernia of abdominal cavity" (550–553) aligned with the "Hernia" category (K40-K46). The new Hernia ClinDx group retains the title consistent with ICD-10-CM terminology and includes all hernias. Then, all codes from the Hernia of abdominal cavity ICD-9-CM ClinDx group were assigned to the new Hernia ClinDx group.

This study used ICD-9-CM codes within the range of 000–999 and ICD-10-CM codes beginning with letter A–U (2021 codes and prior years). Please note, whenever a specific diagnosis code is mentioned in this paper, if the first character is numeric, it is an ICD-9-CM code, whereas ICD-10-CM codes begin with a letter. External cause and history codes were excluded. Quality checks of draft crosswalks were conducted in SAS® (Release 9.4, SAS Institute, Inc., Cary, North Carolina) and Microsoft Excel by two investigators, a Research Epidemiologist and a Registered Health Information Administrator (RHIA). A physician/medical epidemiologist was consulted as needed. In some cases, discontinuities identified during initial interrupted time series analyses (Section 3.3) identified errors that were subsequently corrected in the final version. For example, to align with ICD-10-CM, ICD-9-CM tooth fracture codes were moved to Fracture – head ClinDx group from the Open wounds nec group. Corrections were made in SAS®, and the process was repeated until both reviewers were satisfied with the accuracy of the ICD-10-CM crosswalk. All records were assigned to a single ClinDx group using a SAS® program that included several elements of the Barell Matrix SAS programs (National Center for Health Statistics, 2002).

2.2. Workers' compensation claims data

The Ohio Bureau of Workers' Compensation (OHBWC) is unique because OHBWC insures about two-thirds of workers in Ohio. Ohio is the largest of four states where it is mandatory to maintain WC insurance from the state-based insurer, with the exception of some employers who meet the financial criteria to self-insure and prefer to self-insure (Ohio Bureau of Workers' Compensation, 2024) and sole proprietors, who are not required to insure through OHBWC.

NIOSH maintains a large relational SQL database that includes variables provided by OHBWC that were used to describe the characteristics of the study population of diagnoses and claims overall and stratified by transition stage (pre-transition, 1/1/2001–9/30/2015; post-transition, 10/1/2015–12/31/2018). For claims data from 2011 to 2018, we counted distinct ClinDx groups per claim among all Ohio employers insured by the OHBWC. That is, we counted each group once per claim even when there were multiple diagnoses assigned to the same ClinDx group. For this study, analyses excluded 2,148 (0.32%) accepted claims due to: zero diagnosis codes; diagnosis denial; the injured worker requested dismissal of the condition; black lung diagnoses, which are handled in a separate system; incomplete diagnosis codes; or codes mapped to multiple ClinDx groups.

This activity was reviewed by CDC, deemed not to be research, and was conducted consistent with applicable federal law and CDC policy (See e.g., 45 C.F.R. part 46.102(l)(2), 21 C.F.R. part 56; 42 U.S.C. §241 (d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq.).

2.3. Analysis

Interrupted time series analysis models were used to estimate the effect of the transition on the monthly distribution by distinct ClinDx groups (%). The main purpose of the regression analysis was to identify changes in level (monthly percentage) or slope (monthly trend). A level change is a sudden, sustained change where the time series is shifted up or down by a given value immediately following the transition. For regression analysis of distinct ClinDx groups, the denominator for percentage calculations was the sum of distinct ClinDx groups per claim among all claims. A separate model was used for each of the 57 ClinDx groups. The model used was: $Y_t = \beta_0 + \beta_1$ month $+ \beta_2$ transition $+ \beta_3$ (month – 57) x transition $+ \varepsilon_t$, where Y_t is the monthly ClinDx group percentages measured at each month of observation t, β_0 is the intercept, the baseline outcome proportion in January 2011, β_1 is the slope or trend over months, β_2 is the level change at the transition, β_3 is the change in slope at the transition, and errors are ε_t. The variable month ranges from 0 to 95 for the months January 2011 to December 2018. Month 57 was the month of transition. The variable transition was coded as zero if the month occurred before October 2015 or one if the month occurred on or after October 2015. To account for seasonal effects, we added eleven variables to the model to indicate the months February to December. January was the reference month. An autoregressive model with lags up to 24 months was used for the errors, ε_t. All autoregressive parameters were initially included in the model, and parameters were removed by backward elimination.

Ten of the ClinDx groups had a low number of counts and no visual evidence of a trend or seasonal effect; the model was simplified to: $Y_t = \beta_0 + \beta_2$ transition. A negative binomial model for counts was used to fit these data, with an offset to account for the total number of diagnoses in each month.

Relative level changes (%) compared to September 2015 were calculated to normalize comparisons between ClinDx groups despite large monthly frequency differences. For linear models, the percent change at transition was equal to 100 times the ratio of the level change coefficient (β1) to the difference between the post-transition intercept (β2) and the level change coefficient [100*(β1/ β2- β1)]. For negative binomial models the percent change at transition was equal to 100 times the difference between the exponentiated coefficient minus 1.

All calculations were done with SAS®. The AUTOREG and COUNTREG procedures were used to estimate the models. The residuals of the models were evaluated with the ARIMA procedure and were found to be white noise.

Descriptive analyses for this study were reported overall and stratified by transition stage. We calculated the distribution stratified by diagnosis type (injury or disease) for each claim, for diagnoses that met our inclusion criteria, and for each distinct ClinDx group. For each claim, we calculated the number and percentage of claims that included at least one injury and disease diagnosis, included a single diagnosis code, or included a single ClinDx group. We calculated the mean and standard deviation (SD) overall and by transition stage for the numbers of allowed diagnoses per claim and distinct ClinDx groups per claim.

2.4. Evaluating ClinDx discontinuities

For ClinDx groups with statistically significant level changes of ≥ 20% at the transition, we reviewed diagnosis frequencies to identify potential errors in the code assignments that could be corrected or to identify other potential reasons for the level changes. After correcting errors, models were rerun.

3. Results

3.1. ICD-10-CM ClinDx groups

The final set of 57 mutually exclusive ICD-10-CM ClinDx groups (Supplementary data Table 1) was similar to the 57 ICD-9-CM groups (Meyers et al., 2018) with four main exceptions. First, to improve tracking capabilities for knee injuries made possible by the ICD-10-CM coding structure, we created a new group — the Knee sprains or tears group — which includes knee meniscus tears (previously classified as knee dislocations and knee ligament sprains). ICD-9-CM codes for “unspecific sprains of the lower leg and knee” remained in the Sprains – lower extremity group. Second, we combined knee derangements with other knee joint disorders into a revised group, Knee disorders. Third, we eliminated the Certain traumatic complications and unspecified injuries (ICD-9-CM 958.0–959.9) ClinDx group and assigned those codes to the Other and unspecified effects of external cause not elsewhere classified (nec) group. Fourth, the newborn codes (Perinatal codes, ICD-9-CM 760–779) were assigned to Congenital abnormalities nec and perinatal conditions, rather than Pregnancy related conditions and adverse outcomes.

Minor changes included editing the names of 11 groups to align with ICD-10-CM terminology and moving 50 ICD-9-CM codes from four ClinDx groups to different groups (34 of the 50 diagnoses did not exist in the OHBWC claims database, and 12 diagnoses had < 50 claims). ClinDx group descriptions, case definitions, and ranges of ICD-9-CM and ICD-10-CM codes per group are presented in Supplementary data Table 1.

3.2. Study population

When stratified by transition stage, patterns in the percentage of allowed diagnoses, in distinct ClinDx groups, and in distinct claims were not meaningfully different for any category (Tables 1 and 2). Across both time periods, among 661,683 claims, more than 61% had a single diagnosis (Table 1), about 70% included diagnoses from a single ClinDx group, and about 96% included at least one injury diagnosis. These claims included 1,171,773 diagnosis codes (Table 2), primarily for traumatic injuries (90%). The mean (SD) allowed diagnoses per claim was 1.77 (1.50) overall, 1.78 (1.51) pre-transition, and 1.75 (1.47) post-transition (data not included in Tables).

The five most common ClinDx groups were the same for all time periods (Table 3): 17.96% Open wounds nec, 16.62% Contusions with intact skin surface (Contusions), 10.11% Sprains – upper extremity.

Table 1
Description of study population claim characteristics for Ohio Bureau of Workers’ Compensation, 2011–2018, by transition stage (pre-transition, 1/1/2001–9/30/2015, post-transition, 10/1/2015–12/31/2018) for distinct claims.

Description	Pre-transition N (%)	Post-transition N (%)	Total N (%)
Full study population	411,737 (62.23)	249,946 (37.77)	661,683 (100.00)
Traumatic injuries	395,203 (95.98)	241,816 (96.75)	637,019 (96.27)
Diseases	51,569 (12.54)	26,332 (10.54)	77,901 (11.77)
Claims with traumatic injury and disease ClinDx groups	35,035 (8.51)	18,202 (7.28)	53,237 (8.05)
Claims with a single diagnosis code	252,813 (61.40)	157,033 (62.80)	409,846 (61.90)
Claims with a single distinct ClinDx group	287,845 (69.90)	179,486 (71.80)	467,331 (70.60)

Note: This analysis excludes 2,146 claims without an allowed diagnosis, 2 claims with incomplete diagnosis codes that map to multiple ClinDx groups, and Black lung cases, which are managed separately and excluded from this study population.

Table 2
Description of study population allowed diagnosis code characteristics for Ohio Bureau of Workers' Compensation, 2011–2018, by transition stage (pre-transition, 1/1/2001–9/30/2015, post-transition, 10/1/2015–12/31/2018).

	Allowed Diagnosis Codes		
	Pre-transition N (%)	Post-transition N (%)	Total N (%)
Full study population	734,708 (62.70)	437,065 (37.30)	1,171,773 (100.00)
Traumatic injuries	655,091 (89.16)	398,083 (91.08)	1,053,174 (89.88)
Diseases	79,617 (10.84)	38,982 (8.92)	118,599 (10.12)

Note: This analysis excludes 2,146 claims without an allowed diagnosis, 2 claims with incomplete diagnosis codes that map to multiple ClinDx groups, and Black lung cases, which are managed separately and excluded from this study population.

(Sprains-UE), 9.91% Sprains − back (Sprains-back), and 7.25% Sprains − lower extremity except knee (Sprains-LE). The order for third and fourth ranked groups switched post-transition because there were fewer back sprains. Seventeen ClinDx groups with > 12,000 claims accounted for 90% of all ClinDx groups (N = 864,419); the 17 groups were primarily traumatic injuries and 2 disease groups — Soft tissue/enthesopathy ranked ninth (N = 26,656, 2.78% of ClinDx groups, 4.03% of claims) and Diseases of the nervous system and sense organs nec ranked 17th (N = 12,197, 1.27% of ClinDx groups, 1.84% of claims). When combined, the six ClinDx groups for strain and sprain diagnoses by body region accounted for about 35% of distinct ClinDx groups. The only group with zero claims was Death, cause unknown.

3.3. ITS regression analysis results

3.3.1. Slope and level changes

At the transition, we observed both statistically significant ($P < 0.05$) slope and level changes (Fig. 1 A–D) for four ClinDx groups — 11.8% relative level increase for Other and unspecified effects of external cause nec (level change: 0.25, slope change: −0.172), 54.8% relative level increase for Poisoning and toxic effects, medical or non-medical (hereafter called Poisoning and toxic effects, level change: 0.164; slope change: −0.051), 44.3% relative level increase for Sprains-nec (level change: 0.482; slope change: 0.148), and 8.4% relative level increase for Superficial injury (level change: 0.344; slope change: 0.146). The solid trend line in the figures represents the de-seasonalized trend; visual evidence of seasonality is present for many ClinDx groups. Among the 57 ClinDx groups, we observed statistically significant pre- and post-transition slopes that changed directions (negative to positive) for a single group — Sprains-nec (Figs. 1-3, Supplementary data Fig. 1).

3.3.2. Level changes

Relative to the post-transition intercept, for the seventeen groups with level changes (Figs. 1–3), nine groups had < 20% (+/-) level changes, four groups had 20–49% level changes [Diseases of the digestive systems nec (Fig. 3B), −0.029; Diseases of the skin and subcutaneous tissue nec (Fig. 3C), 0.03; Sprains-LE (Fig. 2G), −2.221; and Sprains-nec (Fig. 1C)], and four groups had ≥ 50% level changes [Knee sprain or tear (Fig. 2E), 2.319; Infectious and parasitic diseases (Fig. 3D), 0.033; Neoplasms (Fig. 3E), 0.016; and Poisoning and toxic effects(Fig. 1B)]. Charts for the groups with statistically significant level changes without significant slope changes are presented in Fig. 2 for traumatic injuries and Fig. 3 for diseases. There was no overlap in confidence intervals pre- and post-transition for large level changes observed for two groups, Knee sprain or tear (2.319 level increase, Fig. 2E) and Sprains-LE (−2.221 level decrease, Fig. 2G).

3.3.3. Slope changes

For five ClinDx groups, we observed statistically significant slope changes of −0.133%–0.148% per year without a level change: Crushing injury; Diseases of the respiratory system nec; Pneumoconiosis, resp. cond. due to external agents; Spinal osteoarthritis; and Symptoms, signs, abnormal clinical or laboratory findings nec (Fig. 4 A-E). Quantitative results for slopes, 95% confidence intervals, and P-values are presented for pre- and post-transition time periods in Supplementary data Tables 2 and 3, respectively. Apart from Diseases of the respiratory system nec, statistically significant pre-transition slopes were observed, but the trend discontinued post-transition after the slope changed in the opposite direction at the transition (Fig. 4B, Supplementary data Tables 2 and 3). Among the nine groups with statistically significant slope changes at the transition (Figs. 1 and 4), only the Poisoning and toxic effects and Sprains-nec groups had statistically significant slopes during the post-transition stage (Supplementary data Table 3). A relatively steep trend was observed for Sprains-nec post-transition (Fig. 1C). Sprains-nec was the only ClinDx group where a statistically significant pre-transition trend changed from negative to positive post-transition (Supplementary data Tables 2 and 3).

Results for 33 ClinDx groups [57.89%; 53.85% injury groups (N = 14), 65.52% disease groups (N = 19)] with at least one claim and zero statistically significant slope or level changes are presented in Supplementary data Table 2 and Supplementary data Fig. 1.

3.4. ClinDx discontinuity evaluation

Based on a frequency analysis of the most common diagnoses by ClinDx group, it seems the case definitions for 13 of 17 ClinDx groups with statistically significant level changes (N = 4 large level changes) were correctly classified and lacked a clear explanation for the level change other than the change in coding systems. The thirteen groups were: Amputation, Carpal tunnel syndrome, Contusions with intact skin surface, Diseases of the digestive systems nec, Diseases of the skin and subcutaneous tissue nec, Dislocation, Fracture − lower extremity, Infectious and parasitic diseases, Other and unspecified effects of external cause nec, Soft tissue/enthesopathy, Sprains-back, Sprains − nec, and Superficial injury. For the other four ClinDx groups with statistically significant level changes, we identified three reasons for the level changes: (1) increased specificity for some lower extremity sprain and strain codes; (2) some external cause codes changed to diagnosis codes; or (3) enactment of a firefighter cancer presumption law. First, level changes for two groups, Knee sprain or tear and Sprains-LE, were caused by two ICD-9-CM codes for Sprains and strains of other specified (844.8) or unspecified (844.9) site(s) of "knee and leg." Although we assigned 844.8 and 844.9 to the Sprains-LE group, *a priori*, some portion of those relatively common diagnoses was miscategorized and should have been in the Knee sprain or tear ClinDx group. Therefore, pre-transition Knee sprain or tear group results were underestimated, and pre-transition Sprains-LE were overestimated. Second, because ICD-9-CM identified some poisonings using external cause codes, this may account for the relatively large increase in Poisoning and toxic effects levels (Annest, Hedegaard, Chen, Warner, & Small, 2014; Slavova et al., 2018). Lastly, the large increase in Neoplasms at the transition may be associated with an increase in neoplasm claims from firefighters due to the Ohio firefighter cancer presumption law that became effective in April 2017 (Ohio Legislature 135th General Assembly, 2017). It is unclear whether the timing of the new law explains the immediate level increase in October 2015; however, preliminary analyses (data not shown) suggest that the percentage of neoplasms attributable to firefighters increased substantially post-transition, at a time when mesothelioma claims were declining. October 2015 claims could have been filed well after the transition because the Ohio statute of limitations for filing a disease WC claim is two years.

Based on an examination of specific diagnoses codes in the Sprains-nec group, it appeared that an increased number of torso region strains and sprains may be contributing to the post-transition changes; these included thorax strain codes (S29.011A, S29.012A, S29.019A); thorax sprain codes (S23.8XXA, S23.9XXA); and an abdominal strain code

Table 3
Number of distinct ClinDx groups (N = 960,288) for claims with at least one diagnosis per ClinDx (ClinDx) Group stratified by transition period (pre-transition is 1/1/2011–9/30/2015, post-transition is 10/1/15–12/31/2018) with percentages among all distinct ClinDx groups.

ClinDx Group	Pre-transition (N = 601,229)		Post-transition (N = 358,093)		Total (N = 959,322)	
	N	%	N	%	N	%
All Traumatic Injury ClinDx groups	538,993	89.58	327,164	91.24	866,157	90.20
Disease ClinDx groups	62,709	10.42	31,422	8.76	94,131	9.80
Acute myocardial infarction/heart failure	49	0.01	22	0.01	71	0.01
Amputation†	1,887	0.31	1,178	0.33	3,065	0.32
Asbestosis	16	0	17	0	33	0
Burn†	10,957	1.82	6,601	1.84	17,558	1.83
Carpal tunnel syndrome	1,688	0.28	806	0.22	2,494	0.26
Cellulitis or abscess	4,422	0.73	2,304	0.64	6,726	0.70
Complications of surgical and medical care nec†	690	0.11	358	0.10	1,048	0.11
Congenital abnormalities nec and perinatal conditions	19	0	4	0	23	0
Congenital spondylolisthesis	3	0	0	0	3	0
Contact dermatitis and other eczema	2,800	0.47	1,381	0.39	4,181	0.44
Contusions with intact skin surface†	101,286	16.83	58,344	16.27	159,630	16.62
Crushing injury†	7,852	1.30	5,300	1.48	13,152	1.37
Death, cause unknown	0	0	0	0	0	0
Disc disorders and spinal stenosis	7,040	1.17	3,044	0.85	10,084	1.05
Diseases of musculoskeletal and connective tissue nec	5,576	0.93	2,858	0.80	8,434	0.88
Diseases of the blood and blood-forming organs	43	0.01	25	0.01	68	0.01
Diseases of the circulatory system nec	845	0.14	448	0.12	1,293	0.13
Diseases of the digestive systems nec	505	0.08	198	0.06	703	0.07
Diseases of the genitourinary system	217	0.04	82	0.02	299	0.03
Diseases of the nervous system and sense organs nec	8,030	1.33	4,167	1.16	12,197	1.27
Diseases of the respiratory system nec[d]	640	0.11	280	0.08	920	0.10
Diseases of the skin and subcutaneous tissue nec	760	0.13	543	0.15	1,303	0.14
Dislocation†	2,724	0.45	1,826	0.51	4,550	0.47
Endocrine, nutritional and metabolic diseases	204	0.03	111	0.03	315	0.03
Foreign body, eye†	9,727	1.62	4,369	1.22	14,096	1.47
Foreign body, not eye†	182	0.03	88	0.02	270	0.03
Fracture – head†	2,853	0.47	1,619	0.45	4,472	0.47
Fracture – lower extremity†	10,240	1.70	6,743	1.88	16,983	1.77
Fracture – nec†	565	0.09	406	0.11	971	0.10
Fracture – neck and trunk†	3,336	0.55	2,210	0.62	5,546	0.58
Fracture – upper extremity†	17,134	2.85	10,978	3.06	28,112	2.93
Hernia	2,390	0.40	1,287	0.36	3,677	0.38
Infectious and parasitic diseases	423	0.07	229	0.06	652	0.07
Injury to nerves and spinal cord†	1,204	0.20	694	0.19	1,898	0.20
Internal or blood vessel injuries nec†	1,034	0.17	690	0.19	1,724	0.18
Intracranial injury†	6,422	1.07	4,764	1.33	11,186	1.16
Joint disorders nec	2,139	0.36	1,391	0.39	3,530	0.37
Knee disorders	1,072	0.18	703	0.20	1,775	0.18
Knee sprain or tear†	7,343	1.22	12,521	3.49	19,864	2.07
Mental disorders from brain damage	864	0.14	588	0.16	1,452	0.15
Mental, behavioral and neurodevelopmental disorders nec	2,775	0.46	1,399	0.39	4,174	0.43
Neoplasms	74	0.01	120	0.03	194	0.02
Open wounds nec†	106,495	17.7	65,937	18.39	172,432	17.96
Other and unspecified effects of external cause nec†	9,480	1.58	8,168	2.28	17,648	1.84
Pneumoconiosis, resp. Cond. Due to external agents	537	0.09	289	0.08	826	0.09
Poisoning and toxic effects†	3,462	0.58	2,399	0.67	5,861	0.61
Pregnancy related conditions and adverse outcomes	15	0	5	0	20	0
Soft tissue/enthesopathy	18,116	3.01	8,540	2.38	26,656	2.78
Spinal osteoarthritis	631	0.10	253	0.07	884	0.09
Sprains-back†	61,205	10.17	33,915	9.46	95,120	9.91
Sprains-LE†	48,507	8.06	21,136	5.89	69,643	7.25
Sprains – nec†	6,699	1.11	5,932	1.65	12,631	1.32
Sprains – neck†	26,601	4.42	15,259	4.26	41,860	4.36
Sprains-UE†	60,250	10.01	36,814	10.27	97,064	10.11
Superficial injury†	30,858	5.13	18,915	5.27	49,773	5.18
Symptoms, signs, abnormal clinical or laboratory findings nec	816	0.14	328	0.09	1,144	0.12

Notes: Black lung cases are managed separately and excluded from this study population. Sprains = sprains & strains. Numerator is distinct ClinDx group (count one diagnosis per ClinDx per claim) by type and year; denominator is total number of distinct ClinDx group counts by type and year (claims counted multiple times).
† All diagnosis codes included in this group are from the traumatic injuries ICD-9-CM and ICD-10-CM chapters.

(S39.011A). We cannot determine whether torso region strains and sprains have increased post-transition because those diagnoses would have been coded as Other specified sites of sprains and strains (848.8); a more specific diagnosis code was unavailable. In terms of the Sprains-nec slope change, perhaps some ICD-10-CM diagnoses in Sprains-nec are being used to replace less specific ICD-9-CM diagnoses in Sprains-UE. If so, that could explain the change to a positive slope post-transition. However, we were unable to identify specific codes that would support that theory.

4. Discussion

4.1. Overview

Despite the major changes introduced by the transition, we successfully created a manageable set of 57 broad ClinDx groups optimized

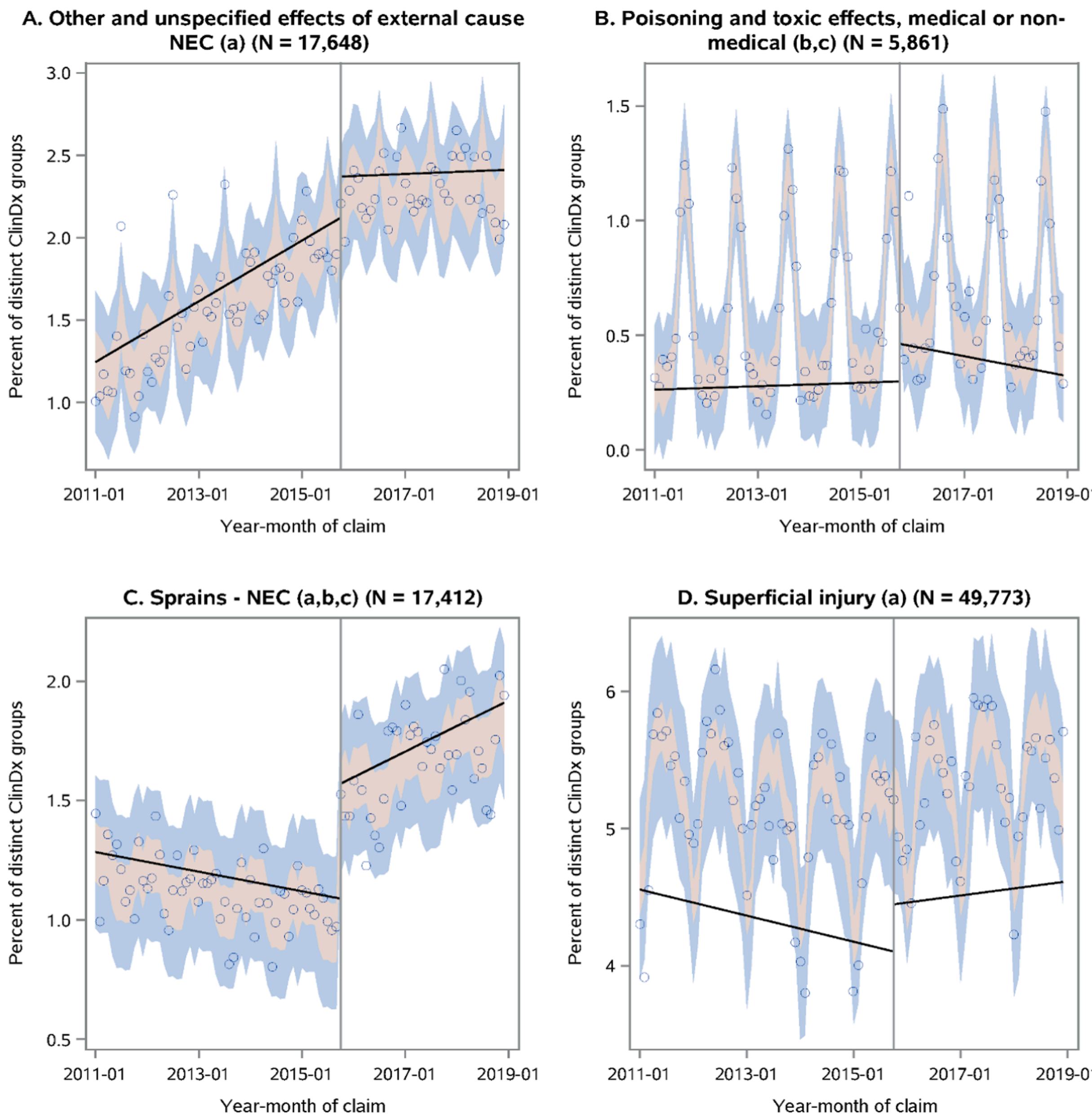

Fig. 1. Four clinical diagnosis groups with statistically significant ($P < 0.05$) level and slope changes. Circles are the observed values, the solid line is estimated deseasonalized trend, light shaded bands are the confidence intervals for the mean, and dark bands are the confidence intervals for the individual values. The seasonal effect is not included. The y-axis for the linear models is monthly percent among all distinct diagnosis groups. The relative change (%) at transition is equal to 100 times the ratio of the level change coefficient (β_1) to the difference between the post-transition intercept (β_2) and the level change coefficient, or $100*(\beta_1/\beta_2-\beta_1)$ for Fig. 1A–D were: A. 11.8%, B. 54.8%, C. 44.3%, D. 8.4%. [a] Pre-transition slope was statistically significant, [b] Post-transition slope was statistically significant, [c] Relative change at transition greater than 20% +/-. CI = confidence interval.

for occupational health surveillance using all ICD-9-CM and ICD-10-CM injury and disease diagnosis codes. While the number of diagnosis codes increased five-fold with the transition from ICD to 9-CM to ICD-10-CM, in this study the mean number of diagnoses and distinct ClinDx groups per claim remained consistent during each transition stage. Pre- and post-transition, the rankings of the top five distinct ClinDx groups included the same groups, with a slightly different order. In this large study, while diagnoses were predominantly injury codes, we counted at least one disease diagnosis for 11.77% of claims. These findings underscore the need for a single system to characterize both injury and disease outcomes when analyzing occupational health data. Specifically, among disease outcomes, diagnoses from the Soft-tissue/enthesopathy musculoskeletal diseases and Diseases of the nervous system and sense organs nec ClinDx groups were the most common; those two groups were unaffected by the transition in terms of slope changes, and the level change for Soft-tissue/enthesopathy was relatively small (−10.8%).

It is our hope that this crosswalk will benefit projects that use administrative billing data to track or analyze work-related injuries and diseases that bridge the transition. The revised crosswalk is improved and corrected some minor errors in the prior version (Meyers et al., 2018). The comprehensive list of ClinDx groups by ICD-9-CM and ICD-10-CM codes (and header rows) will be updated regularly; for the most current listing (one row per code), contact the NIOSH Center for Workers' Compensation Studies at cwcs@cdc.gov.

4.2. ClinDx groups

To the best of our knowledge, these 57 ClinDx groups represent the

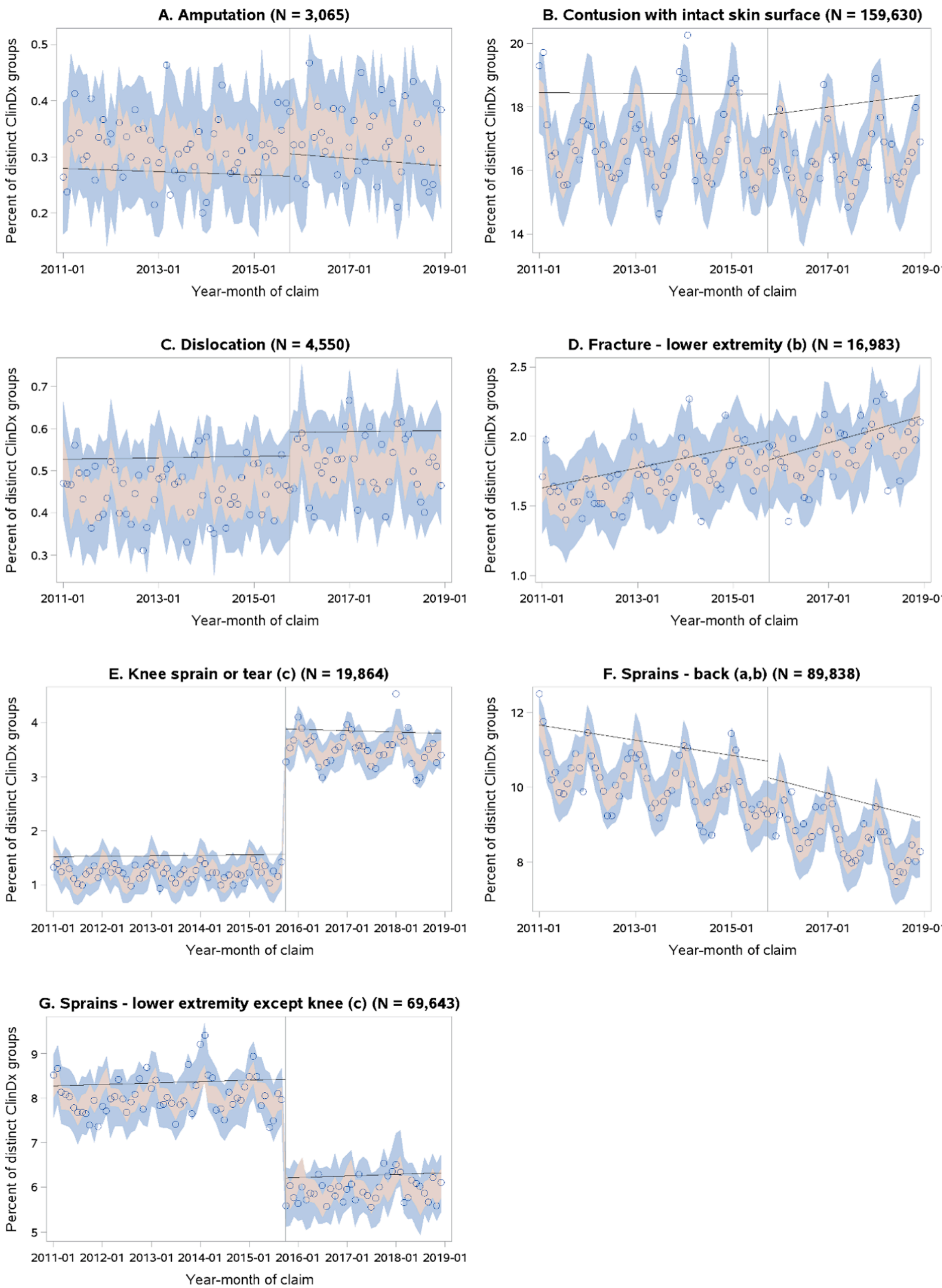

Fig. 2. Seven traumatic injury clinical diagnosis groups had statistically significant ($P < 0.05$) level changes and non-statistically significant slope changes. Circles are the observed values, the solid line is the estimated deseasonalized trend, light shaded bands are the confidence intervals for the mean, and dark bands are the confidence intervals for the individual values. The seasonal effect is not included. The y-axis for the linear models is monthly percent among all distinct diagnosis groups. The relative change (%) at transition is equal to 100 times the ratio of the level change coefficient (β_1) to the difference between the post-transition intercept (β_2) and the level change coefficient, or $100^*(\beta_1/\ \beta_{2-}\ \beta_1)$] for Fig. 2A–F were: A. 15.1%, B. −3.5%, C. 10.5%, D. −7.2%, E. 148.4%, F. −4.4%, G. −26.4%. [a] Pre-transition slope was statistically significant, [b] Post-transition slope was statistically significant, [c] Relative change at transition greater than 20% +/-. LE = lower extremity. CI = confidence interval.

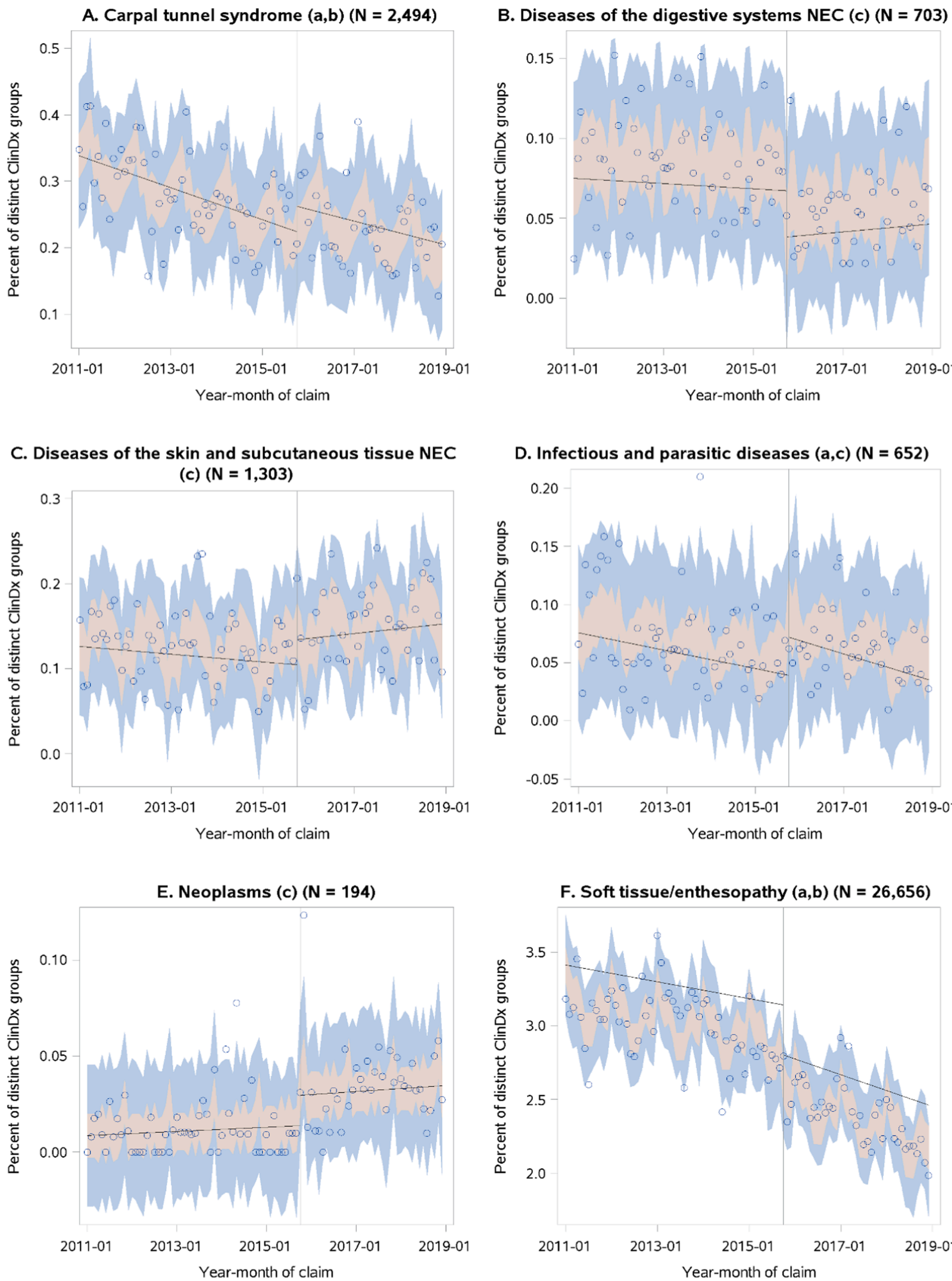

Fig. 3. Six disease clinical diagnosis groups had statistically significant ($P < 0.05$) level changes and non-statistically significant slope changes. Circles are the observed values, the solid line is the estimated deseasonalized trend, light shaded bands are the confidence intervals for the mean, and dark bands are the confidence intervals for the individual values. The seasonal effect is not included. The y-axis for the linear models is monthly percent among all distinct diagnosis groups. The relative change (%) at transition is equal to 100 times the ratio of the level change coefficient (β_1) to the difference between the post-transition intercept (β_2) and the level change coefficient, or 100*(β_1/ β_2- β_1)] for Figure 3A–F were: A. 17.0%, B. -43.3%, C. 28.8, D. 84.6%, E. 114.3%, F. -10.8%. [a] Pre-transition slope was statistically significant, [b] Post-transition slope was statistically significant, [c] Relative change at transition greater than 20% +/-. LE = lower extremity. CI=confidence interval

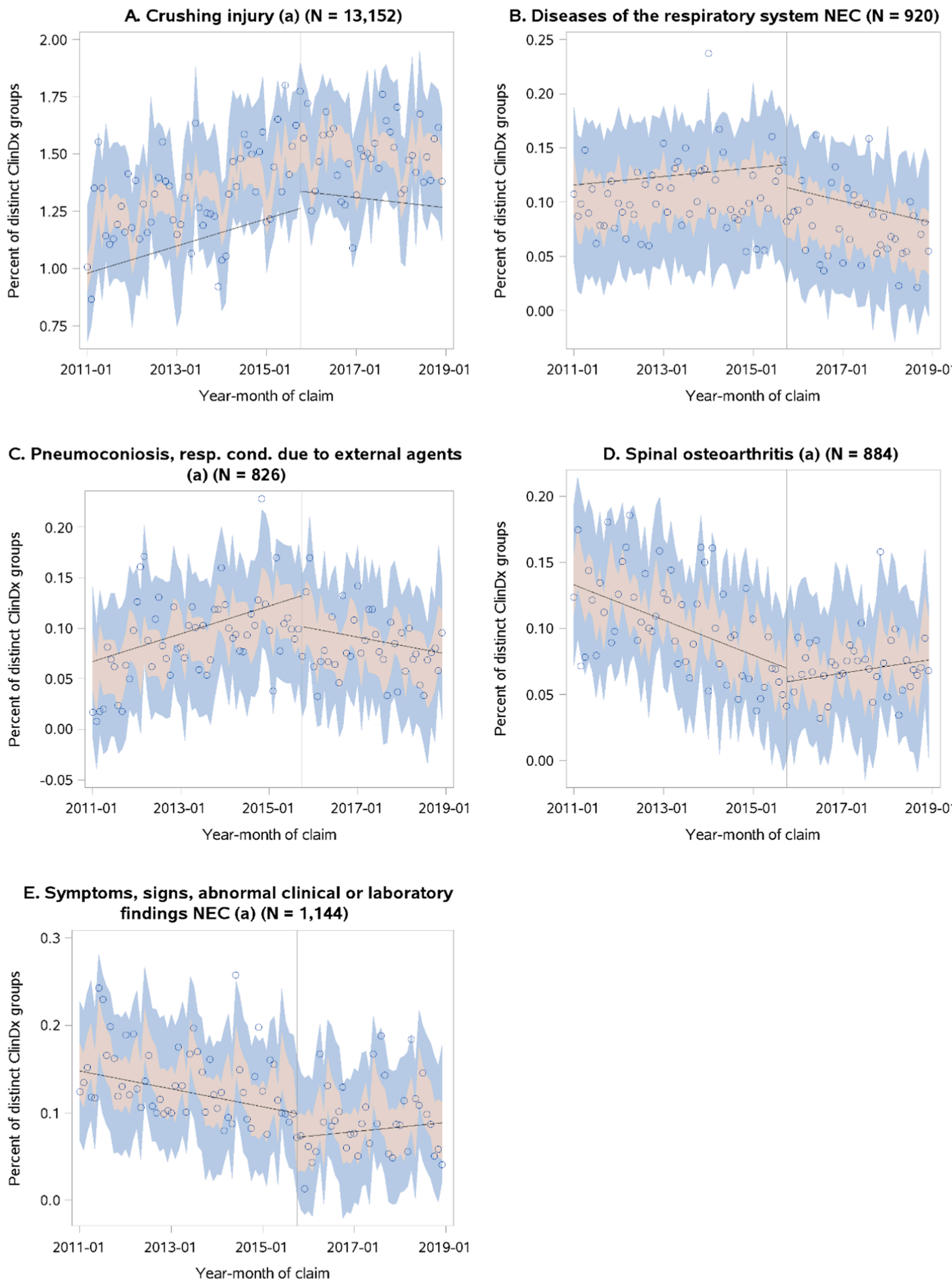

Fig. 4. Five groups had statistically significant ($p < 0.05$) slope changes without statistically significant level changes. Circles are the observed values, the solid line is the estimated deseasonalized trend, light shaded bands are the confidence intervals for the mean, and dark bands are the confidence intervals for the individual values. The seasonal effect is not included. The y-axis for the linear models is monthly percent among all distinct diagnosis groups. [a] Pre-transition slope was statistically significant, [b] Post-transition slope was statistically significant. CI=confidence interval

only classification system with both disease and injury diagnoses using ICD-9-CM and ICD-10-CM codes. This feature is important because large administrative data sets such as the OHBWC claims data include records for both versions during an injured worker's medical journey. Studies with small study populations would be underpowered if they needed to exclude pre-transition diagnosis data due to the transition. To maximize the utility of administrative data sets like these OHBWC data, it is vital to take advantage of all available data, especially when analyzing high-risk occupations and industries with relatively small numbers of policies, employees, and claims.

In the literature, three strategies recommended for overcoming inconsistencies introduced by the transition to a new ICD revision include: (1) using broad groups of diagnosis codes for the same medical concept (such as ICD chapters); (2) using concordance tables based on high-level ICD categories (such as three-digit codes, four-digit codes); or (3) analyzing specific diagnoses where consistency in coding is expected across the transition (Alter & Carmichael, 1996; Janssen & Kunst, 2004; Pickett, 2014). All three strategies were used to create our 57 ClinDx groups.

For the 26 traumatic injury ICD-10-CM chapter ClinDx groups, our code assignments were consistent with the ICD-10-CM injury diagnosis matrix (Hedegaard, Johnson, Garnett, & Thomas, 2020). The few minor differences we identified were for rarely used codes and would not have affected our results.

The six ClinDx groups used to classify strains and sprains accounted for 35% of distinct ClinDx groups. In some cases, it may be beneficial for investigators to create additional body-region-specific ClinDx groups for strains and sprains or use the ICD-10-CM injury diagnosis matrix body regions (Hedegaard et al., 2020). The Sprains-nec group mostly includes strains and sprains from the torso (chest, abdomen, pelvis) and the head (such as jaw sprains).

4.3. Effect of the ICD-10-CM transition on level or slope changes

In this large population of WC claims from Ohio, the effect of the transition varied by ClinDx group. We observed statistically significant level or slope changes for 22 ClinDx groups. Specific reasons for the discontinuities were unclear, with four exceptions, as noted in section 3.4. Other studies have also found discontinuity in Poisonings and toxic effects, which they attributed to reclassifying some poisonings from external cause codes to diagnosis codes (Annest et al., 2014; Slavova et al., 2018). For this study, when interpretating the effect of the transition on the slope changes by ClinDx group we were unable to find alternative reasons in society that would have impacted WC claim slopes or workplace hazards immediately after the transition. Administrative medical coding changes can affect records associated with WC claims but has zero effect on work-related injuries/disease occurrence or WC claim filing patterns. Other investigators have noted situations where there was an adjustment period early in the ICD-10-CM era where health systems adjusted to the new coding rules and new, more specific ICD-10-CM codes that were not represented in ICD-9-CM (Ellis et al., 2020; Salemi, Tanner, Kirby, & Cragan, 2019; Slavova et al., 2018). This could account for some relatively small changes observed at the transition where the levels in 2018 were similar to the levels just prior to the transition. However, typically if you extended the pre-transition trend lines to December 2018, the lines would not intersect with the post-transition trend. ICD-9-CM traumatic injury codes changed more dramatically than any other ICD chapter, with a 15-fold increase in the number of codes and over half with convoluted mappings (where "multiple ICD-9-CM and ICD-10-CM codes share complex, entangled, and non-reciprocal meanings") or no mappings (Boyd et al., 2013). This may have contributed to some of the discontinuities caused by the transition, where specific reasons were unclear.

Existing research on the effect of transitioning between ICD versions is not directly comparable to this study using WC data. Other studies have analyzed data from the military or general healthcare settings by encounter (De Crescenzo, Gabella, & Johnson, 2021; Duchesneau, et al., 2023; Ellis et al., 2020; Gibson, Casto, Young, Karnell, & Coenen, 2016; Hirai, Owens, Reid, Vladutiu, & Main, 2022; Hsu et al., 2021; Inscore, Gonzales, Rennix, & Jones, 2018; Mayhew et al., 2019; Salemi et al., 2019; Sanusi et al., 2022; Schuh-Renner, Inscore, Hauschild, Jones, & Canham-Chervak, 2021; Sebastião, Metzger, Chisolm, Xiang, & Cooper, 2021), rather than our study population of non-military, work-related outcomes where claims-level data have had about two years to mature. Among other studies, some investigators have also conducted segmented regression analyses to evaluate level and slope changes for specific diagnoses or groups of diagnoses (De Crescenzo et al., 2021; Duchesneau et al., 2023; Ellis et al., 2020; Hirai et al., 2022; Hsu et al., 2021; Sebastião et al., 2021). Among these, our study design most closely resembled the comprehensive analyses of monthly rates in the IBM MarketScan Commercial Database (N = 3.4 billion diagnoses) using three different comprehensive classification systems; one system they evaluated was the World Health Organization (WHO) disease chapters, which align with eight of our ClinDx groups (Ellis et al., 2020). Their analysis of WHO disease chapters found zero statistically significant level or slope changes greater than 20%. In contrast, among the eight ClinDx groups equivalent to WHO chapters, three relatively small groups had large level or slope changes at the transition (large level changes: Infectious and parasitic diseases, Neoplasms; large slope changes: Symptoms, signs, abnormal clinical or laboratory findings nec). However, that study used a conservative Bonferroni correction, which required $P < 0.0027$ to be considered statistically significant. We could not compare our results to uncorrected significance levels because those data are unavailable. Also, the claims data for this study were dated by injury date and thus included some ICD-10-CM codes in the pre-transition stage; whereas, Ellis and colleagues (2020) analyzed data by encounter date.

4.4. Practical Applications — Adjust, Combine, exclude (ACE) approach

When working with diagnosis data that bridge the October 2015 transition, we propose three main strategies for overcoming the effect of the transition — adjust, combine, or exclude (ACE) (Gibson et al., 2016; Janssen & Kunst, 2004); that is, either adjust pre-transition distributions, combine ClinDx groups, or exclude some ClinDx groups or all pre-transition data. Even if investigators decided to analyze pre- and post-transition data separately, using the most current version of the ClinDx crosswalk is recommended because it aligns with ICD-10-CM.

For the three ClinDx groups where clear, major changes in ICD coding explained statistically significant level and slope changes, all three strategies could be used to overcome the problem. For example, to correct overestimates for Sprains-LE and underestimates of Knee sprains and tears group, one could exclude pre-transition data for the two interrelated groups. Alternatively, combining the Sprains-LE with the Knee sprains and tears could work when including both pre-transition data is preferred. However, the Knee sprains and tears group was common, and keeping the groups separate could identify more specific contributing factors. Another option would be to use a comparability analysis to adjust pre-transition levels for both ClinDx groups (Pickett, 2014). For example, rather than assigning all 844.9 claims to the Sprains LE ClinDx group, those claims could be redistributed to the Sprains LE and Knee sprains and tears ClinDx groups based on the distribution of all ICD-10-CM diagnoses for unspecified knee sprains and unspecified lower leg sprains. Depending on the project goals and size of the study population, pre-transition Poisoning and toxic effects level underestimates could be adjusted or excluded when studying this ClinDx group across the transition period.

More work is needed to explore how to use ITS coefficients to adjust pre-transition percentages to estimate an 'expected' number of distinct ClinDx groups that would have been coded to a particular group post-transition. A similar approach was used in the UK after the transition to ICD-10 mortality codes (Brock, Griffiths, & Rooney, 2006; Griffiths, Brock, & Rooney, 2004). The UK Office of National Statistics analyzed changes to respiratory or circulatory disease mortality code assignments in ICD-10 to estimate how the transition affected disease deaths rates in England and Wales. Those reports presented unadjusted and adjusted trends after adjusting some ICD-9 mortality estimates using comparability ratios calculated by age and sex. However, comparability ratios (also called comparability factors) typically use dually coded data to calculate the ratios (Gibson, et al., 2016). For example, for future work using these OHBWC claims data, quantitative results from ITS models could be used to adjust pre-transition distributions or slopes. Depending on a project's purpose, it may be appropriate to combine uncommon groups from the same ICD chapter (such as combining all congenital diseases, combining all circulatory system diseases) or to create residual categories for all "uncommon" injury or disease ClinDx groups below a specified percentage threshold. However, due to the highly skewed nature of WC claim costs (Chadarevian & Myers, 2023), we caution against selecting arbitrary frequency thresholds before considering the influence of high-claim cost outliers. While we have suggested using ACE strategies, in some situations (such as projects that avoid time series analyses) investigators may disregard the effect of the transition on their results and acknowledge the resulting misclassification as a limitation.

5. Limitations

There are some limitations to our analyses. First, the data presented here were assigned to the month the incident occurred (called injury date) rather than the month when the injury or illness was diagnosed or treated. OHBWC abstracts WC data from each calendar year annually on July 1st, two years after the calendar year ended (e.g., on July 1, 2020, the 2018 data were abstracted). The administrative data used for this study represent all compensable diagnoses for each claim as of the abstraction date. Some claims that occurred before the transition included ICD-10-CM codes that were added to the record after the transition (such as carpal tunnel syndrome); for those claims, ClinDx groups assigned using an ICD-10-CM code would have been counted in the pre-transition stage. Secondly, we were unable to examine medical records to evaluate the validity of the diagnoses. Lastly, our results may not be representative of WC data from other states, of WC claims from self-insured employers, or for administrative health data from a broader population that includes non-occupational diagnoses for people without paid employment (such as retired people, unemployed people, or young children).

5.1. Strengths

The main strength of this study was the large number of claims, diagnoses, and ClinDx groups included in the analysis. This study included almost five years of pre-transition data and three years of post-transition data and included all compensable diagnoses for approximately two-thirds of workers in Ohio during the eight years. Also, using an exhaustive and mutually exclusive set of 57 ClinDx groups was a strength because a change for one group was likely offset by an equal and opposite change in another group. For example, similar level change values in opposite directions for Sprains-nec and Sprains-back, 0.482 and −0.442%, may be related. In contrast, most other studies have focused on evaluating the effect of the transition on a subset of specific ICD-CM codes or diagnosis types, such as birth defects (Salemi et al., 2019), common conditions (Hsu et al., 2021), common pain conditions (Mayhew et al., 2019), traumatic brain injury (De Crescenzo et al., 2021), or external-cause-of-injury (Slavova et al., 2018).

6. Conclusion

Work-related diseases and injuries are common and result in pain, disability, and substantial cost to workers, employers, and society (Leigh, 2011; Marucci-Wellman et al., 2015; Murphy, Patel, Boden, & Wolf, 2021). Occupational health surveillance programs aim to estimate the burden of common or severe work-related diseases or injuries, target prevention programs, and inform prevention strategies and policy solutions (CSTE, 2024). The 57 ClinDx groups created in this study may be a practical starting point for other occupational epidemiologic analyses that include a mixture of ICD-9-CM and ICD-10-CM data. While the transition is a break in series, about two-thirds of the disease groups and half of the injury groups were relatively stable across the transition in this analysis of a large WC claims population. While diagnoses were predominantly injury codes, we counted at least one disease diagnosis among 11.77% of all claims, underscoring the need for characterizing both injury and disease outcomes when analyzing WC data. The ACE strategies offer researchers and public health professionals three customizable options for overcoming the effect of the transition in future studies.

CRediT authorship contribution statement

Alysha R. Meyers: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tara N. Schrader:** Writing – review & editing, Visualization, Validation, Software, Resources, Methodology, Investigation, Data curation, Conceptualization. **Edward Krieg:** Writing – review & editing, Visualization, Validation, Methodology, Data curation, Conceptualization. **Steven J. Naber:** Writing – review & editing, Validation, Software, Resources, Formal analysis, Data curation, Conceptualization. **Chih-Yu Tseng:** Validation, Software, Resources, Investigation, Data curation. **Michael P. Lampl:** Resources, Methodology, Funding acquisition, Data curation, Conceptualization. **Brian Chin:** Writing – review & editing. **Steven J. Wurzelbacher:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Disclaimer

The findings and conclusions of this report are those of the authors and do not necessarily represent the view of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, or the Ohio Bureau of Workers' Compensation. Mention of a specific product or company does not constitute an endorsement by the Centers for Disease Control and Prevention or Ohio Bureau of Workers' Compensation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsr.2024.12.007.

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