ORIGINAL ARTICLE

Work-related musculoskeletal disorders among construction workers in the United States from 1992 to 2014

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ABSTRACT

Objectives Examine trends and patterns of work-related musculoskeletal disorders (WMSDs) among construction workers in the USA, with an emphasis on older workers.

Methods WMSDs were identified from the 1992–2014 Survey of Occupational Injuries and Illnesses (SOII), and employment was estimated from the Current Population Survey (CPS). Risk of WMSDs was measured by number of WMSDs per 10 000 full-time equivalent workers and stratified by major demographic and employment subgroups. Time series analysis was performed to examine the trend of WMSDs in construction.

Results The number of WMSDs significantly dropped in the US construction industry, following the overall injury trends. However, the rate of WMSDs in construction remained higher than in all industries combined; the median days away from work increased from 8 days in 1992 to 13 days in 2014, and the proportion of WMSDs for construction workers aged 55 to 64 years almost doubled. By occupation, construction labourers had the largest number of WMSD cases, while helpers, heating and air-conditioning mechanics, cement masons and sheet metal workers had the highest rates of WMSDs. The major cause of WMSDs in construction was overexertion, and back injuries accounted for more than 40% of WMSDs among construction workers. The estimated wage loss for private wage-and-salary construction workers was $46 million in 2014.

Conclusions Construction workers continue to face a higher risk of WMSDs. Ergonomic solutions that reduce overexertion—the primary exposure for WMSDs—should be adopted extensively at construction sites, particularly for workers with a higher risk of WMSDs.

What this paper adds

- ► This study found that the number of work-related musculoskeletal disorders (WMSDs) among the US construction industry dropped by 66% from 1992 to 2014, while the proportion of WMSDs among older workers increased during this period.
- ► The significant drop in the number and incidence rate of WMSDs may be due to continuous intervention efforts in the US construction industry, the changes in Occupational Safety and Health Administration (OSHA) record-keeping requirements and potential injury and illness under-reporting in this industry.
- ► The growing proportion of WMSDs among older workers reflects the ageing workforce in the construction industry.
- ► The study findings from a long period and large nationally representative data sources may complement existing research on WMSDs based on a short period or case studies.

INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) are conditions that affect the muscles, tendons, joints, nerves and supporting blood vessels that occur due to work-related activities, such as working in the same position for long periods of time, overexertion in carrying and lifting heavy objects, repetitive tasks, awkward body postures and whole body vibrations.[1–5] WMSDs are among the most frequently reported causes of lost or restricted work time, accounting for one-third of all work-related injury and illness cases in the USA (https://www.osha.gov/SLTC/ergonomics/). In addition to discomfort, pain and physical suffering for injured workers, WMSDs have brought financial burdens to workers and their families, employers and society with loss of income and productivity, increasing medical expenses and workers' compensations, and Social Security disability payments (http://www.cdc.gov/niosh/). For example, on average, workers' compensation costs of lost time for a shoulder injury are $20 000 and for a back injury are $25 000, respectively.[6]

The construction industry is a high-risk industry for WMSDs.[2–4 7] Previous studies have identified a number of occupational risk factors for WMSDs in construction including the following: overexertion,[2 4 7] excessive vibration,[8] bending and twisting,[2 4 7] awkward body postures,[1 4 7] pressure pinch points[1] and working in static positions.[1 3–4 7] Each of these risk factors has effects on various body parts. The most frequently reported musculoskeletal pain in construction occurs in the back, neck/shoulders, knees and hand/wrist areas.[1–3]

Studies showed that musculoskeletal disorders among construction workers varied by occupation. A recent study found that bricklayers were more likely to report work-related musculoskeletal symptoms than supervisors.[7] The type of work and the location of musculoskeletal symptoms corresponded

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to different construction trades.[1] For example, crane operators, insulators and painters had higher odds of neck disorders, while roofers and floorers had higher odds of WMSDs in the lower back and lower extremities.[9]

MSDs are common among older workers. A longitudinal study on older construction workers in the USA found that about 40% of those over the age of 50 years suffered from persistent back pain or problems; the prevalence was even higher among workers whose longest-held jobs were in construction, or jobs involving a great deal of stress or physical effort.[10] Some studies suggest that musculoskeletal symptoms increased linearly with age,[11 12] while others indicate that the risk of WMSDs increased until a certain age and then decreased.[9] In contrast, some studies found that there was no significant relationship between age and WMSDs.[8 13] In fact, attribution of MSDs to work versus ageing independently is often difficult as work exposures may cause MSDs as well as aggravate or accelerate the degenerative effects of ageing.

With regard to these inconsistent findings, many studies on WMSDs are often limited by small sample sizes,[14 15] a particular state/region,[16] a specific musculoskeletal illness,[17] a specific occupation.[18–21] Moreover, a large number of the studies only examined WMSDs at one point in time,[4 17] which leaves the overall trends of WMSDs in the US construction industry unclear.

In recent decades, the US labour force has been rapidly growing older. Following this trend, construction workers are also ageing. The average age of construction workers increased from 36.0 in 1985 to 41.5 in 2010, and the proportion of those aged 45 to 64 years increased from 25% to 39% during the same time period.[2] To better understand the patterns of WMSDs and ageing, this study examined the trends of WMSDs among construction workers in the USA from 1992 to 2014 using national data, with an emphasis on older workers.

METHODS

Data sources

Three large nationally representative data sets were used in this study, the 1992–2014 Survey of Occupational Injuries and Illnesses (SOII), the 1992–2014 Current Population Survey (CPS) and the 1997–2014 Occupational Employment Statistics (OES). The number of non-fatal injuries and WMSDs were obtained from the SOII as special requests through the US Bureau of Labor Statistics (BLS). The SOII is an annual establishment survey designed to collect data on injuries and illnesses based on records that employers maintain under the Occupational Safety and Health Act of 1970. Self-employed workers are not considered to be employees under the 1970 act. Private households (NAICS 814), the USA Postal Service (NAICS 491), farms with fewer than 11 employees and federal government workers are also out of scope for the SOII. Since 2008, the SOII has included state and local government workers (http://www.bls.gov/opub/hom/pdf/homch9.pdf). The SOII has undergone several substantial changes during the study period, including changes in the data classification system. This has affected the data comparability across years, and limited data analysis on subgroups. For example, some case characteristics (eg, source of injury) were only stratified using the 2011–2014 data due to the revision in the Occupational Injury and Illness Classification System in 2011 (OIICS, http://www.bls.gov/iif/oshoiics.htm)

To calculate injury rates, denominators (in terms of full-time equivalent workers (FTEs)) were obtained from the CPS, a large monthly household survey sponsored by the US Census Bureau and the BLS (http://www.bls.gov). The FTEs were estimated based on the weighted work hours reported by respondents who were aged 16 years or older and employed as private wage-and-salary workers.

To calculate the wage loss due to WMSDs, the average hourly wage rate for construction workers were obtained from the 1997–2014 OES (http://www.bls.gov/oes/). Since the OES data were incomplete for the construction industry prior to 1997, wage loss was only estimated for 1997 and after. Dollar value was adjusted by the Consumer Price Index for Urban Wage Earners and Clerical Workers (CPI-W) to allow for yearly comparisons.

Measures

Cases of WMSDs: The definitions differ before and after 2011 due to changes in the OIICS used by the BLS (http://www.bls.gov/iif/oshdef.htm). Since 2011, under OIICS V.2.01, WMSDs include cases where the nature of the injury or illness is a pinched nerve (nature codes: 1131xx); herniated disc (1211xx); meniscus tear (1221xx); sprains, strains, tears (123xxx); traumatic hernia (124xxx); pain, swelling and numbness (1972xx, 1973xx and 1974xx); carpal or tarsal tunnel syndrome (2241xx and 2244xx); Raynaud's syndrome or phenomenon (2371xx); or non-traumatic hernia (253xxx). Diseases or disorders affecting the musculoskeletal system, including tendonitis and bursitis, which generally occur over time because of repetitive activity, are also included and coded in Musculoskeletal System and Connective Tissue Diseases and Disorders (27xxxx). The events or exposures leading to the aforementioned injury or illness include overexertion and bodily reaction, repetitive motion involving microtasks, vibration and others. Different from OIICS 2.01, Raynaud's phenomenon, tarsal tunnel syndrome and herniated spinal discs were not counted as WMSDs in the previous OIICS. Therefore, data of WMSDs prior to 2011 and after were not directly comparable.

Risk of WMSDs: Risk of WMSDs was measured by injury rate, number of WMSDs per 10 000 FTEs, assuming that a full-time employee works 2000 hours per year, or 40 hours×50 weeks. Risk was also measured by an index using the average rate of WMSDs in a subgroup divided by the average rate of WMSDs in construction.

Lost wage cost of WMSDs: Low wage cost of WMSDs was calculated based on average hourly wage rate×eight hours per day×median days away from work×number of cases. The costs were then adjusted to 2014 dollars using the Consumer Price Index for Urban Wage Earners and Clerical Workers (CPI-W).

Industry: The construction industry in the SOII was coded according to the 1987 Standard Industrial Classification (SIC: 15, 16, 17) system prior to 2003, and the North American Industry Classification System (NAICS: 23) for 2003 onwards. The construction industry in the CPS was based on the Census Industry Classification (code 0770), corresponding to the systems used in the SOII.

Occupation: The SOII used the Standard Occupational Classification, while the CPS used the Census Occupational Classification system. About 19 common construction occupations were selected and matched according to a crosswalk of these two coding systems provided by the BLS (http://www.bls.gov/cps/cenocc2010.pdf).

Hispanic: Persons who identified themselves as being Spanish, Hispanic or Latino. Persons of Hispanic or Latino ethnicity may be of any race.

Statistical analyses

Time series analyses were conducted to examine the trend of WMSDs (eg, number, rate, median days away from work, lost wage costs) in construction. Stratified analysis was applied to compare the distribution of WMSDs by different age groups, race/ethnicity, occupations, source of injury, part of body, event and exposures and length of service. To calculate the injury rate of WMSDs, the SOII data and the CPS data were matched by basic demographics (ie, age, race/ethnicity and occupation). Around 20% of WMSD cases in the SOII did not report race/ethnicity information, which was adjusted in the rate calculation assuming that the information was missing at random.[22] In addition, since self-reported hours worked from the CPS tend to be overestimated,[23] injury rates for subgroups were adjusted using the ratio between the rate of the overall construction industry reported by the BLS and the rate from the CPS. For example, the ratio 1.23 from the 2011 data was used as an adjustment factor (1.23) to calculate rates in 2011 for all subgroups assuming that the reporting behaviour was the same for all CPS respondents. In addition, 95% CIs were tabulated for injury rates by basic demographics using δ methods for survey variance estimates.[24 25] All statistical analyses were performed using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Between 1992 and 2014, more than one-quarter (25.6%) of the non-fatal occupational injuries resulting in days away from work (DAFW) in construction were WMSDs (see online supplementary table S1). WMSDs as a percentage of all non-fatal injuries have remained relatively stable from 25.9% in 1992 to 24.6% in 2014. Following the overall injury trends in construction, the number of WMSDs dropped dramatically by 66% from 54 235 in 1992 to 18 350 in 2014 (figure 1). The incidence rate of WMSDs was also reduced by 76% from 137.0 to 32.7 per 10 000 FTEs during this time period. Despite the decrease, the median DAFW due to WMSDs in construction increased from 8 days in 1992 to 13 days in 2014, a 62.5% increase (see online supplementary table S1). In terms of costs of WMSDs, estimated wage loss for private wage-and-salary construction workers was as much as $46 million in 2014 alone (see online supplementary table S1).

Demographically, the percentage of WMSDs among construction workers aged 45 to 64 years rose from 27.6% between 2003 and 2007 to 38.1% between 2011 and 2014, reflecting an ageing workforce in this industry (table 1). Specifically, the proportion of WMSD cases for workers aged 55 to 64 years increased by 80%, from 6.4% to 11.5%, during the same time period. Across the years, the proportion of WMSDs shared by Hispanic construction workers remained at about 15%.

In general, the rate of WMSDs increased with age until age 55 years, and then declined among older age groups (table 2). Overall, those aged 35–44 years and 45–54 years had a higher rate of WMSDs than other age groups (51.3 and 50.8 per 10 000 FTEs, respectively), while those aged 65 years and older had the lowest rate (14.1 per 10 000 FTEs). On average, white workers had a higher rate of WMSDs than Hispanic workers between 2003 and 2014 (52.6 vs 32.5 per 10 000 FTEs, respectively).

When stratified by occupation, construction labourers, the largest trade in construction, had the highest number of WMSDs, accounting for 18.7% of WMSDs among all construction occupations from 2011–2014 (table 3), followed by carpenters (12.5%), heating and air-conditioning mechanics (8.2%) and plumbers (8.2%). While helpers had a small number of WMSD cases, they had the highest incidence rate of WMSDs among the selected occupations (100.9 per 10 000 FTEs), and more than twice the average risk of all construction occupations combined (39.5 per 10 000 FTEs). Other high-risk occupations with a risk index ≥2 include heating and air-conditioning mechanics, cement masons and sheet metal workers.

By body part affected by WMSDs, the back ranked at the top for the construction industry and for all industries as well (42.5% and 41.6%, respectively; table 4). The event and exposure that led to the most WMSDs was overexertion involving outside sources for both construction and for all industries (65.3% and 67.8%, respectively). The number of WMSDs increased with length of service for both construction and for all industries combined. In particular, working over 5 years accounted for the highest percentage of WMSDs in construction (35.6%) and for all industries (40.3%). The major source of WMSDs was 'persons/plants/animals/minerals', which for WMSDs is associated with body reaction, repetitive motion or sustained viewing with no impact involved.

DISCUSSION

This study examined the trends and patterns of WMSDs among construction workers in the USA from 1992 to 2014. During the study period, the number and rate of WMSDs in construction decreased significantly, following the overall injury trends. However, the average rate of WMSDs in construction was continually higher than that for all industries combined. At the same time, the median days away from work (ie, a key measure of severity for the injury or illness) for WMSDs have increased. In addition, the proportion of WMSD cases for workers aged 55 to 64 years almost doubled in the past decade, and workers aged 35 to 54 years had a higher rate of WMSDs than any other age group. While construction labourers made up the largest proportion of WMSDs, construction helpers experienced the highest risk of WMSDs among construction occupations. This study also found that the major event and exposure of WMSDs among construction workers was overexertion; and the back was the primary body part affected by WMSDs, accounting for more than 40% of the WMSDs in construction. Moreover, the study suggests that WMSDs are costly; the estimated wage loss for private wage-and-salary construction workers was $46 million in 2014.

The significant drop in the number and incidence rate of WMSDs as well as in the overall non-fatal injuries during the study period may reflect continuous intervention efforts in the US construction industry. However, work-related injuries and illnesses, in particular MSDs, could be underestimated due to various reasons. For example, the numbers reported in this study are less likely to cover MSDs caused by accumulative job exposures since it is more difficult to establish work-relatedness for such cases than for cases from acute and traumatic injuries. In fact, many cases of MSDs may have no clear causal relations to an individual's work, especially for construction workers who are mobile and can work for a number of employers at different locations within a short time period. In addition, employers and employees may under-report MSDs willingly or unwillingly.[26 27] Moreover, the OSHA recordkeeping regulation changes may partially contribute to the injury decline during the study period.[28]

The study found that the rate of WMSDs increased with age until age 55 years, and then declined among older age groups (table 3). Other studies have observed a similar pattern with age.[9] One of the explanations could be that older workers who continue employment in the construction industry might move to positions such as foreman, with reduced work exposures and WMSD risk. Moreover, the possibility of a healthy worker survivor effect in construction should be

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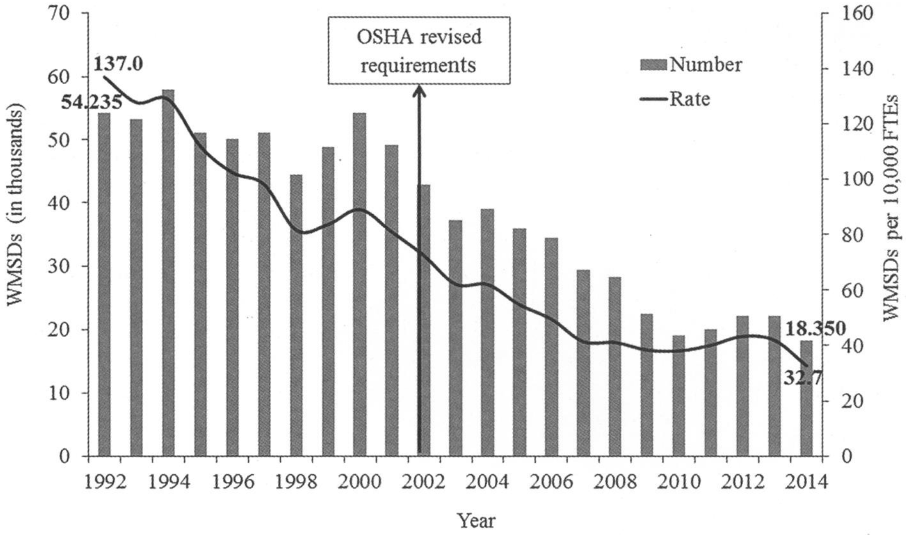

Figure 1 Number and rate of work-related musculoskeletal disorders in construction, 1992–2014. FTEs, full-time equivalent workers; WMSDs, work-related musculoskeletal disorders.

Table 1 Distribution of WMSDs in construction by age group and race/ethnicity, 2003–2014

	2003–2007		2008–2010		2011–2014	
	Number	Per cent	Number	Per cent	Number	Per cent
Age (in years)						
16–19	2100	1.2	430	0.6	860	1.0
20–24	17 690	10.1	4870	7.0	5100	6.2
25–34	51 670	29.4	21 060	30.1	20 410	24.7
35–44	53 310	30.3	20 030	28.6	23 170	28.0
45–54	37 240	21.2	16 780	24.0	21 990	26.6
55–64	11 240	6.4	6100	8.7	9510	11.5
65+	880	0.5	310	0.4	410	0.5
Age not reported	1850	1.1	400	0.6	1180	1.4
Race/ethnicity						
White	108 760	61.8	42 160	60.2	47 990	58.1
Hispanic or Latino	27 540	15.6	10 930	15.6	12 730	15.4
African-American	6020	3.4	2460	3.5	1880	2.3
Other	2450	1.4	1100	1.6	1130	1.4
Race not reported	31 100	17.7	13 310	19.0	18 890	22.9
Total	176 000	100.0	69 990	100.0	82 630	100.0

Source: US Bureau of Labor Statistics, 2003–2014 Survey of Occupational Injuries and Illnesses.
WMSDs, work-related musculoskeletal disorders.

considered as some older workers might have left the construction workforce due to health concerns, such as work-related disability or inability to perform the demanding tasks associated with construction; or those older workers who remain in their jobs have coped better with their tasks/work than younger ones.[13]

The growing proportion of WMSDs among older workers reflects the ageing workforce in the construction industry. Coupled with the increasing overall median days away from work due to WMSDs suggests a pattern consistent with longer recovery times among older workers experiencing WMSDs.[29] Research has found that MSDs were the leading reason for occupational disability in all age categories and a strong trend in the risk of disability with increasing age.[30] A review of the literature highlighted that older workers are more susceptible to WMSDs than younger workers because of decreased functional capacity, and the risk of injury was more related to the difference between the demands of work and the worker's physical work capacity rather than age.[31] While this study did not analyse costs by age group, previous research found that delayed return to work following an injury among older workers increased compensation costs.[32 33] Given the continuing trends of the ageing workforce,[34] preventative ergonomic interventions should target older workers in construction to promote healthy ageing at work.

Ergonomic interventions should meet the needs of workers through redesigned tools, adjusted tasks and improved working environments.[35 36] Since ergonomic hazards vary from job to job as well as site to site, ergonomic solutions must be job-specific and site-specific. Such solutions range from simple tool modifications such as ergonomic tool belts (http://www.cpwrconstructionsolutions.org) and full-fingered antivibration gloves,[37 38] to elaborate ergonomic material handling/lifting devices or automation of construction processes.[1 8 37] Resources for practical ergonomic interventions, for example, Solutions for Home Building Workers,[6] Simple Solutions: Ergonomics for

Table 2 Incidence rate of WMSDs in construction by age group and race/ethnicity, 2003–2014

				Average of 2003–2014			
					95% CI		
	Average of 2003–2007 Rate*	Average of 2008–2010 Rate*	Average of 2011–2014 Rate*	Rate*	Lower	Upper	Risk index†
Age group (in years)							
16–19	22.9	15.2	24.3	21.4	12.3	34.2	0.47
20–24	42.5	27.1	28.3	33.9	27.5	41.3	0.75
25–34	53.2	41.3	35.3	44.2	39.1	49.8	0.97
35–44	62.3	42.8	43.9	51.3	45.3	57.8	1.13
45–54	58.5	43.1	47.1	50.8	44.4	58.0	1.12
55–64	45.8	34.0	37.8	40.2	32.7	48.9	0.88
65+	21.1	9.7	8.8	14.1	6.5	25.0	0.31
Race/ethnicity							
White	62.0	45.3	46.4	52.6	48.4	57.0	1.16
Hispanic or Latino	38.7	28.0	28.1	32.5	28.0	37.4	0.71
African-American	42.3	36.3	25.5	35.2	25.9	47.0	0.77
Other	32.0	34.6	21.8	26.8	12.8	44.9	0.59
Total	53.9	39.2	39.5	45.4	42.2	48.8	1.00

Source: US Bureau of Labor Statistics, 2003–2014 Survey of Occupational Injuries and Illnesses; 2003–2014 Current Population Survey.
Note: Only private wage-and-salary workers were included.
*Rates are number of injuries per 10 000 FTEs.
†The average risk of WMSDs between 2003 and 2014 was used as the reference (risk=1).
FTEs, full-time equivalent workers; WMSDs, work-related musculoskeletal disorders.

Table 3 Number and incidence rate of WMSDs in construction, selected occupations, 2011–2014

	Number of WMSDs		Incidence rate of WMSDs			
				95% CI		
Occupation	2011–2014 total	Per cent	2011–2014 average rate*	Lower	Upper	Risk index†
Helper	1520	1.8	100.9	53.0	192.6	2.56
Heating A/C mechanic	6800	8.2	98.9	73.3	132.8	2.50
Cement mason	1290	1.6	86.3	45.4	162.5	2.19
Sheet metal	1110	1.3	86.2	42.1	173.3	2.18
Ironworker	850	1.0	72.9	32.1	159.5	1.85
Plumber	6740	8.2	61.9	46.8	80.6	1.57
Power line installer	390	0.5	61.1	17.3	180.9	1.55
Truck driver	2300	2.8	53.1	33.7	80.7	1.34
Carpenter	10 370	12.5	48.8	39.3	59.9	1.24
Construction labourer	15 490	18.7	47.4	39.5	56.3	1.20
Electrician	6190	7.5	46.8	35.7	60.3	1.18
Roofer	1740	2.1	39.8	24.1	62.0	1.01
Drywall	990	1.2	31.9	16.6	55.6	0.81
Foreman	4110	5.0	31.7	23.1	42.3	0.80
Brickmason	910	1.1	28.9	14.5	50.6	0.73
Painter	1830	2.2	20.6	13.2	30.2	0.52
Operating engineer	1180	1.4	17.5	10.0	27.6	0.44
Welder	400	0.5	15.6	5.2	32.8	0.39
Construction manager	670	0.8	4.5	2.2	7.3	0.11
All construction	82 670	100.0	39.5	36.1	43.0	1.00

Source: US Bureau of Labor Statistics, 2011–2014 Survey of Occupational Injuries and Illnesses; 2011–2014 Current Population Survey.
Note: Only private wage-and-salary workers were included.
*Rates are number of injuries per 10 000 FTEs.
†The average risk of WMSDs between 2011 and 2014 was used as the reference (risk=1).
FTEs, full-time equivalent workers; WMSDs, work-related musculoskeletal disorders.

Construction Workers (http://www.cdc.gov/niosh/docs/2007–122/pdfs/2007–122.pdf), CPWR's Handouts and Toolbox Talks (http://www.cpwr.com), and many other available ergonomic work practices, should be widely promoted through training, campaigns and other intervention programmes.

Previous research has shown that keeping workers physically fit has many benefits, including lower injury rates and insurance costs.[36] Furthermore, OSHA requires that employers must provide all workers with a safe, healthy place to work (https://www.osha.gov/SLTC/ergonomics/). Therefore, the role of

Table 4 Case characteristics of WMSDs, construction versus all industries, 2011–2014 total

	Construction		All industries	
	Number	Per cent	Number	Per cent
Source of injuries*				
Containers/furniture and fixtures	10 580	12.8	355 240	28.8
Machinery	5890	7.1	42 500	3.4
Parts and materials	20 200	24.4	119 490	9.7
Persons/plants/animals/minerals	27 860	33.7	551 990	44.7
Structures and surfaces	4840	5.9	23 410	1.9
Tools/instruments/equipment	10 700	12.9	68 980	5.6
Vehicles	1480	1.8	48 090	3.9
Other sources	770	0.9	18 870	1.5
Non-classifiable	340	0.4	6080	0.5
Part of body				
Head	0	0.0	620	0.1
Neck (including throat)	980	1.2	18 260	1.5
Trunk	45 280	54.8	624 950	50.6
Back injuries	35 090	42.5	513 220	41.6
Upper extremities	19 530	23.6	357 390	28.9
Lower extremities	14 310	17.3	175 440	14.2
Multiple body parts	2470	3.0	55 170	4.5
Non-classifiable	40	0.0	2840	0.2
Event and exposure				
Rubbed, abraded, or jarred by vibration	260	0.3	1850	0.1
Overexertion and bodily reaction—unspecified	2300	2.8	32 500	2.6
Overexertion involving outside sources	54 010	65.3	836 770	67.8
Repetitive motions involving microtasks	2890	3.5	97 410	7.9
Other exertions or bodily reactions	22 780	27.6	260 030	21.1
Multiple types of overexertions and bodily reactions	420	0.5	6100	0.5
Length of service				
Less than 3 months	7470	9.0	93 760	7.6
3–12 months	13 510	16.3	206 470	16.7
1–5 years	25 690	31.1	420 340	34.0
Over 5 years	29 440	35.6	497 900	40.3
Not reported	6570	7.9	16 200	1.3
Total	82 670	100.0	1 234 670	100.0

Source: US Bureau of Labor Statistics, 2011–2014 Survey of Occupational Injuries and Illnesses.
Note: Only private wage-and-salary workers were included.
*For WMSDs, this injury source is associated with stresses or strains induced by free movement of the body or its parts, with no impact involved, associated with exposure of bodily reaction, repetitive motion or sustained viewing (http://www.bls.gov/iif/oshwc/osh/os/osh06_appd.pdf).
WMSDs, work-related musculoskeletal disorders.

employers is extremely important for reducing WMSDs and overall work-related injuries and illnesses. For example, construction employers can establish a task-specific programme that may limit the weight an individual should lift or carry at one time and the maximum carry distance and adjust it accordingly for older workers and those with medical conditions (http://www.hse.gov.uk/msd/faq-manhand.htm#manual).

As with other WMSD studies, this study has strengths and limitations. A major strength was the use of large nationally representative data sets that had a better representation of construction trades and age groups than small samples. In addition, the long study period provided a relatively comprehensive picture of the WMSDs in construction over time. The stratified analysis identified workers with a higher risk of WMSDs, as well as found issues related to ageing, which may provide a basis for future research and prevention priorities of WMSDs.

Using national survey data also has limitations. Although the missing values for race/ethnicity from the SOII were adjusted in this study, misclassification could exist if the data were not missing at random. In addition to the potential underestimate aforementioned, undercounting may be more common among Hispanic workers,[39] which might partially explain the lower rate of WMSDs among Hispanic construction workers reported in this study. While the number of WMSDs could be under-reported, the FTEs from the CPS may be overestimated; each could result in underestimating the real risk of WMSDs in construction. In addition, self-employed workers are excluded from this study. Previous research shows that self-employed workers are much older than wage-and-salary workers in construction on average,[2] yet the risk of WMSDs for those self-employed workers remains unknown. Moreover, owing to the strict confidentiality rules, this study did not have access to the research files of the SOII, thereby restricting data analyses (eg, unable to provide age-adjusted rates of WMSDs). Finally, there is evidence suggesting that use of work-related injury data sources for the surveillance of WMSDs may underestimate the burden of these disorders as many cases are treated through private health insurance and not reported.[40]

Despite the limitations, this study highlights the importance of preventing WMSDs among construction workers, in particular for high-risk workers. Given the prevalence of WMSDs at worksites and the increasingly ageing workforce in the USA, the significance of this study would encompass the construction industry and beyond.

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REFERENCES

1 Choi SD, Yuan L, Borchardt JG. Musculoskeletal disorders in construction: practical solutions from the literature. *Prof Saf* 2016;61:26–32.
2 CPWR—the Center for Construction Research and Training. *The construction chart book: the US construction industry and its workers*. Silver Spring, MD: CPWR—The Center for Construction Research and Training, 2013.
3 Merlino LA, Rosecrance JC, Anton D, *et al*. Symptoms of musculoskeletal disorders among apprentice construction workers. *App Occup Environ Hyg* 2003;18:57–64.
4 Goldsheyder D, Weiner SS, Nordin M, *et al*. Musculoskeletal symptom survey among cement and concrete workers. *Work* 2004;23:111–21.
5 Kittusamy NK, Buchholz B. Whole-body vibration and postural stress among operators of construction equipment: a literature review. *J Safety Res* 2004;35:255–61.
6 National Institute for Occupational Safety and Health. Simple solutions for home building workers. DHHS (NIOSH) Publication Number 2013–111. 2013. http://www.cdc.gov/niosh/docs/2013-111/ (accessed Apr 2016).
7 Boschman JS, Van Der Molen HF, Sluiter JK, *et al*. Musculoskeletal disorders among construction workers: a one-year follow-up study. *BMC Musculoskelet Disord* 2012;13:26–32.
8 Choi SD. Safety and ergonomic considerations for an ageing workforce in the US construction industry. *Work* 2009;33:307–15.
9 Holmstrom E, and Engholm G. Musculoskeletal disorders in relation to age and occupation in Swedish construction workers. *Am J Ind Med* 2003;44:377–84.
10 Dong XS, Wang X, Fujimoto A, *et al*. Chronic back pain among older construction workers in the United States: a longitudinal study. *Int J Occup Environ Health* 2012;18:99–109.
11 Ueno S, Hisanaga N, Jonai H, *et al*. Association between musculoskeletal pain in Japanese construction workers and job, age, alcohol consumption, and smoking. *Ind Health* 1999;37:449–56.
12 Engholm G, Holmström E. Dose–response associations between musculoskeletal disorders and physical and psychosocial factors among construction workers. *Scand J Work Environ Health* 2005;31(Suppl 2):57–67.
13 Widanarko B, Legg S, Stevenson M, *et al*. Prevalence of musculoskeletal symptoms in relation to gender, age, and occupational/industrial group. *Int J Ind Ergon* 2011;41:561–72.
14 Halim I, Abdullah R, Ismail AR. A survey on work-related musculoskeletal disorders (WMSDs) among construction workers. *J Occu Saf Health* 2012;9:1–6.
15 Rwamamara RA, Lagerqvist O, Olofsson T, *et al*. Evidence-based prevention of work-related musculoskeletal injuries in construction industry. *J Civil Eng Manag* 2010;16:499–509.
16 Choi SD, Hudson L, Kangas P, *et al*. Occupational ergonomics issues in highway construction surveyed in Wisconsin, United States. *Ind Health* 2007;45:487–93.
17 Kim SS, Perry MJ, Okechukwu CA. Association between perceived union connection and upper body musculoskeletal pains among unionized construction apprentices. *Am J Ind Med* 2013;56:189–96.
18 McGaha J, Miller K, Descatha A, *et al*. Exploring physical exposures and identifying high-risk work tasks within the floor layer trade. *Appl Ergon* 2014;45:857–64.
19 Visser S, Van Der Molen HF, Kuijer PP, *et al*. Evaluation of two working methods for screed floor layers on musculoskeletal symptoms, work demands and workload. *Ergonomics* 2013;56:69–78.
20 Moriguchi CS, Carnazn L, Veiersted KB, *et al*. Occupational posture exposure among construction electricians. *Appl Ergon* 2013;44:86–92.
21 Van Der Molen HF, Kuijer PPFM, Hopmans PPW, *et al*. Effect of block weight on work demands and physical workload during masonry work. *Ergonomics* 2008;51:355–66.
22 Little RJA, Rubin BB. *Statistical analysis with missing data*. 2nd edn. New York, NY: John Wiley and Sons, 2002.
23 Robinson JP, Godbey G. *Time for life: the surprising ways Americans use their time, University Park*. PA: Pennsylvania State University Press, 1997.
24 Lohr SL. Complex survey. In: Lohr SL. *Sampling: design and analysis*. 2nd edn. Boston, MA: Brooks/Cole, 2010:281–319.
25 Lin TC, Marucci-Wellman HR, Willetts JL, *et al*. Combining statistics from two national complex surveys to estimate injury rates per hour exposed and variance by activity in the USA. *Inj Prev* 2016;22:427–431.
26 Dong XS, Fujimoto A, Ringen K, *et al*. Injury underreporting among small establishments in the construction industry. *Am J Ind Med* 2011;54:339–49.
27 Wuellner SE, Bonauto DK. Exploring the relationship between employer recordkeeping and underreporting in the BLS Survey of Occupational Injuries and Illnesses. *Am J Ind Med* 2014;57:1133–43.
28 Friedman LS, Linda F. The impact of OSHA recordkeeping regulation changes on occupational injury and illness trends in the US: a time-series analysis. *Occup Environ Med* 2007;64:454–60.
29 Peek-Asa C, McArthur DL, Kraus JF. Incidence of acute low-back injury among older workers in a cohort of material handlers. *J Occup Environ Hyg* 2004; 1:551–7.
30 Arndt V, Rothenbacher D, Daniel U, *et al*. Construction work and risk of occupational disability: a ten-year follow-up of 14,474 male workers. *Occup Environ Med* 2005;62:559–66.
31 Okunribido O, Wynn T. *Ageing and work-related musculoskeletal disorders: a review of the recent literature*. UK: Health and Safety Executive, Health and Safety Laboratory, 2010.
32 Kucera KL, Lipscomb HJ, Silverstein B, *et al*. Predictors of delayed return to work after back injury: a case–control analysis of union carpenters in Washington State. *Am J Ind Med* 2009;52:821–30.
33 Schwatka NV, Butler LM, Rosecrance JC. Age in relation to worker compensation costs in the construction industry. *Am J Ind Med* 2013;56:356–66.
34 US Bureau of Labor Statistics. Employment projection, 2014–2024. BLS news release, December 2015, USDL-15–2327. http://www.bls.gov/news.release/pdf/ecopro.pdf (accessed May 2016).
35 Choi SD, Borchardt J, Proksch T. Translating academic research on manual lifting tasks observations into construction workplace good practices. *J Saf Health Environ Res* 2012;8:3–10.
36 Kowalski-Trakofler KM, Stiener LJ, Schwerha DJ. Safety considerations for the ageing workforce. *Saf Sci* 2005;43:779–93.
37 Albers J, Estill C, MacDonald L. Identification of ergonomics interventions used to reduce musculoskeletal loading for building installation tasks. *Appl Ergon* 2005;36:427–39.
38 Eastman Kodak Company. *Kodak's ergonomic design for people at work*. 2nd edn. Hoboken, NJ: John Wiley and Sons, , 2004.
39 Dong XS, Men Y, Ringen K. Work-related injuries among Hispanic construction workers—evidence from the Medical Expenditure Panel Survey. *Am J Ind Med* 2010;53:561–9.
40 Lipscomb HJ, Dement JM, Silverstein B, *et al*. Who is paying the bills? Healthcare costs for musculoskeletal back disorders, Washington State Union Carpenters, 1989–2003. *J Occup Environ Med* 2009;51:1185–92.