

(eg, occupational bursitis). To improve the sensitivity of our coding scheme for detecting nontraumatic knee disorders, we also included nontraumatic disorders that had codes for body parts near the knee (eg, leg), or the knee itself, in addition to knee-specific ICD-9 codes (eg, patellar tendinitis). The validity of the coding scheme was evaluated in a medical records abstraction exercise. One investigator (J.T.S.) reviewed the medical records of a random sample of 100 Washington State Fund knee WMSD claims, as defined in the Appendix (<http://links.lww.com/JOM/A51>). The assessment provided by the claimant's health care provider was consistent with the case definition in approximately 89% of these claims.

Data Abstraction

Data on claims were extracted from L&I databases on August 10, 2009. The L&I claims management database consists of two main data processing systems: the Medical Information and Payment System, which receives all billing information generated by provider bills, and the L&I Industrial Insurance System, which contains data necessary for the administration of state fund claims. Extracted information included date of injury, sex, date of birth, height and weight (self-reported at claim opening and available for 86% of the state fund compensable claims), 4-digit Washington Industrial Codes, 6-digit North American Industrial Classification System codes, six digit Standard Occupational Classification codes, procedure (Current Procedural Terminology) codes, claim status (compensable lost time claim [four or more days of time loss] versus medical treatment only claim codes), lost time days for compensable claims (mean from 1999 to 2007), total costs of claims, time loss payments, dollar amount of medical aid payments, and payroll hours (self-reported by state fund employers).

Number of employees per year was calculated assuming each full-time employee works 2000 hours per year (40 hours per week for 50 weeks per year). Hours were converted to full time equivalent workers (FTEs) as total hours reported/2,000. Body mass index was calculated as (weight [kg]/height [m]²). Obesity was defined as a body mass index of 30 or greater.⁴² Total costs of claims reflected actual totals for closed claims. For state fund claims that were not closed, costs reflected actual totals plus the additional case reserve, as estimated by agency staff. For work-related knee disorder claims, approximately 2.7% and 5.5% of accepted and compensable claims, respectively, were still open, compared with 2.3% and 5.7% of WMSD claims and 1.4% and 5.1% of all claims. All bills were adjusted using the Consumer Price Index for Urban Wage Earners and Clerical Workers for Seattle-Tacoma-Bremerton, Washington. Bills were adjusted on a simplified basis using the date of injury as the "payment date" for all bills. Incurred Medical costs were adjusted using the Medical Care Series (ID CWURA423SAM, CWUSA423SAM) while all other costs were adjusted using all items except Medical Care Series (ID CWURA423SA0L5, CWUSA423SA0L5). Time loss days are paid on a 7-day workweek. While the initial pension reserve is included as part of the total incurred costs, L&I stops counting time loss days as of the date a worker is moved to the pension rolls. Lost workdays are not reflected as time loss days when an employee is kept on salary. All costs and payments were in dollar amounts.

Claims incidence rates (CIRs) were calculated by year and industry class and are expressed as number of claims per 10,000 FTEs. To eliminate unstable rates, only those North American Industrial Classification System codes with a mean of 50 FTEs per year or more and those Washington Industrial Codes with a mean of 50 employees per year over the 9-year period were included in the industry analysis. Incidence rates were estimated by age and sex using the Quarterly Workforce Indicators from the US Census Bureau to determine the number of employees (rather than FTEs). Each industry code-specific rate was compared with the industry-wide rate, and a crude incidence rate ratio was calculated. A prevention index was calculated for each industry by adding the frequency rank (rank

order number of the frequency of claims) and incidence rank (rank order of incidence rates) and dividing the sum by 2.

Diagnosis Groups and Procedures

The percentage of knee WMSD claims with any ICD-9 codes corresponding to the following a priori diagnosis groups was examined: "meniscal/ligamentous disruption" (ICD-9 717, 717.0 to 717.4, 717.40 to 717.43, 717.49, 717.5 to 6, 717.8, 717.81 to 717.85, 717.89, 836.0 to 836.2), "sprain/strain" (ICD-9 844, 844.0 to 3, 844.8 to 9), "tendinitis/bursitis/enthesopathy" (ICD-9 726.6, 726.60 to 65, or 726.69), "chondromalacia patellae" (ICD-9 717.7), "ganglion/cyst" (ICD-9 727.4, 727.40 to 43, 727.49, 727.51), and "synovitis" (ICD-9 727, 727.0, 727.00, 727.01, 727.09, 727.83). An additional subset of knee WMSD case claims, designed to be most consistent with the existing ergonomic principle of cumulative trauma,⁴³ was also examined. The cases in this subset were defined as those with ICD-9 codes for tendinitis, bursitis, or enthesopathy (726.6, 726.60 to 65, or 726.69) that did not have secondary ICD-9 codes that reflected ligamentous, tendinous, or meniscal disruptions (717, 717.0 to 717.4, 717.40 to 717.43, 717.49, 717.5 to 6, 717.8, 717.81 to .85, 717.89, 727.6, 727.60, 727.66, 727.69, 836.0 to 836.2). Diagnosis codes corresponding to degenerative arthritis were not considered, because arthritis is rarely deemed to be a work-related condition in Washington State. Knee arthroscopic surgery procedures were identified by current procedural terminology codes (29866 to 29887).

Statistical Analyses

To obtain estimates of yearly changes in CIRs, Poisson regression models of log counts of claims were fit using the log of the denominator (10,000 FTEs) as an offset variable with year as a continuous variable. The coefficient for year in the Poisson models was exponentiated, to obtain the factor of expected yearly decrease in CIR, and then subtracted from one, to obtain the percent of yearly decline in CIRs. Corresponding *P* values from the Wald Chi-Square test were reported.

To compare differences in CIRs in different case groups, Poisson models of log counts of claims were fit with year as a continuous variable, case group as a categorical variable, an interaction term for year and group (year × group), and the log of the denominator as the offset variable. Two models were run: one comparing the "cumulative trauma knee WMSDs" case group with the "remaining knee WMSDs" case group and another comparing the "cumulative trauma knee WMSDs" case group with the "all other WMSDs" case group. Wald Chi-Square *P* values for year × group interaction coefficients were reported. Standard errors were adjusted for over-dispersion as a ratio of the Pearson Chi-Square to its associated degrees of freedom.

The odds of arthroscopic surgery was estimated using logistic regression models adjusted for age, sex, and obesity status (obese/nonobese). Pearson and deviance goodness-of-fit tests were used. All analyses were performed using SAS Software (SAS Proprietary Software Version 9.1, SAS Institute Inc., Cary, NC).

RESULTS

Burden of Knee WMSDs

There were 24,490 total knee WMSD Washington State Fund claims costing about \$494 million between 1999 and 2007 (Table 1). Knee WMSD claims represented about 2% of all state fund accepted claims, 7% of all WMSD claims, and about 10% of WMSD costs. Knee WMSDs in the cumulative trauma subset were responsible for 8% of total knee WMSD claims and \$11.9 million (2.4%) of total knee WMSD direct costs. Of all accepted knee WMSD claims, about half were medical only and half were compensable, and about two-thirds of cumulative trauma knee WMSDs were medical only. The percentage of total direct costs attributable to compensable knee WMSD versus medical only knee WMSD claims was

TABLE 1. Knee Work-Related Musculoskeletal Disorder Workers' Compensation Claims, 1999–2007

	All Claims Total	Total Work-Related Musculoskeletal Disorder			Knee Work-Related Musculoskeletal Disorder		
		Compensable	Medical Aid Only	Total	Compensable	Medical Aid Only	Total
Total claims, 1999–2007	1,168,618	124,211	219,478	343,689	11,976	12,514	24,490
Percent of all claims	100.0	10.6	18.8	29.4	1.0	1.1	2.1
Percent of accepted claims		36.1	63.9	100.0	48.9	51.1	100.0
Total direct cost (millions of dollars), 1999–2007	10,990.7	4,833.2	286.0	5,119.2	477.8	16.6	494.4
Mean total number of claims per year	129,846	13,801	24,386	38,188	1,331	1,390	2,721
Percent female	33.0	35.6	37.2	36.9	24.5	28.1	26.5
Median age	36	40	36	38	42	39	41
Median body mass index (kg/m ²)	26.9	27.4	27.1	27.3	28.7	28.2	28.4
Median months on the job	12	18	18	18	18	21	19
Mean yearly claim rate per 10,000 full-time equivalents	861.9	91.9	162.6	254.4	8.9	9.3	18.2
Mean time loss (days)	198.2	232.5			212.7		
Median time loss (days)	36	47			54		
Mean total direct cost per claim (\$)	9,508	38,950	1,361	15,313	39,901	1,333	20,222
Median total direct cost per claim (\$)	539	8,778	522	1,145	12,744	487	1,900

96.6%. The mean number of state fund knee WMSD claims was 2721 per year, averaging \$20,222 per claim. The mean number of cumulative trauma knee WMSD claims was 212 per year, averaging \$6252 per claim. The median cost per knee WMSD claim, however, was \$1900, consistent with a right-skewed cost distribution. The mean total direct cost per knee WMSD claim was about 30 times higher for compensable versus medical only claims. The mean (median) compensable lost workdays for knee WMSDs was 212.7 (54). This is in comparison to 198.2 (36) for all claims, 232.5 (47) for all WMSD claims, and 116.0 (22) for all cumulative trauma knee WMSD claims.

The mean yearly CIR was 18.2 per 10,000 FTEs for all knee WMSDs and 1.4 per 10,000 FTEs for cumulative trauma knee WMSDs. There was a decrease in compensable CIRs for knee WMSDs between 1999 and 2007 (Fig. 1). The yearly rate of decline of CIRs for cumulative trauma knee WMSDs was 5.7% ($P < 0.0001$). There was no significant difference in the rate of decline for cumulative trauma knee WMSDs compared with the remaining knee WMSDs ($P = 0.84$) or cumulative trauma knee WMSDs compared with all other WMSDs ($P = 0.81$).

Claimant Characteristics

Approximately 27% of all knee WMSD claimants, 37% of all WMSD claimants, and 15.6% of cumulative trauma knee WMSD claimants were female. Median ages of claimants in different categories of knee WMSDs were similar (range = 39 to 42). The median BMI was similar for compensable and medical only knee WMSD claims (range = 28.2 to 28.7). The median number of months on the job was 18 for compensable and 21 for medical only knee WMSD claims.

Diagnosis Groups and Procedures

The vast majority (about 86%) of knee WMSD claims fell into the “sprain” diagnosis group, followed by about 42% in the “meniscal/ligamentous disruption” group. About 12% of claims fell into the “chondromalacia patellae” group, and 11%, 3%, and 1% were “tendinitis/bursitis/enthesopathy,” “synovitis,” and “ganglion/cyst” claims, respectively. Of note, percentages do not sum to 100 because diagnosis groups are not mutually exclusive. In cumulative trauma

claimants, female sex, but not obesity or age, was associated with an increased odds of having arthroscopic knee surgery (odds ratio 3.48, 95% confidence interval 1.75 to 6.91).

Industry and Occupation

For all accepted state fund knee WMSD and compensable knee WMSD claims, building and finishing contractors and foundation, structure, and building exterior contractors were the top-two industries of concern by prevention index (Tables 2A and 2B). For cumulative trauma state fund compensable knee WMSD claims, ship and boat building was the second industry of concern followed by foundation, structure, and building exterior contractors (Tables 2C and 2D). Other top industries of concern by prevention index for all knee WMSDs were: logging; justice, public order, and safety; nursing care; waste collection; trucking; scenic and sightseeing transportation; and leather and hide tanning and finishing (Tables 2A and 2B). For cumulative trauma state fund claims, additional industries of concern by prevention index were: goods repair and maintenance; automotive stores; animal slaughtering and processing; and spectator sports (Tables 2C and 2D).

Incidence rates of state fund compensable cumulative trauma knee WMSDs by age and industry sector for males and females are shown in Figs. 2a and 2c, respectively. The compensable claims rate peaked for men at age 45 to 54 in the mining sector and at age 25 to 44 in the construction sector (Fig. 2a). For women, incidence rates peaked at age 25 to 34 in administrative support, 45 to 54 in utilities, 65 and over in accommodation/food services, and 35 to 44 in real estate (Fig. 2c). Bimodal peaks in incidence rates occurred in women in the construction (ages 19 to 24 and 45 to 54) and transportation and warehouse (19 to 24 and 55 to 64) sectors.

Incidence rates of state fund claims for all other knee WMSDs by age and industry sector for males and females are shown in Figs. 2b and 2d, respectively. The compensable claims rate peaked for men at age 14 to 18 in the mining sector and at age 35 to 44 in the construction sector (Fig. 2b). For women, incidence rates peaked at age 45 to 54 in accommodation/food services and construction and at age 55 to 64 in real estate, wholesale, transportation & warehouse, health care, retail, and utilities (Fig. 2d).

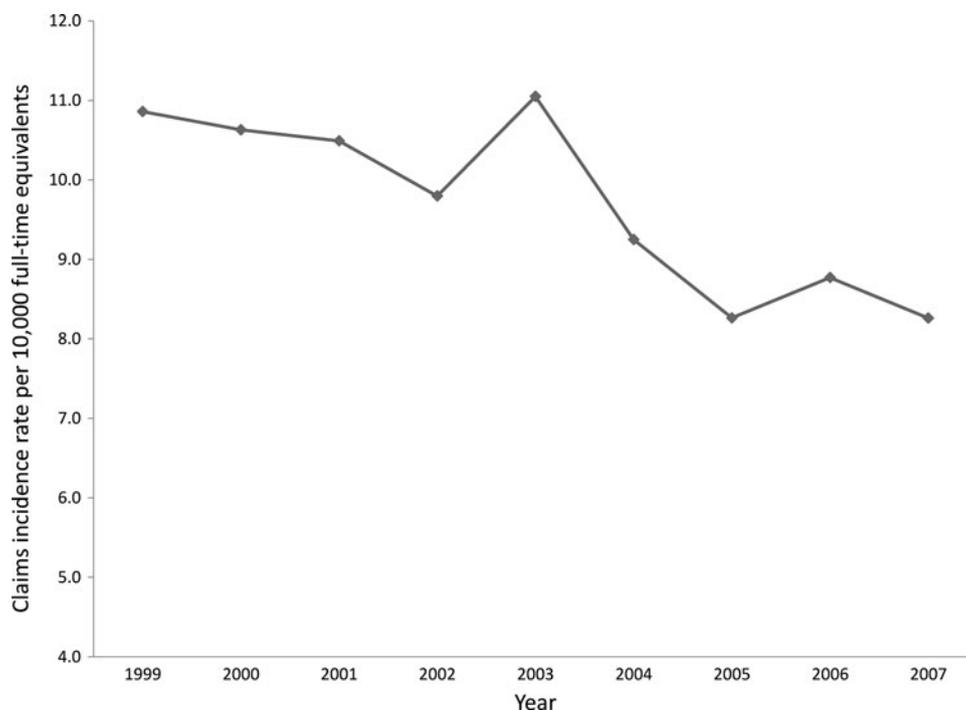


FIGURE 1. State fund compensable claims incidence rates by year for all knee work-related musculoskeletal disorders.

TABLE 2A. Top-10 Industries for Knee WMSDs by Prevention Index, Accepted State Fund Claims, 1999–2007

NAICS Code/Descriptor	Hours	Count	Lost Days	Incidence Rate*	Rate Ratio	Severity Rate*	Rate Rank	Count Rank	Prevention Index
2381 Foundation, structure, and building exterior contractors	448,080,678	1315	159,243	58.7	2.76	7107.8	15	2	8.5
2383 Building finishing contractors	258,391,446	782	101,830	60.5	2.85	7881.8	13	4	8.5
2382 Building equipment contractors	624,936,450	1718	395,722	55.0	2.58	12664.4	21	1	11
2361 Residential building construction	323,788,612	822	96,646	50.8	2.39	5969.7	26	3	14.5
1133 Logging	62,461,165	256	40,786	82.0	3.85	13059.6	5	26	15.5
9221 Justice, public order, and safety activities	302,747,864	677	43,359	44.7	2.10	2864.4	38	6	22
6231 Nursing care facilities	182,268,689	424	30,798	46.5	2.19	3379.4	33	12	22.5
5621 Waste collection	38,129,686	152	12,189	79.7	3.75	6393.4	7	41	24
4841 General freight trucking	163,825,837	382	49,944	46.6	2.19	6097.2	32	17	24.5
2362 Nonresidential building construction	165,059,747	379	52,094	45.9	2.16	6312.1	34	18	26
†4872 Scenic and sightseeing transportation, water	1,371,706	9	388	131.2	6.17	5657.2	2	232	117
†3161 Leather and hide tanning and finishing	469374	2	0	85.2	4.01	0.0	3	279	141

NAICS, North American industrial classification system; WMSD, work-related musculoskeletal disorder.

*Incidence rates and severity rates (lost days) are per 10,000 full-time equivalents.

†Because the prevention index is an average of two ranks, it is possible that a very small industry with a high claims incidence rate or an industry with a large population but a low incidence rate would not have a high prevention index. We therefore included the top-three industries by either count or rate unless the industry was already within the body of the table.

The top-15 classifiable occupations by percent of compensable knee WMSD state fund claims are listed in Table 3. About 20% of occupations were coded as nonclassifiable. The top-two occupations for men were carpenters and truck drivers and for women were nursing aides and housekeepers (Table 3A). A similar distribution of occupations by sex was seen for all accepted knee WMSD claims. Carpet installers and floor layers were ranked among the top-15 occupations (No. 8 and No. 15, respectively) for cumulative trauma

knee WMSD claims (Table 3B) but not for all WMSD knee claims. Carpenters were the most represented occupation for knee WMSDs and cumulative trauma knee WMSDs.

DISCUSSION

In this descriptive study of knee WMSDs using Washington workers' compensation state fund data between 1999 and 2007, knee WMSDs were associated with substantial costs and morbidity.

TABLE 2B. Top-10 Industries for Knee WMSDs by Prevention Index, Compensable State Fund Claims, 1999–2007

NAICS Code/Descriptor	Hours	Count	Lost Days	Incidence Rate*	Rate Ratio	Severity Rate*	Rate Rank	Count Rank	Prevention Index
2383 Building finishing contractors	258,391,446.4	434	101,826	34	3.515773	7881.53	10	4	7
2381 Foundation, structure, and building exterior contractors	448,080,677.5	712	159,234	32	3.326082	7107.381	13	2	7.5
2382 Building equipment contractors	624,936,450.3	904	395,711	29	3.027902	12664.04	17	1	9
2361 Residential building construction	323,788,611.9	461	96,581	28	2.980222	5965.682	18	3	10.5
1133 Logging	62,461,165.1	168	40,786	54	5.63	13059.63	3	19	11
4841 General freight trucking	163,825,837	228	49,944	28	2.913142	6097.207	21	9	15
9221 Justice, public order, and safety activities	302,747,864	361	43,338	24	2.495947	2862.976	29	5	17
2389 Other specialty trade contractors	167,571,108.2	214	36,809	26	2.673153	4393.239	25	11	18
4842 Specialized freight trucking	95,582,075	142	36,645	30	3.109719	7667.756	16	25	20.5
5621 Waste collection	38,129,686.44	73	12,188	38	4.007456	6392.919	6	39	22.5
†4872 Scenic and sightseeing transportation, water	1,371,706	4	388	58	6.10391	5657.189	2	227	114.5

NAICS, North American industrial classification system; WMSD, work-related musculoskeletal disorder.

*Incidence rates and severity rates (lost days) are per 10,000 full-time equivalents.

†Because the prevention index is an average of two ranks, it is possible that a very small industry with a high claims incidence rate or an industry with a large population but a low incidence rate would not have a high prevention index. We therefore included the top-three industries by either count or rate unless the industry was already within the body of the table.

TABLE 2C. Top-10 Industries for Cumulative Trauma Knee WMSDs by Prevention Index, Accepted state fund Claims, 1999–2007

NAICS Code/Descriptor	Hours	Count	Lost Days	Incidence Rate*	Rate Ratio	Severity Rate*	Rate Rank	Count Rank	Prevention Index
2383 Building finishing contractors	258,391,446.4	161	4387	12.46171	7.891521	339.5623	3	3	3
2381 Foundation, structure, and building exterior contractors	448,080,677.5	207	7041	9.239408	5.850959	314.2738	6	2	4
2382 Building equipment contractors	624,936,450.3	256	5067	8.192833	5.188204	162.1605	10	1	5.5
2361 Residential building construction	323,788,611.9	113	1343	6.979863	4.420077	82.95536	14	4	9
3366 Ship and boat building	33,854,903	19	2059	11.22437	7.10796	1216.367	4	21	12.5
4422 Home furnishings stores	72,582,069	27	317	7.439854	4.711372	87.3494	11	16	13.5
7112 Spectator sports	8,052,875	12	0	29.80302	18.8731	0	1	37	19
8114 Personal and household goods repair and maintenance	30,670,238.05	13	305	8.477274	5.368329	198.8899	9	33	21
4413 Automotive parts, accessories, and tire stores	119,735,860	28	77	4.676961	2.961739	12.86164	28	15	21.5
1133 Logging	62,461,165.1	18	1276	5.763581	3.649853	408.5739	20	24	22
†4871 Scenic and sightseeing transportation, land	1,540,676	1	0	12.98131	8.220564	0	2	171	86.5

NAICS, North American industrial classification system; WMSD, work-related musculoskeletal disorder.

*Incidence rates and severity rates (lost days) are per 10,000 full-time equivalents.

†Because the prevention index is an average of two ranks, it is possible that a very small industry with a high claims incidence rate or an industry with a large population but a low incidence rate would not have a high prevention index. We therefore included the top-three industries by either count or rate unless the industry was already within the body of the table.

Knee WMSDs accounted for 7% of all WMSD claims and 10% of WMSD costs. Although CIRs of knee WMSDs have declined between 1999 and 2007, the rate of decline was not significantly different comparing cumulative trauma knee WMSDs with the remaining knee WMSDs or all other WMSDs. The majority of knee WMSD claims fell into diagnosis groups representing “sprains” or “meniscal/ligamentous disruptions.” Knee WMSD claims most consistent with the traditional ergonomic definition of cumulative trauma (tendinitis, bursitis, or enthesopathy without ligamentous,

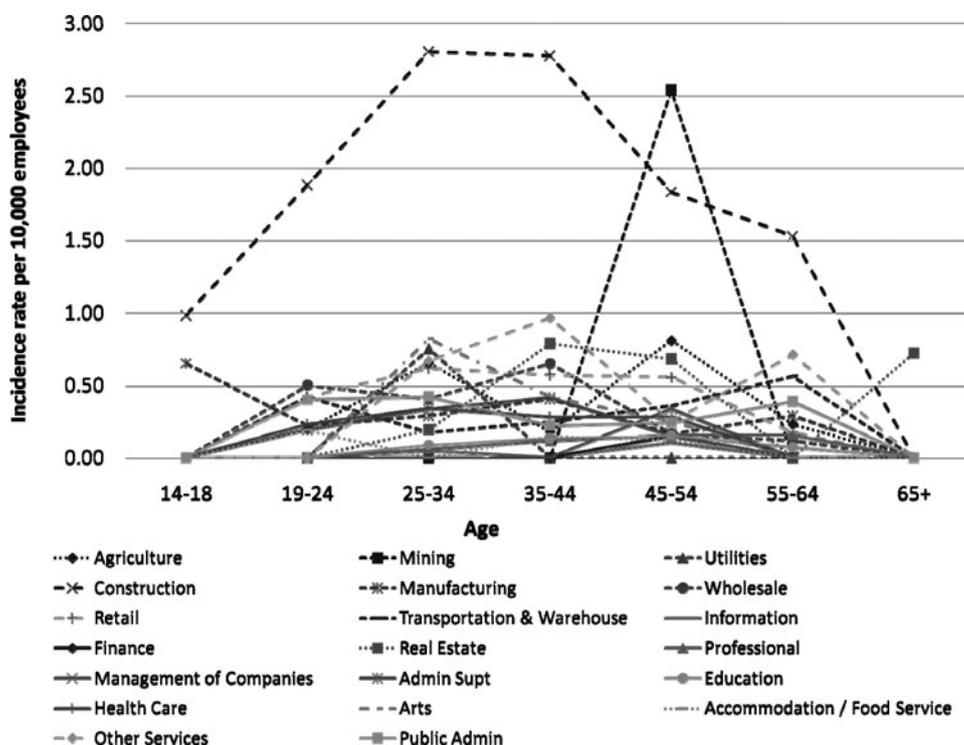
tendinous, or meniscal disruptions) were responsible for a minority of knee WMSD claims and costs. Industries at highest risk for knee WMSDs by prevention index included construction and building contractors. In general, mining and construction industries had high knee WMSD incidence rates in men, and peak incidence rates appeared to be distributed over a larger group of industry sectors by age group in women. Occupations of greatest concern included carpenters and truck drivers in men, and nursing aides and housekeepers in women.

TABLE 2D. Top-10 Industries for *Cumulative Trauma Knee WMSDs* by Prevention Index, Compensable State Fund Claims, 1999–2007

NAICS Code/Descriptor	Hours	Count	Lost Days	Incidence Rate*	Rate Ratio	Severity Rate*	Rate Rank	Count Rank	Prevention Index
2383 Building finishing contractors	258,391,446.4	60	4387	4.6441	9.470001	339.562	4	3	3.5
3366 Ship and boat building	33,854,903	9	2059	5.3168	10.84171	1216.37	2	10	6
2381 Foundation, structure, and building exterior contractors	448,080,677.5	69	7041	3.0798	6.280146	314.274	10	2	6
2382 Building equipment contractors	624,936,450.3	80	5057	2.5603	5.220728	161.84	15	1	8
4422 Home furnishings stores	72,582,069	10	317	2.7555	5.618852	87.3494	12	9	10.5
2361 Residential building construction	323,788,611.9	40	1343	2.4707	5.038199	82.9554	18	4	11
1133 Logging	62,461,165.1	8	1276	2.5616	5.223442	408.574	14	14	14
5617 Services to buildings and dwellings	315,071,074	24	4530	1.5235	3.106559	287.554	30	5	17.5
3116 Animal slaughtering and processing	25,896,636	4	469	3.0892	6.299318	362.209	9	30	19.5
8114 Personal and household goods repair and maintenance	30,670,238.05	4	305	2.6084	5.318874	198.89	13	30	21.5

NAICS, North American industrial classification system; WMSD, work-related musculoskeletal disorder.

*Incidence rates and severity rates (lost days) are per 10,000 full-time equivalents.

**FIGURE 2a.** State fund compensable *cumulative trauma* knee work-related musculoskeletal disorder claims incidence rates for males by age and industry sector.

Our findings are consistent with other published WMSD reports. A 2008 U.S. Bureau of Labor Statistics report indicates that about 30% of nonfatal occupational injuries and illnesses involving any days away from work were musculoskeletal disorders, about 8.5% involved the knee, and approximately 80% of these required 3 or more days away from work.⁴⁴ This is roughly comparable to the 1% of compensable knee WMSD claims, relative to all claims, observed in our study. Many industries and occupations found to be

at risk in our study were similar to those reported in previous studies. Male miners, floor and carpet-layers, and carpenters have been previously described as groups at high risk for knee WMSDs.^{5,14,15,24-32} Similarly, our results indicate that peak compensable cumulative trauma knee WMSD CIRs for middle-aged men and for other knee WMSDs in young men were in the mining sector. Carpenters and floor layers were ranked among the top-15 occupations for all knee and cumulative trauma knee WMSD claims, respectively, in men in

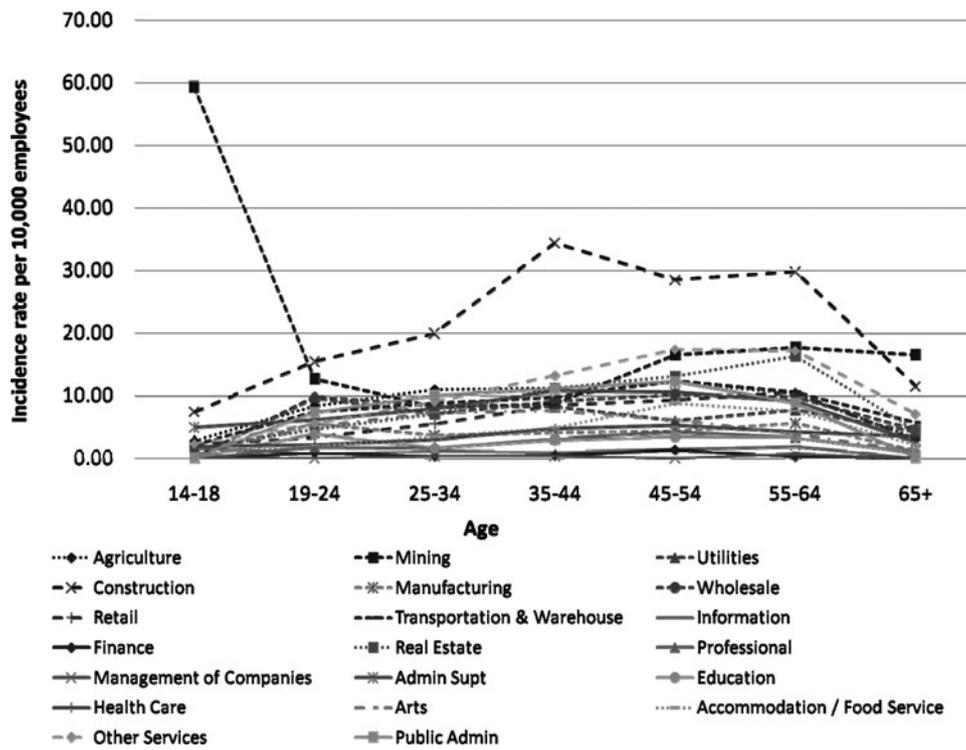


FIGURE 2b. State fund compensable non-cumulative trauma knee work-related musculoskeletal disorder claims incidence rates for males by age and industry sector.

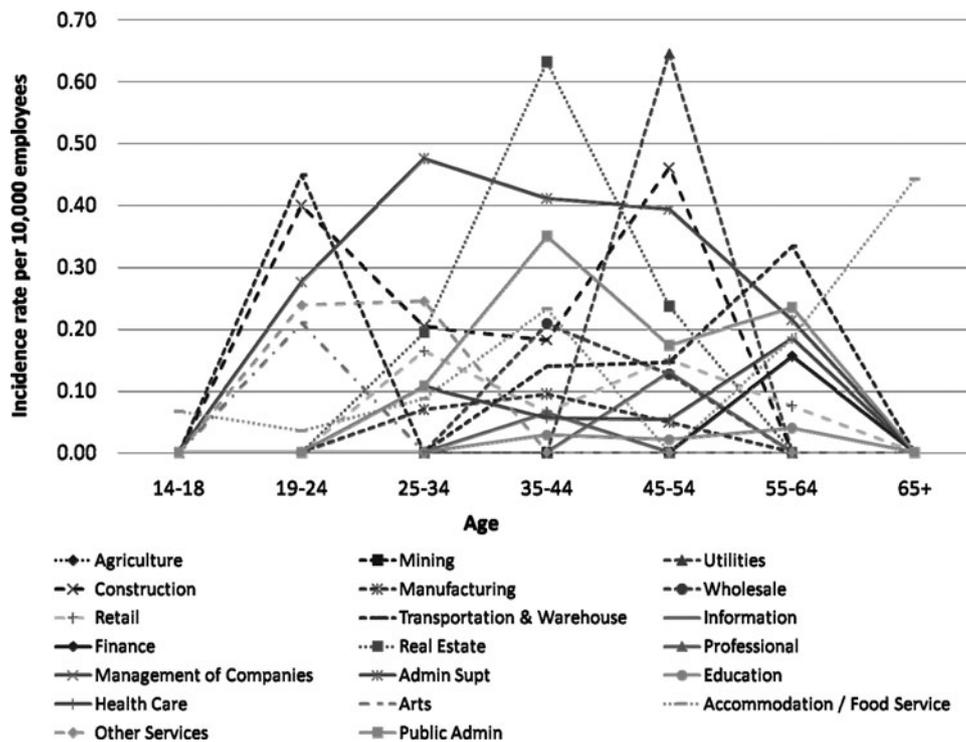


FIGURE 2c. State fund compensable cumulative trauma knee work-related musculoskeletal disorder claims incidence rates for females by age and industry sector.

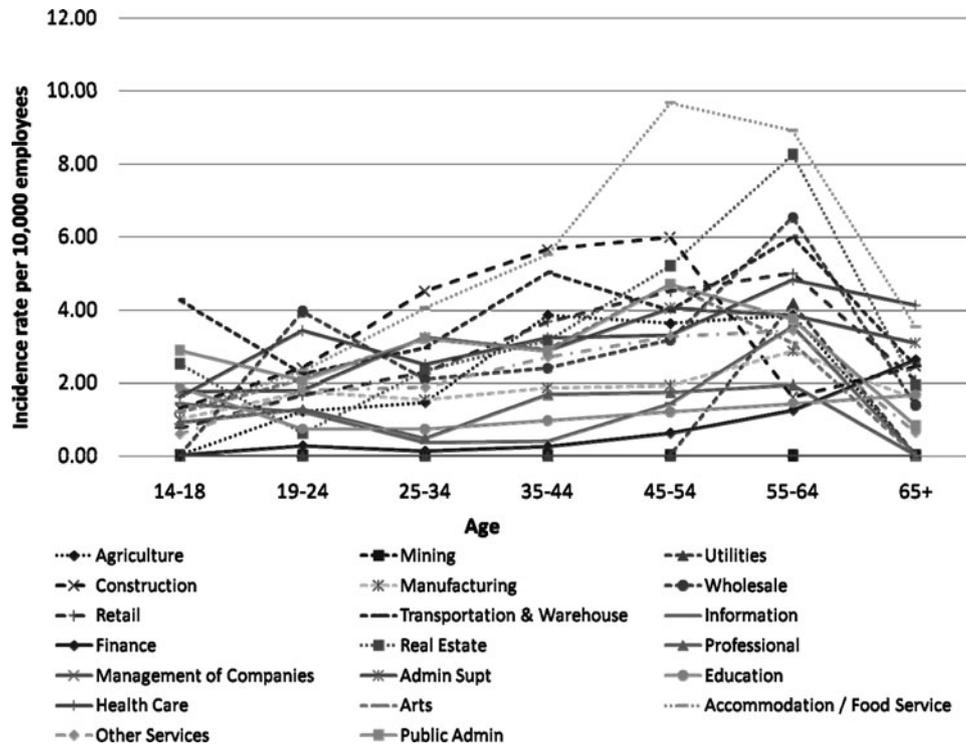


FIGURE 2d. State fund compensable non-cumulative trauma knee work-related musculoskeletal disorder claims incidence rates for females by age and industry sector.

our study. Knee disorders have also been previously described in nursing aides,²¹ an occupation that we found to be at potentially high risk for knee WMSDs.

This study also identified new areas of concern that have not previously been reported. The spectator sport industry, which includes athletes, owners of racing animals, and establishments that support sports participants, was identified as one of the top industries at risk for cumulative trauma knee WMSDs by prevention index. Although numbers of claims were small, a post-hoc investigation revealed that standard occupational classification codes with the majority of knee WMSD claims within this industry included athletes, dancers, fitness trainers and aerobics instructors, installation and maintenance, and laborers. The construction and logging industries were identified as top industries of concern for knee WMSDs in our study, yet previous studies of knee disorders in these industries have focused primarily on knee arthritis^{45,46} rather than soft tissue WMSDs. Similarly, knee arthritis in custodians has been studied,^{46,47} but few studies have been published on soft tissue knee WMSDs in custodians or housekeepers. Several other industries and occupations identified in our study as being at potentially high risk for knee WMSDs have not been described extensively in the literature. These include the building contractor and ship-building industries and electricians, where musculoskeletal hazards may be similar to those in the construction industry. Trucking, real estate (which includes property management), administrative support (which includes janitorial services), and accommodation/food services were also industries of concern.

The large proportion of knee WMSD claims that did not fall into the cumulative trauma category raises important questions about the scope of cumulative trauma knee disorders and the mechanism of development of certain knee WMSDs. For example, meniscal disruptions are not included in the traditional definition of cumulative trauma.⁴³ The degree to which certain meniscal disruptions result

from repeated trauma over time, a single traumatic exposure, an underlying degenerative disease process, or a combination of factors is often difficult to determine. The pattern of meniscal tears may provide insight into the mechanism of the tear (eg, vertical longitudinal tears often result from a single traumatic exposure), but tears can also be consistent with multiple potential mechanisms, including degenerative disease.⁴⁸ On the basis of findings reported in the biomechanical literature, it is plausible that repetitive knee bending, kneeling, squatting, and twisting may lead to substantial stress on the menisci over time.⁴⁹⁻⁵¹ Recent studies of floor-layers, who frequently kneel, compared with controls, have reported an increased odds of positive McMurray tests¹⁴ and magnetic resonance imaging-diagnosed tears of the medial meniscus³¹ after adjustment for age, body mass index, and knee straining sports.

Several strengths of this study are notable. First, we were able to analyze a large number of knee WMSD claims by cost, North American Industrial Classification System industry coding, standard occupational classification occupation coding, and claims incidence rates and trends over time. Second, use of injury nature, accident type, body part coding, and ICD-9 diagnostic codes to define knee WMSDs allowed for a case definition that was largely consistent with the health care providers' assessments.

Our study has several important limitations. First, temporary workers were not included in our analysis. However, in a post-hoc analysis of temporary service agencies using Washington Industrial Codes, construction, machine operation, and assembly were among the highest risk industries for knee WMSDs by prevention index. Second, misclassification of injury type was not completely avoided. The majority of the 11% of claims that were not consistent with health care providers' assessments were acute and traumatic in nature. Prior reports of Washington State workers' compensation data suggest that initial reporting may be biased toward acute, traumatic disorders, which tend to gain more ready acceptance in the workers'

TABLE 3A. Top-15 Classifiable Occupations for State Fund Compensable Knee WMSDs, 1999–2007

Overall				Men					Women				
SOC Code	Occupation	Number of Claims	% of Claims	SOC Code	Occupation	Number of Claims	% of Claims	% Men	SOC Code	Occupation	Number of Claims	% of Claims	% Woman
472031	Carpenters	497	4.4	472031	Carpenters	495	4.4	5.8	311012	Nursing aides, orderlies	239	2.1	8.8
537062	Laborers and freight	453	4.0	533032	Truck drivers, heavy	403	3.6	4.8	372012	Maids and housekeeping	107	1.0	3.9
533032	Truck drivers, heavy	428	3.8	537062	Laborers and freight	375	3.3	4.4	412031	Retail salespersons	86	0.8	3.2
472061	Construction craft	318	2.8	472061	Construction craft	305	2.7	3.6	412011	Cashiers	79	0.7	2.9
533033	Truck drivers, light	291	2.6	533033	Truck drivers, light	266	2.4	3.1	537062	Laborers and freight	78	0.7	2.9
471011	First-line supervisors	273	2.4	471011	First-line supervisors	266	2.4	3.1	399021	Personal & home care aides	76	0.7	2.8
311012	Nursing aides, Orderlies	262	2.3	499099	Installation, Maintenance	212	1.9	2.5	119199	Managers, all other	70	0.6	2.6
519199	Production workers	248	2.2	472111	Electricians	205	1.8	2.4	372011	Janitors and cleaners	67	0.6	2.5
499099	Installation, maintenance	224	2.0	519199	Production workers	194	1.7	2.3	353031	Waiters and waitresses	60	0.5	2.2
472111	Electricians	214	1.9	472152	Plumbers, pipefitters	165	1.5	1.9	519199	Production workers	54	0.5	2.0
119199	Managers, all other	208	1.9	119199	Managers, all other	138	1.2	1.6	411011	First-line supervisors	53	0.5	1.9
412031	Retail salespersons	193	1.7	373011	Landscaping	133	1.2	1.6	291111	Registered nurses	52	0.5	1.9
472152	Plumbers, pipefitters	167	1.5	493023	Automotive mechanics	132	1.2	1.6	351012	First-line supervisors	41	0.4	1.5
372011	Janitors and cleaners	162	1.4	514121	Welders, cutters, Solderer	117	1.0	1.4	311011	Home health aides	39	0.3	1.4
373011	Landscaping	142	1.3	412031	Retail Salespersons	107	1.0	1.3	353021	Combined food preparation	34	0.3	1.2

SOC, standard occupational classification; WMSD, work-related musculoskeletal disorder.

TABLE 3B. Top-15 Classifiable Occupations for State Fund Compensable *Cumulative Trauma* Knee WMSDs, 1999–2007

SOC Code	Occupation	Number of Claims	% of Claims
472031	Carpenters	49	7.3
471011	First-line supervisors/managers	26	3.9
472111	Electricians	26	3.9
472152	Plumbers, pipefitters	24	3.6
472061	Construction craft laborer	20	3.0
537062	Laborers and freight	19	2.8
499099	Installation, maintenance	19	2.8
472041	Carpet installers	15	2.2
499021	Heating, air conditioning	15	2.2
372012	Maids and housekeeping	13	1.9
472181	Roofers	13	1.9
519199	Production workers	12	1.8
533032	Truck drivers, heavy and T	11	1.6
372011	Janitors and cleaners	11	1.6
472042	Floor layers	11	1.6

SOC, standard occupational classification; WMSD, work-related musculoskeletal disorder.

compensation system.⁵² Third, misclassification of diagnoses is possible. More general ICD-9 diagnosis codes (eg, sprain or strain) may be used early in the life cycle of a claim before a more specific diagnosis can be made. However, we included any ICD-9 code throughout the claim's life cycle as long as it met our case definition. Our analysis of the risk of surgery by obesity status is also likely limited by potential misclassification of obesity, as weight and height were self-reported by claimants. Fourth, we did not include arthritis claims in our case definition, because arthritis is rarely deemed to be a work-related condition in Washington State. Yet there have been multiple recent studies that have suggested that there is an association between certain occupational activities and osteoarthritis.^{45,46,53-67} It is difficult for us to compare our results with recent studies that have included arthritis in the case definition.⁶⁸

The results of this study may not be generalizable to other populations and settings. Self-insured claims represent about one-third of Washington State workers' compensation claims. Self-insured claims were not included in this study because diagnosis codes and billing information were rarely available for these claims. In Washington State, self-insured employers tend to be large employers who may have a greater capacity to return employees to work.⁵² Exclusion of self-insured claims may have therefore led to overestimates of knee WMSD costs. Underreporting of knee WMSDs is also possible, and underreporting has been hypothesized to lead to underestimates of the magnitude and costs of other WMSDs.⁵²

The results of this study should be used to guide further investigation, with the eventual aim of knee WMSD prevention. Further study of common characteristics of knee WMSD claims that are associated with especially high morbidity and cost is warranted. Longitudinal studies with accurate exposure assessment are needed to better quantify the contribution of specific occupational factors to the development of meniscal disorders and other potential knee WMSDs.

CONCLUSIONS

Between 1999 and 2007, Washington State Fund knee WMSDs were widespread and associated with a large cost. Industries at highest risk for knee WMSDs included construction and building contractors. Occupations at highest risk included carpenters and truck drivers in men, and nursing aides and housekeepers in women. Identification of specific occupational knee WMSD risk factors in high-risk industries and occupations is needed. Further study to better define the contribution of occupational factors to the development of certain knee WMSDs is warranted. Data from such studies should be used to guide knee WMSD prevention efforts.

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