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The direct cost burden of 13 years of disabling workplace injuries in the U.S. (1998–2010): Findings from the Liberty Mutual Workplace Safety Index

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ABSTRACT

Introduction: Although occupational injuries are among the leading causes of death and disability around the world, the burden due to occupational injuries has historically been under-recognized, obscuring the need to address a major public health problem. *Methods*: We established the Liberty Mutual Workplace Safety Index (LMWSI) to provide a reliable annual metric of the leading causes of the most serious workplace injuries in the United States based on direct workers compensation (WC) costs. *Results*: More than $600 billion in direct WC costs were spent on the most disabling compensable non-fatal injuries and illnesses in the United States from 1998 to 2010. The burden in 2010 remained similar to the burden in 1998 in real terms. The categories of *overexertion* ($13.6B, 2010) and *fall on same level* ($8.6B, 2010) were consistently ranked 1st and 2nd. *Practical application*: The LMWSI was created to establish the relative burdens of events leading to work-related injury so they could be better recognized and prioritized. Such a ranking might be used to develop research goals and interventions to reduce the burden of workplace injury in the United States.
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1. Introduction

Injuries are the leading cause of death in the United States for people aged 15 to 44 (CDC, 2013) and a leading cause of worldwide death and disability (Lim et al., 2012; Lopez, 2005; World Health Organization, 2008). Injuries on the job are a substantial and important part of the total U.S. injury burden (Smith, Sorock, Wellman, Courtney, & Pransky, 2006). The direct and indirect costs of *work-related* injuries and illnesses in the United States in 2007 was approximately $250 billion, a cost equivalent to cancer (Leigh, 2011). Leigh's estimated costs included medical, along with other direct and indirect costs (e.g., future lost earnings, fringe benefits, and the cost associated with lost ability to contribute to household activities such as chores, child care, and home maintenance, as well as employer costs such as those for turnover, hiring, and re-training).

Approximately 58.5 million nonfatal workplace injuries (and illnesses)[1] occurred in the United States between 1998 and 2010 (BLS, 2014d); approximately 9 million of these (15%) caused workers to lose more than five days away from work (DAW; BLS, 2014c). DAW injuries make up the greatest proportion of direct insured costs. Some injured workers may fully recover, others are partially disabled and return to restricted work, and others are permanently disabled and never return to work.

We established the Liberty Mutual Workplace Safety Index (LMWSI) in 2000 to provide an annual metric based on direct, insured costs for the most severe non-fatal workplace injuries in the United States. We assumed that the sum of medical costs and lost wages is a reasonable surrogate measure of severity — and perhaps the best currently available metric on a population-wide basis. The Index also ranks the relative burdens of events leading to work-related injury. This ranking might help identify interventions to reduce the burden of workplace injuries in the United States. Our methods were developed in 2000 for injuries in 1998 and applied consistently up through data year 2010. Three data sources were used: The U.S. Bureau of Labor Statistics (BLS) annual

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[1] Greater than 90% of the injury and illness cases reported to the BLS are injuries (Wiatrowski, 2014).

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survey of occupational injury and illness (SOII) data, Liberty Mutual Insurance (LM) workers compensation (WC) claims data, and the National Academy of Social Insurance (NASI) annual estimate of all benefits paid data. Beginning with data year 2011 (Index year 2013), the BLS Occupational Injury and Illness Classification System (OIICS) introduced a redesigned event coding structure and declared a break in series, which is reflected in the subsequent LMWSI.

Our objective in this paper is to summarize the LMWSI findings for its first 13 years, prior to this break in series. We rank the relative costs of injury events and describe trends over time.

2. Methods

The LMWSI presents the insured, direct costs of the most disabling non-fatal injuries in the United States by injury event (e.g., fall, highway incident). Annual estimates were developed from three data sources. For injuries and illnesses resulting in more than 5 DAW, average estimated lifetime costs of workers' compensation claims (LM) were multiplied by the national estimated counts (BLS) for each two-digit BLS OIICS event category in the BLS SOII data. The top 10 disabling event categories were then determined (see full definitions in Appendix A). Finally, to compensate for potential undercounting in the other components of the Index (American Journal of Industrial Medicine Special Issue, 2014; Boden & Ozonoff, 2008; Leigh, Marcin, & Miller, 2004; Rosenman et al., 2006; Spieler & Wagner, 2014) the National Academy of Social Insurance (NASI) estimate of total U.S. benefits paid was used to adjust the projected national burden estimates in each category (Fig. 1).

2.1. LMWSI ultimate mean costs

All claims incidents occurring in a particular year were obtained from LM WC insurance data. Fatalities were removed since cost metrics will vary substantially (e.g., amount of direct vs. indirect costs) between fatal and non-fatal events; other literature also separates fatal from non-fatal events (Lim et al., 2012). Claims without indemnity payments (wage replacement) were also removed to permit better matching to BLS frequency data for lost-time cases. Accordingly, only those non-fatal cases with at least one indemnity payment ('indemnity') were included. Nationally, the mean and median of state waiting periods for wage replacement was found to be approximately 5 days. This value aligns well with BLS reported aggregations of greater than 5 DAW lost-time cases. Therefore, indemnity cases (including aggregated indemnity, medical and expense costs) were matched against BLS frequencies for cases losing more than 5 DAW.

Administratively assigned cause and nature-of-injury codes and narrative text information on the injury circumstances were used to classify claims into 2-digit level BLS event codes according to the BLS OIICS Scheme (versions 1.01) (BLS, 2007). A combination of methods was used to code cases including: (a) crosswalks from LM's assigned "cause coding" (see Appendix A for examples), (b) computer searching the accident narrative text for keywords (McKenzie, Scott, Campbell, & McClure, 2010), and (c) manual review and assignment by a coding panel trained for this purpose.

Claims data were extracted in July of the Index year allowing for a minimum of 18 months of development after the injury occurred and the claim was filed. For claims that were closed, the *ultimate* cost of the claim included the costs paid to date. For claims still open, the *ultimate* cost of the claim was projected based on development factors for each event category using actuarial development methods.

2.2. Bureau of Labor Statistics frequencies

The BLS Survey of Occupational Injuries and Illnesses (SOII) (BLS, 2014b) provides national annual estimates of occupational injuries and illnesses in the United States based on a sample of injury and illness logs from private-sector employers as required under OSHA recordkeeping guidelines (OSHA logs). Self-employed workers, farms with fewer than 11 workers, and employees of federal, state, and local government agencies and certain other sectors are excluded from the survey (n.b. while the BLS introduced specific estimates of state and local government employees in 2008; we maintained the original protocol and utilized only the private industry data). We used case frequencies reported in SOII BLS R70 tables (BLS, 2000, 2012). Frequencies were aggregated to include numbers of cases which had 6–10, 11–20, 21–30, and 31 + days away from work (i.e. >5 DAW cases).

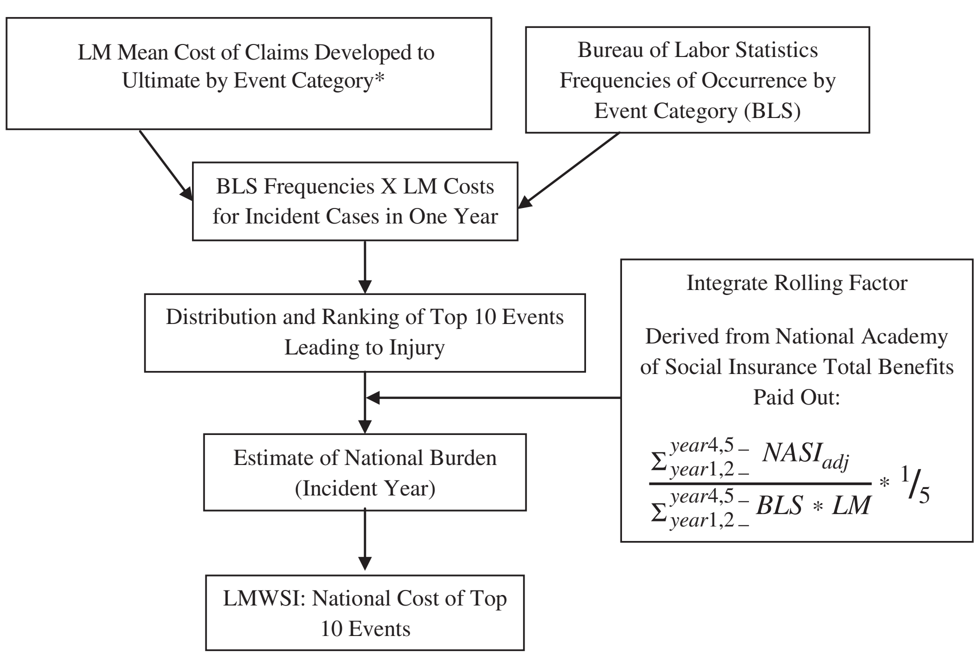

Fig. 1. Liberty Mutual Workplace Safety Index Methodology. $NASI_{adj}$ = NASI overall benefits paid multiplied by % of costs for indemnity only claims then discounted to 1998 dollars using Consumer Price Indices (CPI) current and 1998. * Mean costs were also discounted to 1998 dollars, to permit assessment of growth/decline beyond inflation/deflation of the US dollar. See explanation of terms for more complete description of developing and discounting methods.

2.3. National Academy of Social Insurance (NASI) estimate of total WC costs

We adjusted the total national count results for potential undercount using the annual NASI cost estimate which includes all WC medical and indemnity annual *benefits* (Mont, Burton, & Reno, 2000; Sengupta, Reno, Burton, & Baldwin, 2012), based on input from state agencies. The NASI estimate includes benefits paid to workers excluded from the BLS survey. Specifically we applied a rolling factor that was the five-year average of the ratio between the NASI estimate of benefits paid out for all DAW claims and the BLS × LM-derived national estimate. The NASI estimate is a calendar year estimate while the BLS × LM-derived estimate is an incident year estimate. Equilibrium or a steady state should cause these two estimates to converge (Burton, 2005; Leigh & Du, 2012; Sengupta, Reno, & Burton, 2005).

3. Data analyses

We calculate the nominal (current year dollars) and real (in terms of 1998 dollars) costs for *the top 10 injury categories* for 1998 and 2010 using the LMWSI. Real costs were determined by discounting subsequent years to 1998 dollars. This permitted the assessment of growth or decline beyond inflation/deflation of the U.S. dollar. Indemnity and expense payments were discounted using the Consumer Price Index (BLS, 2014a). Medical payments were discounted using the Medical Services Price Index (BLS, 2014a).

We used sensitivity analyses (allowing one metric to vary while holding the other constant) to understand real growth and decline in the component metrics: the BLS frequency and the LM WC mean cost. Each year's real values were normalized to the 1998 value (indexed at 100).

Aggregated BLS frequencies for the >5 DAW cases incident in 1998 and 2010 were tabulated along with LM mean cost of each category normalized to the overall average cost for all claims. Our intent was to make explicit the relative severity, and growth or decline in severity of 13 years of reported claims. In order to assess external validity, we compared nominal growth in the LMWSI overall mean cost values with: (a) the National Council of Compensation Insurance (NCCI) mean costs for indemnity only cases (Mealy, 2013) using a similar sensitivity analyses as described above and (b) the BLS SOII median DAW metric for the >5 DAW cases. NCCI used a sample of WC claims from all insurance carriers for 38 states to determine their estimates.

We used linear regression analyses to determine significant trends over the 13-year period in the overall Index and by event categories. We also included a dummy variable for data source (LM vs. NCCI) to test the significance of the interaction term (total $\text{cost}_y * \text{data source}$) to determine if LM cost growth was substantially different from NCCI cost growth over time, validating that cost growths/declines were not due to LM market share. All of our analyses were performed in SAS® 9.3 (SAS Institute, Cary, NC).

3.1. Standard error estimate component measures

We provide standard error estimates of the 1998 and 2010 components (LM mean cost and BLS frequency) to determine the precision of each measure. We aggregated counts across DAW categories for each event category resulting in adjusted BLS standard error estimates and median days away from work calculations. Standard errors for the aggregated counts were estimated by the BLS using a modified Taylor series expansion. For BLS median DAW by event category, we interpolated the median value (50th percentile point) from the BLS R70 table. This table aggregates counts of cases into 6–10, 11–20, 21–30, and 30+ DAW categories overall for each event category (BLS, 2000, 2012). We also requested a special run table from the BLS so we could replicate this procedure with the counts presented by age within 2-digit BLS event category (BLS personal communication, 2014).

The LMWSI combines data from three different data sources that rely on different sampling mechanisms and estimating procedures. Each of these estimates was based on a large sample; hence, they are expected to have good precision. We expect issues of external validity (due to reporting/sampling biases) of each of the data sources to far outweigh concerns related to precision. (Note: Please see Appendix A for: (a) definitions of the top ten 2-digit BLS event categories, (b) a list of acronyms, (c) an explanation of terms, and (d) examples demonstrating LMWSI methods for coding LM claims narratives to BLS 2-digit event codes.)

4. Results

4.1. Overall direct cost burden

Aggregating incident year costs over the 13-year period, we estimated that a total of $625 billion in direct WC costs were spent for the most disabling *work-related* injuries between 1998 and 2010. In 1998, the U.S. estimated direct WC insured costs of the most disabling work-related injuries was $37.1 billion (Liberty Mutual Research Institute for Safety, 2011). There was substantial growth in the index through 2002, when the burden peaked at $51.7 billion ($45.6 in 1998 dollars), followed by a steady decline through 2006. In 2010, the nominal burden was 38% higher at $51.1 billion (Liberty Mutual Research Institute for Safety, 2012) than in 1998 and slightly lower in real terms (−5%, $35.4 billion in 1998 dollars).

4.2. Component metrics

From sensitivity analyses (Fig. 2), we are able to see the trends in the two separate data sources. The upper curve (+46%, diamond markers) illustrates the percent increase from 1998 in *real* WC cost if the frequency was held constant (at the 1998 value) for all 13 years. Alternatively, if real cost were held constant (at the 1998 value), the percent decline in the frequency of cases from 1998 values is shown in the bottom curve (−38%, square markers). The two opposing trends (increase in costs mirrored by decrease in frequency) resulted in little change in the overall *real* LMWSI burden; as stated earlier, 2010's *real* burden was almost unchanged from that of 1998, reflecting a drop of only 5% in real value (Table 1). Based on the regression analysis, increases in WC costs in the first few years (until 2002) increased the LMWSI values (+23%, $p < .05$). This was followed by steep declines in BLS frequency between 2002 and 2006 and a relatively stable real cost that trended the LMWSI

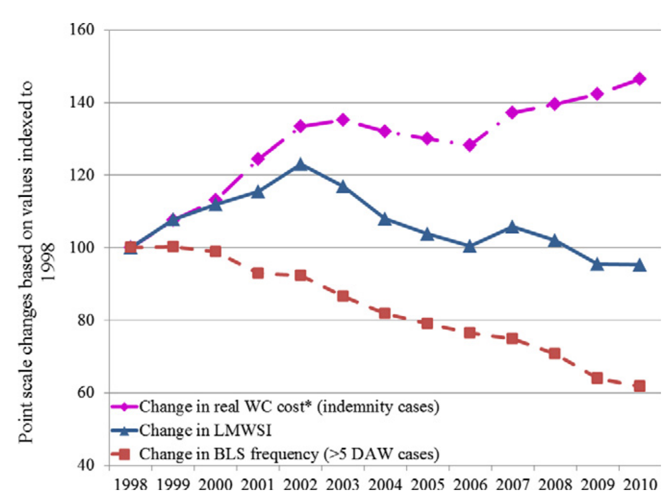

Fig. 2. Sensitivity analyses: point percent increases/declines in each year's values normalized to 1998 values (indexed at 100) (LMWSI real cost, BLS frequency for >5 DAW cases) when cost or frequency was held constant. *LM mean costs were developed to ultimate and inflation adjusted to 1998 dollars — nominal cost growths/declines match NCCI trend, 1998–2010.

Table 1
Growth/decline in LMWSI overall and for each top 10 event category 1998–2010.

Event description	Estimated national compensation cost 1998	Estimated national compensation cost 2010 (in 2010 dollars)	Estimated national compensation real cost 2010 (in 1998 dollars)	Nominal growth 1998–2010 %	Real growth 1998–2010 %
Total	$37,085,627,563	$51,093,318,336	$35,355,657,128	37.8	−4.7
Overexertion	$10,044,925,915	$13,605,697,769	$9,469,258,776	35.4	−5.7
Fall on same level	$4,192,212,522	$8,605,245,252	$5,964,693,145	105.3	42.3
Bodily reaction	$3,419,581,492	$5,782,655,938	$4,022,023,837	69.1	17.6
Fall to lower level	$3,405,415,496	$5,115,680,517	$3,532,740,341	50.2	3.7
Struck by object	$3,084,778,278	$4,096,064,914	$2,823,757,601	32.8	−8.5
Struck against object	$1,643,860,232	$2,106,936,243	$1,455,419,990	28.2	−11.5
Repetitive motion	$2,326,142,677	$2,015,772,342	$1,402,019,815	−13.3	−39.7
Highway incident	$1,896,158,374	$1,988,379,246	$1,366,720,944	4.9	−27.9
Caught in or compressed by	$1,451,028,635	$1,794,917,752	$1,230,010,897	23.7	−15.2
Assaults & violent acts by persons	$403,901,812	$638,681,436	$444,552,620	58.1	10.1
All other	$5,217,622,130	$5,343,286,928	$3,644,459,163		

values down to their 1998 level in real terms. Following 2006, BLS frequency declines were balanced by cost increases.

LMWSI mean costs corresponded closely with NCCI values, and the mean cost growth for the entire series (+46% 1998–2010, Table 2) closely mirrored NCCI mean cost growth after adjusting for inflation (growth/decline similar, $p > .05$ for interaction term, Fig. 3 (Mealy, 2013)). Coincidentally, during this time period there was also growth in the median days away from work for >5 DAW cases reported by the BLS (which increased steadily from 22 to 30 days from 1998 to 2010, Table 2) suggesting that the severity of BLS reported workplace injuries and illness cases were similar to the increase in the LMWSI costs over time.

4.3. Allocation of burden

The top 10 most disabling events over the 13-year period produced 86% of the overall burden in 1998 and 90% of the burden in 2010. The real and nominal costs and rankings of the top 10 events for 1998 and 2010 are presented in Table 1. During this time, *overexertion* and *fall on same level* were consistently first and second ranks. Between 1998 and 2010 the burden of the *overexertion* category dropped 5% in real terms; however, in 2010 it remained by far the leading category at $9.5 billion (1998$, $13.6 billion in 2010$). Overall, the same events comprised the top 5 each year despite some changes in rank within the top 5. The real dollar burden of *fall on same level* increased substantially ($1.8 billion real dollars): 42% after adjusting for inflation, with a doubling in nominal value. Additionally, *bodily reaction* generated a real value increase of $0.6 billion.

Four categories had higher real costs in 2010 compared with 1998 (*fall on same level*, *bodily reaction*, *fall to lower level*, and *assaults and violent acts by persons*). Rankings also changed in the lower 5 ranks (6–10) where *repetitive motion* and *highway incident* declined to 7th and 8th ranks, respectively, and *struck against* moved up into 5th rank (from 6th). The real dollar burden of the *repetitive motion* category declined the most of any category (40%), resulting in a real dollar value decline of almost $1 billion.

The growth or decline over time for the top 10 events is shown in Fig. 4. The trending of the overall Index appears influenced by the *overexertion* category given its scale. Two categories, *fall on same level* and *repetitive motion*, exhibited distinct and unique trends in opposite directions and are further explored.

4.4. Fall on same level

The fall on same level category, while having a similar trend as the overall index through 2006, has mainly been on an upward trend since then and has had an overall significant increase in real burden since 1998 ($p < .05$). The growing burden of the same level falls Index category reflects a less than average decline in frequency compared with all other injury types (−17% vs. −38% respectively), combined with greater growth in average cost or severity per case compared with the overall Index (63% vs. 46%, See Table 2, Fig. 5a).

4.5. Repetitive motion

While increasing in the first couple of years (1998–2001), the *repetitive motion* category has experienced an overall steady downward trend since 2002 ($p < .05$) reflecting a steep downward trend in cases reported to the BLS in this category (−50%). Additionally, mean costs in this category increased much less than the overall Index (15% vs. 46%, respectively).

5. Discussion

5.1. Direct vs. indirect costs

Over $600 billion in direct WC costs were spent on the most disabling compensable non-fatal injuries in the American workplace from 1998 to 2010 (the summation of current year dollars); this figure is a significant but small portion of the overall burden of all workplace injuries and illnesses in the United States. Also, while the majority of direct, insured costs are captured, there are many other direct and indirect societal, business, and individual costs arising from compensable workplace injuries not covered such as: wages lost during waiting periods or from partial compensation rates (state rates are approximately 66% or less of worker's wages, although benefits are generally not taxed); the burden on employers to retrain, replace, or provide modified duty opportunities to workers; the burden on injured workers due to the inability to perform basic activities of daily living and work; and the burden on families in terms of lost household income and requirements to take care of and compensate for the injured workers sometimes for many years (Leigh, 2011; Leigh & Du, 2012; Seabury, Scherer, O'Leary, Ozonoff, & Boden, 2014).

5.2. Growth over time

Over the 13-year period, the direct WC costs spent on the most disabling, compensable non-fatal injuries in the American workplace grew nominally by 38% from $37.1 billion in 1998 rising to $51.1 billion in 2010 — reaching a burden of almost a billion dollars a week. The burden in 2010 was similar to the burden in 1998 in real terms ($35.4 billion vs. $37.1 billion, respectively, in 1998$), indicating a continued need for research, along with implementation and evaluation of workplace interventions.

While it is clear that the frequency of reported injuries and illnesses has declined in recent years (−38% between 1998 and 2010), costs have risen, possibly resulting from greater injury severity for cases reported by employers in 2010 than 1998. In general, workers compensation costs, in the absence of better indicators, may be used as a proxy

Table 2
Growth/decline in LMWSI component measures for each top 10 event category 1998 – 2010.

	Bureau of Labor Statistics (BLS) survey of occupational injury and illness (SOII) frequencies[a]							Liberty Mutual mean costs ($98)					BLS × LM	
	1998 > 5 DAW cases[a]			2010 > 5 DAW cases[a]			% +/− frequencies 1998–2010	Adj. cost normalized to average cost of all claims[b]		% +/− avg cost 1998–2010	S.E. avg cost 1998 as frac. of mean cost	S.E. avg cost 2010 as frac. of mean cost	Proportion of WC benefits by event category	
Event Description	n	S.E.[c]	M_{DAW}[a]	n	S.E.[c]	M_{DAW}[a]		1998	2010				1998	2010
All > 5 DAW cases	860,213	8326	22	530,530	3817	30	−38.3	1	1	46.4	0.011	0.011	100	100
Overexertion	251,321	2631	21	140,790	1162	29	−44.0	0.93	1.01	59.4	0.011	0.014	27.1	26.8
Fall on same level	98,777	1187	25	81,910	752	31	−17.1	0.98	1.09	62.5	0.015	0.022	11.3	16.9
Bodily reaction	99,528	1194	20	64,280	626	30	−35.4	0.80	0.94	72.5	0.023	0.024	9.2	11.4
Fall to lower level	58,188	790	29	40,080	447	32	−31.1	1.36	1.32	42.6	0.043	0.031	9.2	10.0
Struck by object	92,400	1125	18	52,890	543	20	−42.8	0.77	0.80	51.4	0.032	0.035	8.3	8.0
Struck against object	49,609	703	17	30,720	374	24	−38.1	0.77	0.71	35.4	0.027	0.027	4.4	4.1
Repetitive motion	46,695	674	28	23,210	313	32	−50.3	1.16	0.91	14.8	0.015	0.022	6.3	4.0
Highway incident	24,966	442	29	13,940	230	29	−44.2	1.76	1.47	22.2	0.066	0.068	5.1	3.9
Caught in or compressed by	41,043	615	21	23,470	315	24	−42.8	0.82	0.79	40.4	0.046	0.056	3.9	3.5
Assaults & violent acts by persons	7,995	225	19	8,790	177	24	9.9	1.17	0.76	−5.2	0.082	0.063	1.1	1.3
Other	89,691	1078		50,450	525		−43.8						14.1	10.3

[a] Bureau of Labor Statistics (BLS) Frequencies of Cases with >5 days away from work (DAW) and Median DAW estimates (MDAW) by event category retrieved and estimated from BLS R70, http://www.bls.gov/iif/.
[b] Ultimate cost for open claims (developed with historical data) and adjusted for inflation ($98), Consumer Price Index used for indemnity & expense costs, Medical Service Price Index for medical costs.
[c] Standard errors (S.E.) were approximated through special request by the BLS using a modified Taylor series expansion. Differences in S.E.'s between 1998 and 2010 are due to modifications in the BLS SOII sampling methodology in the early 2000s.

measure for severity (Maxwell & Wozny, 2014; Sears, Blanar, & Bowman, 2014). At the individual level, especially with regard to some injuries (e.g., low back pain), higher cost may be partially caused by other factors un-related to severity (Baldwin, Butler, Johnson, & Côté, 2007, e.g. specific diagnostic or surgical procedures, or other return to work issues).

We observed that the overall mean cost growth for LM WC tracked NCCI WC cost growths. Additionally, the BLS median DAW metric increased with a similar trend.

5.3. Rising costs — increase in severity of cases reported, reduced reporting of young or less severe cases, and/or an aging U.S. workforce?

We could not determine whether the increase in severity of reported cases – a finding observed in 3 data sources – was due to the initial injury being more severe, more costly treatment (e.g., an increase in lost time due to increases in medical procedures, diagnostic tests, surgery or drugs prescribed than in the past (Webster, Bauer, Choi, Cifuentes, & Pransky, 2013; Webster & Cifuentes, 2010; Webster, Verma, Willetts, Hopcia, & Wasiak, 2011), or a decline in reporting of lower severity cases).

However, we noted that BLS injury case counts (>5 DAW) *increased* for older workers (≥45). This occurred in sharp contrast to the trend in the number of reported cases for those <45 years old, which declined by almost half from 1998 to 2010 (BLS, 2000, 2012). This could indicate that the increase in severity per case may be due to a selective reduction in reports by younger workers (Breslin & Smith, 2005; Runyan, Lewko, Rauscher, Castillo, & Brandspigel, 2013), and, given the aging workforce (Restrepo & Shuford, 2011; Silverstein, 2008; Wegman & McGee, 2004), the distribution of >5 DAW cases becoming more skewed towards older workers. In some circumstances, older workers could be at higher risk when similarly exposed and could take longer to recover from an injury and potentially receive more medical care.

5.4. Category analyses

The *overexertion* and *fall on same level* categories have been consistently ranked 1st and 2nd since the beginning of the LMWSI. *Overexertion* injuries cost America $13.6 billion in 2010 (nominal) compared with $10.0 billion in 1998 despite much research and focus on safer material handling practices during this time period. There was a $.5 billion decline in the real cost indicating some improvement. While there was a large reduction in reporting of injuries (−44%), costs increased almost 60% from 1998 to 2010, and the median DAW also increased (+38%), indicating again the possibility of a greater proportion of more severe cases reported in this category (BLS, 2014c).

The *fall on same level* category has had *substantial* nominal growth, costing $8.6 billion in 2010 compared with $4.2 billion in 1998. Even after adjusting for inflation, costs for *fall on same level* injuries effectively cost $2 billion more in 2010 than in 1998. This category showed substantial cost growth with only a *minor* reduction in reported incidence. The limited decline could possibly be due to an increase in the frequency of older workers falling at work reported by the BLS SOII (40,501 to 49,730 cases reported ≥45 years old, 1998 to 2010) (BLS, 2000, 2012). The cost growth may be driven by an increase in severity of cases supported by an increase in the BLS SOII median DAW values for this category (from 25 to 31 for >5 DAW cases, 1998 to 2010). The increasing burden from falls observed here is also supported by the Global Burden of Disease and Injury study that observed falls as one of the steepest rising causes of Disability Adjusted Life Years in the United States and Canada during the period from 1990 to 2010 (Lim et al., 2012).

In contrast *repetitive motion* injuries exhibited a steady decline in real cost burden ($2.3 billion to $1.4 billion in 2010), especially since 2002, driven by a steep downward trend in BLS SOII reporting. Potential explanations include: fewer workers in high risk environments, a decrease in workers' willingness to report these injuries, advances in

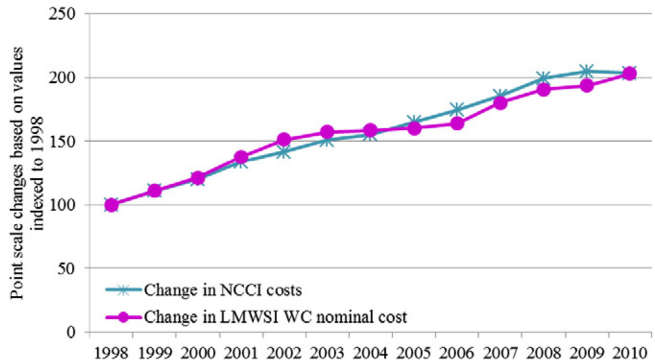

Fig. 3. Point percent increases in each year's values normalized to 1998 values (NCCI mean costs, LM ultimate nominal WC cost).

repetitive motion injury prevention, and lower average severity or improvements in return to work strategies. Interestingly, there was no substantial growth in the number of injury cases for older workers and cost leveling was supported by an elevated but stable BLS median DAW value (32 days, 2002 through 2010).

5.5. Strengths and limitations

The LMWSI is an annual metric that allows the total national estimate of the direct, insured cost of the most severely disabling injuries to be tracked over time and the highest burden by "cause" of injury to be identified. Because our methods during the 13 years from 1998 to 2010 were unchanged, and since costs can be discounted to 1998$ values, we believe that trends in the Index are good indicators of growth or decline in the burden and reveal the significance of the most serious causes of *work-related* injuries each year. Thus, the Index provides an annual, national perspective on the relative contributions of different injury risks and allows for these to be appreciated and prioritized by industry, practitioners, and public health organizations.

During the initial development of the LMWSI, our estimates were compared with other estimates of national burden (Leigh, Markowitz, Fahs, & Landrigan, 2000; Leigh, Markowitz, Fahs, Shin, & Landrigan, 1997; NSC, 2000), and found to be representative of the burden comprised from WC benefits as defined. We also understood during the development of the Index that there were several limitations resulting from our combining data from three different national data sources. Of

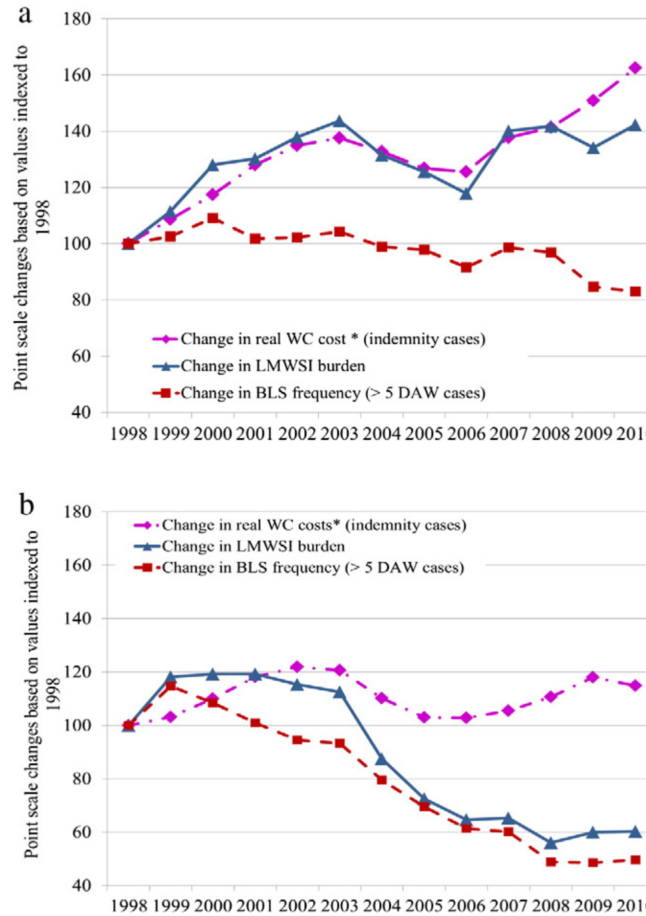

Fig. 5. a. Sensitivity analyses for *fall on same level* category: point percent increases/declines in each year's values normalized to 1998 values indexed at 100 (LMWSI real cost, BLS frequency for >5 DAW cases) when cost or frequency is held constant. b. Sensitivity analyses for *repetitive motion* category: point percent increases/declines in each year's values normalized to 1998 values indexed at 100 (LMWSI real cost, BLS frequency for >5 DAW cases) when cost or frequency is held constant.

most significance is the determination of whether the biases introduced by any of the data sources were *differential* with regard to the proportionate magnitude of cost by event category or by the way costs change annually by category.

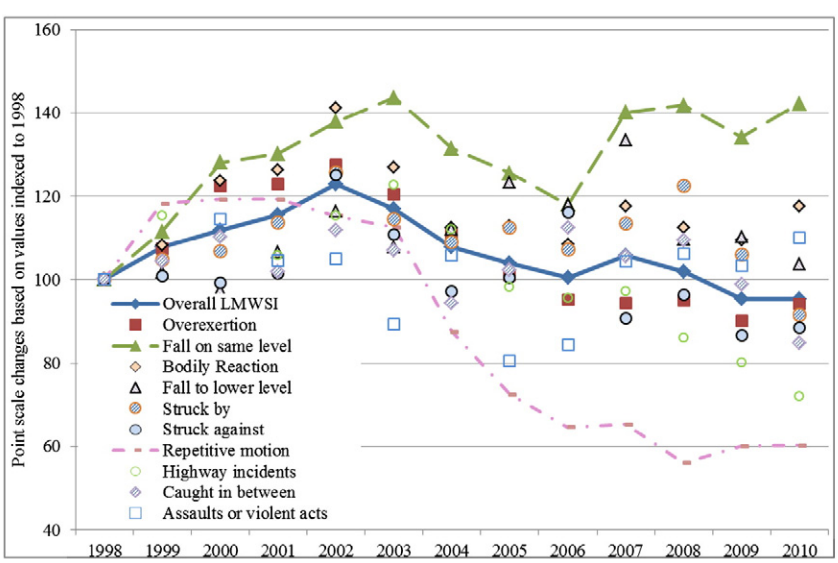

Fig. 4. Point percent increases/declines in each year's values of the top 10 LMWSI categories normalized to 1998 values.

An obvious issue in using cost data from a single carrier is that the sample of industries may not necessarily be representative of the nation as a whole. However, previously published research has demonstrated reasonable alignment at an aggregated level between BLS data and LM data (Murphy, Sorock, Courtney, Webster, & Leamon, 1996) and during the 13-year period reported here, LM carried a significant portion of the workers' compensation market. We also found LM costs and growth values to be closely aligned with NCCI costs and the BLS reporting of *median days away from work*. Alignment with these other national metrics suggests that our costs were not likely to have been unrepresentative due to market share.

Of similar concern for the external validity of our findings is the undercount in BLS frequencies due to the exclusion of important risk groups from the survey, sample design, and other issues brought up in recent literature (Boden & Ozonoff, 2008; Leigh et al., 2004; Rosenman et al., 2006). A recent special issue of the American Journal of Industrial Medicine presented further evidence of the undercounting in the BLS frequencies following an analysis of within-state comparisons of alternative sources of surveillance data with the SOII data from Massachusetts, California and Washington State (American Journal of Industrial Medicine Special Issue, 2014). The results demonstrated significant undercounts (Boden, 2014; Davis et al., 2014; Joe et al., 2014), and the potential for differential reporting or misclassification of cases (Tak, Grattan, Boden, Ozonoff, & Davis, 2014; Wuellner & Bonauto, 2014). Therefore, it is possible that some reporting biases exist leading to differences in the distribution of cost by event category. We attempted to minimize this bias by including only the most severe injuries (e.g. >5 DAW cases), including compensation for lost time, and classifying event for LM cases using the BLS event coding classification scheme. We also note that the majority of case reports into both the BLS and WC data systems are injuries (>90% Wiatrowski, 2014). Since illnesses are not well captured with these systems, we consider the LMWSI index values as predominantly an accounting and ranking of the direct compensable WC burden of work-related injuries and their associated events (Leigh et al., 2004; Spieler & Wagner, 2014).

The proportionate distribution used for the Index has been shown to align reasonably well with work-related injury data from household-based reporting sources such as the National Health Interview Survey (Smith et al., 2005). Therefore, while both the mean cost and frequency data used in the Index have limitations, we believe that the relative rankings by event category, for both data sources, are fairly representative at the broad aggregate level.

From the Index's inception, we have considered that future analyses would lead to the introduction of modifications to our methods to address some of the limitations. However, introducing improvements at specific points in time can compromise analyses of historical trends since the data may no longer be comparable. In order to maintain an acceptable level of inter-year comparability, we chose to continue the original methods with minimal adjustment during the period reported. When combining event category data from both LM and the BLS, it is critical that compatible case definitions be used from both data sources. This can be quite challenging with the limited information in claims narratives and tens of thousands of claims to classify each year. Using a one-year sample (for injuries incident in 2008) we found 75% agreement between codes assigned manually and those assigned using our combined (human–computer) approach. Additionally, during training of coders on the BLS event coding protocol over the 13-year period, inter-rater agreement of manually assigned codes has ranged from 56% to 90%. We believe that semi-automated approaches for more reliable and efficient classification have been described elsewhere and could be leveraged for improving the accuracy of LM-assigned codes as well as the BLS-assigned codes (Lehto, Marucci-Wellman, & Corns, 2009; McKenzie et al., 2010).

6. Conclusion

Although workplace injuries are among the leading causes of death and disability around the world, the burden due to them has historically been under-recognized, obscuring the need to address a major public health problem. The LMWSI was established in 2000 to provide a reliable, annual measure of the direct insured costs of the most disabling workplace injuries in the United States that also allows for ranking and tracking over time. Close to 1 billion U.S. dollars a week is being spent on direct, insured costs for the most disabling work-related injuries. Despite workplace interventions and large reductions in the overall reported frequency of workplace injury, there has been a lack of substantial, real reduction in burden over the past 13 years.

Changes in the Index-reported burden due to the various causes of workplace injury occurring over the 13 years have not occurred uniformly. Overexertion injuries still far outweigh any other cause despite much research and focus on safer materials handling practices. Falls on the same level have grown at a steady rate since 2002, whereas repetitive motion injuries have experienced a significant reduction.

Beginning with data year 2011 (LMWSI year 2013), we have initiated a new Index series. The new series incorporates the new 2-digit event classification strategy developed by the BLS (BLS OIICS, 2012) and includes more advanced techniques (Naïve Bayes algorithms) for more accurate assignment of classifications.

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Appendix A

Top ten 2-digit BLS event categories (Bureau of Labor Statistics (BLS) Occupational Injury and Illness Coding System (OIICS), 2007) defined

BLS 2-digit category	Brief definition (taken from BLS OIICS coding manual, 2007)
Overexertion	Overexertion applies to cases, usually non-impact, in which the injury or illness resulted from *excessive physical effort directed at an outside source of injury or illness*. The physical effort may involve lifting, pulling, pushing, turning, wielding, holding, carrying, or throwing the source of injury/illness.
Fall on same level	Fall on same level applies to instances in which the injury was produced by impact between the injured person and the source of injury, the motion producing the contact being that of the person, under the following circumstances. –the motion of the person was generated by gravity following the employee's loss of equilibrium (the person was unable to maintain an upright position) and, –the point of contact with the source of injury was at the same level or above the surface supporting the person at the inception of the fall.
Bodily reaction	Codes in this major group apply to injuries or illnesses generally resulting from a *single incident of free bodily motion* which imposed stress or strain upon some part of the body. For example, injuries due to reaching, bending, twisting, and climbing.
Fall to lower level	Fall to lower level applies to instances in which the injury was produced by impact between the injured person and the source of injury, the motion producing the contact being that of the person, under the following circumstances: - the motion of the person and the force of impact were generated by gravity and - the point of contact with the source of injury was lower than the surface supporting the person at the inception of the fall.
Struck by object*	The "struck by" codes apply to injuries produced by forcible contact or impact between the injured person and the source of injury when *the motion producing the contact is primarily*

(*continued*)

BLS 2-digit category	Brief definition (taken from BLS OIICS coding manual, 2007)
	that of the source of injury rather than the person.
Struck against object*	The "struck against" codes apply to injuries produced by forcible contact or impact between the injured person and the source of injury when the *motion producing the contact is primarily that of the injured person*.
Repetitive motion	Repetitive motion applies when an injury or illness resulted from bodily motion which imposed stress or strain upon some part of the body due to a task's *repetitive nature*.
Highway incident	Highway accidents include accidents to vehicle occupants occurring on that part of the public highway, street, or road normally used for travel as well as the shoulder and surrounding areas, telephone poles, bridge abutments, and trees aligning roadway.
Caught in or compressed by*	This major group includes cases in which the injury was produced when a person or part of a person was injured by *being squeezed, crushed, pinched or compressed between two or more objects, or between parts of an object*.
Assaults and violent acts*	Assaults and violent acts by persons include cases in which the worker was injured or made ill by intentional assaults by a person other than the injured person or by violent, harmful actions of unknown intent by a person.

*Full titles: struck by object or equipment, struck against object or equipment, caught in or compressed by equipment or objects, assaults and violent acts by person(s).

List of acronyms

Acronyms	Definition
BLS	Bureau of Labor Statistics
CDC	Centers for Disease Control and Prevention
DAW	Days away from work
LM	Liberty Mutual
LMWSI	Liberty Mutual Workplace Safety Index
NASI	National Academy of Social Insurance
NCCI	National Council of Compensation Insurance
OIICS	Occupational Injury and Illness Classification System
OSHA	Occupational Safety and Health Administration
SOII	Survey of Occupational Injuries and Illnesses
WC	Workers Compensation

Explanation of terms

Term	Description
Calendar year estimate	A calendar year estimate accrues payments made in the same year. The National Academy of Social Insurance estimates the total cost of all WC benefits paid out each year.
Consumer Price Index (CPI)	The CPI is an index of the price level changes over time for a typical set (basket) of consumer goods and services.
Discounting	Because the value of a dollar today is not worth the same as the value of a dollar many years ago, we discounted the costs of claims each year to 1998 dollar values. Discounting is the method used to figure out how much of the payments made in each year would have been worth in a base year, 1998, and allows for comparison in costs across years without regard to inflation or deflation of the dollar. Indemnity and expense payments were discounted using the Consumer Price Index (BLS, 2014a) and medical payments were discounted using the Medical Services Price Index (BLS, 2014a).
Expense cost	The sum of all administrative costs for handling and processing the claim.
Incident year estimate	The LMWSI estimate is an incident year estimate and is the summation of the lifetime costs for all injuries that occurred in a particular year.
Indemnity cost	The sum of all wage replacement payments for a claimant.

(*continued*)

Term	Description
Indemnity cases	Injured workers must be out of work a minimum time period required by each state in order to receive wage replacement for the time they could not work (between 3 and 7 days depending on the state). To be included as an indemnity case, the case had to receive some compensation (>0 dollars) in wage replacement for their injury.
Index year	The index year is the year data that were extracted and results that were reported. Claims are extracted in the first week of July of the year allowing for a minimum of 18 months from December 31 of the incident year. For example on July 1st for the 2000 index year, the cost data were extracted and analyzed for all injuries that were incident in 1998 (incident year). For example on July 1st for the 2000 index year, the cost data were extracted and analyzed for all injuries that were incident in 1998 (incident year).
Medical cost	The sum of all medical payments for a claimant.
Medical Services Price Index (MSPI)	The MSPI is an index of the price level changes over time of Medical care (e.g., professional services, hospital and related services; health insurance and medicinal drugs; and medical equipment and supplies) and is one of eight major groups in the Consumer Price Index (CPI). There are two medical care classifications included in this index, medical care commodities (MCC), and medical care services (MCS).
National Academy of Social Insurance (NASI) rolling adjustment factor	The NASI rolling factor provides us with an upper bound estimate to correct for exclusions in the BLS. The NASI rolling factor is an average of the ratios of the most recent NASI figures compared to the BLS × LM total compensable costs for the last 5 years.
Nominal cost	The "nominal" cost will be the cost expressed in historical nominal monetary terms or the amount which was actually paid out at the time the payment was made.
Normalization	Normalization is adjusting values to a notionally common scale. We do this to describe point percent increases in cost and frequency data from 1998, the baseline year of the index, as well as to understand relative severity by comparing cost values for the various event categories to the overall average cost.
Real cost	Cost which has been adjusted from a nominal value to remove the effects of price level changes over time and is measured in terms of the general price level in some reference year (the base year). For the LMWSI, the base year was 1998.
Sensitivity analyses	Sensitivity analyses were used here to study how changes in the overall Index were influenced by changes in the various sources of data comprising the Index.
The Liberty Mutual Workplace Safety Index (LMWSI)	An annual metric that allows the total national estimate of the direct, insured cost of the most severely disabling injuries to be tracked over time, and the highest burden by "cause" of injury to be identified.
Ultimate cost	The actuarial method of development triangles use historical cost data to determine the final cost of claims which are still "open" or incurring costs at the time of extraction (between 18 and 30 months post injury). For closed claims, the final or "ultimate" cost will be the cost at the date of extraction. For all claims, costs are developed according to historical data to estimate the "ultimate" cost of the claim.

Examples demonstrating Liberty Mutual Workplace Safety Index methods for coding LM claims narratives to BLS 2-digit event codes

Tier 1 coding: crosswalk from Liberty Mutual claims office assigned cause code to BLS 2 digit event code

Example 1

"STANDING ON A LADDER TO INSTALL AIR CLEANER ON TRUCK AND FELL OFF LADDER"

LM cause code: *fall from elevation* → cross-walked (automatic assignment by computer) to BLS event code of *fall to lower level*

Example 2

"EMPLOYEE SLIPPED ON WET FLOOR. FELL AND TWISTED RIGHT ANKLE"

LM cause code: *fall on same elevation* → cross-walked to BLS event code of *fall on same level*

Example 3

"EMPLOYEE WAS SERVICING PIECE OF EQUIPMENT, CABINET DOOR FELL ONTO EMP LT TOE CAUSING INJURY"

LM cause code: *struck by falling objects* → cross-walked to BLS event code of *struck by objects*

Tier 2 coding: if there was no direct crosswalk from LM cause code, the 2nd tier coding included searching for highly predictable terms in the narrative

Example 4

"EMP LIFTING A CASE OF WATER WHEN FELT PAIN IN BACK"

LM cause code: *manual material handling* → could not cross-walk directly to a BLS event code because a claimant could be injured many ways while actively involved in manual material handling. However the 2nd tier method classified this by searching for and finding the text "lift", and "felt", and "pain" in the narrative. If these search terms were found the computer algorithm automatically assigned the BLS event code of *overexertion*

Example 5

"REPETITIVE USE OF KEYBOARD RESULTING IN CARPAL TUNNEL SYNDROME"

LM cause code: *manual material handling* → could not cross-walk directly to a BLS event code because a claimant could be injured in many ways while actively involved in manual material handling. However the 2nd tier method classified this by searching for and finding the text "repet" and "carpal tunnel syndrome" in the narrative. If these search terms were found the computer algorithm automatically assigned the BLS event code of *repetitive motion*

Tier 3 coding: if there was no direct crosswalk from LM cause code, and none of the search terms included in the tier 2 computer algorithm were found in the narrative, the narrative was pulled out for manual review

Example 6

"PUTTING A BELT ON A FAN AND HIS FINGER GOT CAUGHT UNDER BELT AND SCREWDRIVER"

LM cause code: *materials handling — mechanical* → could not cross-walk directly to a BLS event code because many BLS events are possible considerations with mechanical work. Also none of the computer algorithm combination of search terms were found in this narrative. This narrative reached tier 3 of our coding methods, was pulled out for manual review and assigned the BLS event code of *caught in or compressed by equipment or objects*

Example 7

"EMP DRIVING DOWN ROWS, HIT RUT AND PUT ATV ON ITS SIDE"

LM cause code: *materials handling — mechanical* → could not cross-walk directly to a BLS event code because many BLS events are possible considerations. Also none of the computer algorithm combination of search terms were found in this narrative. This narrative reached tier 3 of our coding methods, was pulled out for manual review and assigned the BLS event code of *non-highway accident*

Helen R. Marucci-Wellman, M.S., Sc.D. has a background in occupational health surveillance and ergonomics. She is an epidemiologist at the Liberty Mutual Research Institute for Safety's (LMRIS) Center for Injury Epidemiology. Her work has involved analyzing data from large national health databases, such as the Liberty Mutual Claims data and the U.S. National Health Interview Survey as well as developing new research methods for surveillance of injuries including an understanding of work structure characteristics associated with an increased risk of injury, developing a model for work-related injury surveillance in Vietnam, and developing semi-automated methods for narrative text mining and analysis.

Theodore (Ted) K. Courtney, M.S., CSP, is the Director of the Center for Injury Epidemiology at the Liberty Mutual Research Institute for Safety in Hopkinton, Massachusetts where he is also responsible for Institute-wide extramural research and institutional engagement. He is also an instructor on Injury, Safety and Ergonomics in the Department of Environmental Health at the Harvard TH Chan School of Public Health. Mr. Courtney received the 2003 William Floyd Medal (Ergonomics Society), the 2006 NORA Partnering Award (CDC-NIOSH), the 2008 *Ergonomics* Best Paper Award, and the 2014 Excellence in Science Award from the APHA Injury Control & Emergency Health Services Section.

Helen R. Corns, M. Eng., M.S. is a research associate with the Liberty Mutual Research Institute for Safety's Center for Injury Epidemiology. She earned her Masters degree with a concentration in biostatistics from the University of Massachusetts at Amherst in 2006. Her work involves analysis of data from large nationwide databases to study health outcomes and injuries, with an emphasis on text mining narrative data and methods of automated coding of text data including Bayesian methods.

Gary S. Sorock, PhD has degrees in biology, physiology, public health/education, and nursing. His primary research interests have been in injury epidemiology and community health. He has conducted both case-control and cohort studies of falls in older adults in hospital and community settings and has also worked on surveillance studies of workplace fatal injuries in New Jersey. While at Liberty Mutual, he collaborated on studies of occupational injury using various epidemiologic approaches, including narrative text analyses, case-crossover studies and descriptive studies of injuries in the U.S. and in China. More recently, he has worked in psychiatric nursing and has written descriptive pieces based on his clinical experiences.

Barbara Webster, BS PT, PA-C. is currently the manager of the Special Projects for Helmsman Management Services. Previously, she was a research scientist with the Liberty Mutual Research Institute for Safety focusing on treatment outcomes for low back pain (LBP); epidemiology and cost studies for LBP and cumulative trauma disorders (CTD); and studies to develop engineering guidelines for CTD prevention. Barbara earned her B.S. in Physical Therapy from Ithaca College and Physician Associate degree from Yale University School of Medicine. She is a recipient of the American Industrial Hygiene Association's Alice Hamilton Award in recognition of her achievements in the field of occupational and environmental hygiene.

Radoslaw Wasiak, PhD, MA, MSc, is a vice president of the Meta Research and Retrospective Observational Studies at Evidera, a global health care consultancy. In addition to managing these teams, he contributes to conceptualizing study designs of observational studies. His published works includes applied and theoretical investigations of recurrence of pain and investigations of the relationship between healthcare interventions, and work productivity. Prior to joining Evidera, Dr. Wasiak was a Research Scientist at the Liberty Mutual Research Institute for Safety. Dr. Wasiak holds a PhD and MA from the University of Connecticut, and an MSc from the University of Economics, Poznan, Poland.

Ian Noy, PhD is the vice president and director of the Liberty Mutual Research Institute for Safety. He holds a doctorate degree in Industrial Engineering from the University of Toronto, specializing in human factors. He is a certified professional ergonomist (CPE) with 40 years of professional experience. His applied research spans applications in the air, on the ground, and underwater. Dr. Noy is a past president of the International Ergonomics Association (IEA), a fellow of the Human Factors and Ergonomics Society (HFES), and a past president and honorary fellow of the Human Factors Association of Canada/Association canadienne d'ergonomie (HFAC/ACE). Dr. Noy is a recipient of several awards.

Simon Matz, M.S. joined the research staff in 1998, bringing his more than 19 years of experience in medical and pharmaceutical statistics to the Institute. His current research projects include the statistical evaluation of floor surface friction measurements, and multivariate analysis in laboratory studies. As a co-investigator for electrical injuries study he was responsible for data management and statistical analyses and currently involved in investigating stochastic distribution of coefficient of friction. Mr. Matz earned a B.S. in computer science and a M.S. in biostatistics at Belarus State University. He is a member of the American Statistical Association.

Tom B. Leamon, PhD established ergonomics departments in coal and glass industries, held senior academic appointments in the US and the UK, and been recognized by the Finish Institute of Occupational Health, the International Ergonomics Association, the Institute of Ergonomics, the Human Factors and Ergonomics Society, and the Institute of Industrial Engineers. Directing the Liberty Mutual Research Institute he expanded the terminally degreed staff from two to 20+, the facilities to 9 laboratories and established the principle of sharing the research findings by peer reviewed publication. He formally instituted research partnerships with Harvard, Tsinghua and Fudan Universities and the National Institute in HaNoi.