

Morbidity from repetitive knee trauma in carpet and floor layers

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ABSTRACT Carpet layers comprise less than 0.06% of the United States workforce yet they submit 6.2% of compensation claims for traumatic knee inflammation. Their work involves multiple sources of acute and chronic knee trauma including kneeling, pressure from sharp objects, and use of a device called a "knee kicker" to stretch wall to wall carpet. To characterise the knee morbidity in carpet layers and to identify occupational risk factors, a questionnaire was completed by 112 carpet and floor layers, 42 tile and terrazzo setters, and 243 millwrights and bricklayers (MWBL). The MWBL comparison workers seldom kneel and do not use a knee kicker. Physical and x ray examinations were conducted on a subset of 108 respondents to validate the questionnaire responses. Compared with the MWBL, carpet layers reported more frequent bursitis (20% v 6%), needle aspiration of knee fluid (32% v 6%), and skin infections of the knee (7% v 2%). A score indicating frequency of using the knee kicker was the only statistically significant predictor of bursitis, whereas the score for kneeling was one of several predictors of knee aspiration and skin infections of the knee. These data suggest that carpet and floor layers experience substantially more knee morbidity than other occupational groups, and that kneeling and use of the knee kicker are risk factors providing opportunities for prevention.

Workers who kneel to perform their jobs inflict chronic trauma to their knee joints. Disorders such as the "housemaid's knee" of women who kneel to scrub floors and the "beat knee" of British low seam coalminers, are well recognised.¹ The former is characteristically a prepatellar bursitis, whereas the latter is often a combination of bursitis and disfiguring localised cellulitis.²⁻⁶

Carpet and floor layers have received relatively less attention as workers at high risk of knee trauma. Not only do both groups kneel but carpet layers also use a device called the "knee kicker" to stretch the carpet for wall to wall installation. Workers using this tool generate force by striking the suprapatellar area of their knee against the instrument.⁷ In 1982 the National Institute for Occupational Safety and Health (NIOSH) became concerned about knee dis-

ease in carpet layers when one of us (WH) observed the technique of workers installing carpet and learnt of anecdotal reports of knee surgery, evacuation of effusions, and treatment of skin infection among floor layers.

Substantiation of the reports of knee problems among carpet layers was provided by the Bureau of Labor Statistics, supplemental data system.⁸

Carpet layers submit a disproportionately large fraction of the claims for worker's compensation for knee joint inflammation attributed to kneeling, leaning, repetition of pressure, or striking against a stationary object.⁹ The estimated 88 000 carpet installers in the United States comprise only 0.0575% of the total workforce (table 1) yet they account for approximately 6.2% of such claims, a nearly 108-fold increase.

Because of the concern about chronic knee trauma in carpet and floor layers, we conducted an interview and medical survey to define the nature and mag-

Table 1 Workers' compensation claims in 1979 for knee joint inflammation attributed to kneeling, leaning, repetition of pressure, or striking against a stationary object*

Occupation	No of claims	% of claims	% of workforce	Occupational knee morbidity ratio†
Carpet installers	46	6.199	0.0575	107.81
Tilesetters	16	2.156	0.0410	52.59
Floor layers	10	1.348	0.0291	46.32
Dry wall installers and lathers	10	1.348	0.0605	22.28
Cement and concrete finishers	10	1.348	0.0814	16.56
Brick or stonemasons	9	1.213	0.2026	5.99
Millwrights	3	0.404	0.1497	2.70

*From the supplementary data system of the Bureau of Labor Statistics, 1979. Modified from reference—(Tanaka).⁹

†Percentage of claims/per cent of workforce.

nitude of the knee morbidity and to identify causative factors that might be eliminated or controlled.

Participants and methods

HYPOTHESES

The question of interest was whether carpet layers, who both kneel and strike their knees repeatedly against the knee kicker have an increased prevalence of reported knee symptoms and of physical and radiological abnormalities compared with workers who neither kneel nor use this tool. A secondary question was whether the increased knee morbidity, if it occurs, results from repetitive use of the knee kicker, chronic kneeling, or both.

STUDY POPULATION

The study was initially requested by the Resilient Floor Layers and Decorators' Union, Local 873. This union Local represents an estimated 20–33% of car-

pet and floor layers in Cincinnati, Ohio. Two other union Locals in Cincinnati also agreed to participate as comparison populations (fig 1). Because each of the three unions included workers from multiple trades, subjects were recategorised in the analysis into three activity categories reflecting the exposures of interest (fig 1). Reassignment was based on the worker's description of his usual occupation. Carpet layers were grouped with other resilient floor layers, since both groups kneel and use a knee kicker when installing carpet. Tilesetters, terrazzo, mosaic and stone layers were grouped together as workers who kneel extensively but do not use a knee kicker. Millwrights, bricklayers, and decorators (MWBL) were grouped together as workers who kneel only intermittently and never use a knee kicker. Bricklayers stand when erecting walls and millwrights kneel only intermittently when assembling industrial fixtures and machinery. To our knowledge, no trade group uses a knee kicker in the absence of kneeling.

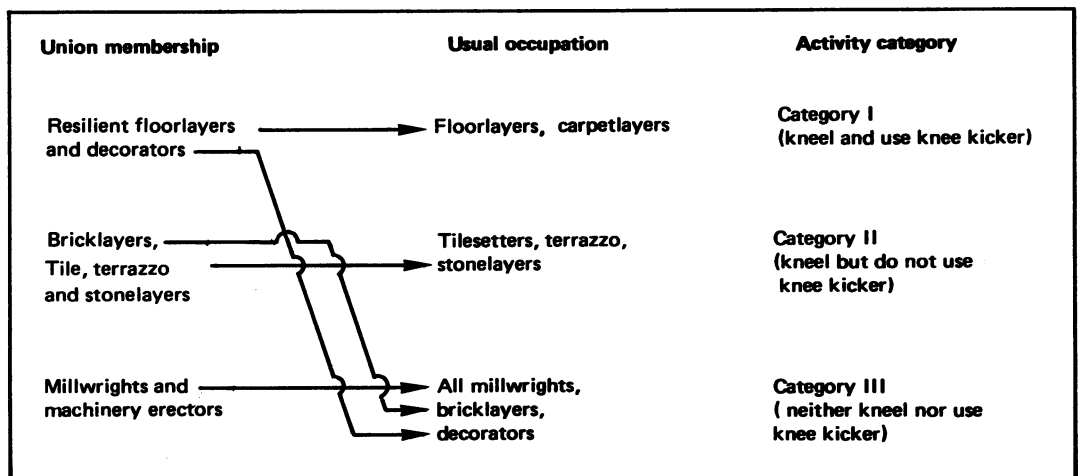


Fig 1 Categorisation of workers according to union membership: occupation and activity category.

SAMPLING STRATEGY

All active floor layers, and one third of currently active members of the larger Bricklayers' and Millwrights and Machinery Erectors' unions were invited to participate. All retired workers were also sampled, regardless of union membership. Although the purpose of including retired workers was to minimise losses from the study due to premature retirement from knee disease, only retired workers who paid their dues were listed on the union register. Thus workers who had ceased paying dues after leaving the trade were lost.

OUTCOMES MEASURED

The study consisted of two questionnaires and a medical examination (fig 2). Initially a self administered questionnaire, developed by us, was posted to all workers selected to participate. Questions inquired about the lifetime prevalence of seven knee conditions (appendix A). The questionnaire also inquired about non-occupational knee injury, personal characteristics (age, weight, and height), and work practices (retirement status, usual occupation, use of the knee kicker, use of the power carpet stretcher, and percentage of time spent kneeling, standing, or squatting while at work).

A second interview was subsequently administered

by telephone to all respondents to the initial questionnaire. Trained interviewers asked standardised questions about seven symptoms of knee disease from the arthritis supplement of the National Health and Nutrition Examination Survey (NHANES).¹⁰ Symptoms included knee pain, swelling and tenderness to touch. The purpose of these questions (appendix B) was to provide standardised information about symptom prevalence that could be compared with the United States male population.

MEDICAL EXAMINATIONS

Physical and xray examinations of the knee were offered to everyone who completed the self administered and telephone questionnaires who resided in Indiana, Kentucky or Ohio. The medical examination data were not intended to be representative of the entire study group; rather, they were obtained to validate the questionnaire responses. Knee examinations were conducted by eight physician faculty and fellow members of the University of Cincinnati division of immunology/rheumatology. Participants were randomly assigned to one of these eight physicians who were unaware of the subject's occupation or medical history. The examiners assessed gait, lower leg alignment, tibial torsion, knee skin changes, patellar bursitis, knee joint mobility, crepitation, tenderness,

Instrument	Outcome measured
1) NIOSH questionnaire (posted, self administered)	Lifetime prevalence of seven knee <i>conditions</i> (bursitis, arthritis, knee taps, infections, fractured patella, surgery, other)
2) NHANES questionnaire (telephone, trained interviewers)	Prevalence of ten standardised knee <i>symptoms</i>
3) Physical and x ray examinations	Quantitative assessment of about 60 parameters on self selected subset of subjects

Fig 2 Outcomes measured in knee study.

swelling, pain, ligament stability, meniscus, and measurements for girth and range of motion of knee joint.

Knee x ray films included anteroposterior, lateral, tunnel, and axial views. Two radiologists separately reviewed the films for a variety of outcomes: (1) osseous spurs, erosions, cysts, or sclerosis of either the distal femur or the proximal tibia; (2) narrowing of the knee joint space; (3) patellar spurs; (4) approximation of the patella to the femur; (5) loose bodies; (6) osteochondromatosis; (7) chondrocalcinosis; (8) soft tissue calcification; and (9) suprapatellar effusion. Because of the low rate of participation in the physical and x ray examinations, only those data used to validate the questionnaire responses will be reported here.

DATA TRANSFORMATION

Two different classification schemes were used to reflect exposure status in the analysis. The crudest measure was the trichotomy of "activity categories" seen in fig 1. As discussed, these activity categories provided a qualitative measure of whether the usual job necessitated both kneeling and use of the knee kicker, kneeling alone, or neither. A more quantitative, although still subjective, measure of exposure was the score with which each worker described the frequency of standing, sitting, squatting, bending, kneeling, heavy lifting, and use of knee pads, a knee

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kicker, or of a power carpet stretcher. Workers rated each activity on a scale of from one (never) to six (always). To simplify these scores, we subsequently reduced the categories to three: 1-2 (seldom), 3-4 (intermediate), and 5-6 (frequent). We then used factor analysis to combine pairs of related working postures into groups. The resultant three pairs of working postures were bending/lifting (factor 1), kneeling/standing (factor 2), and sitting/squatting (factor 3). Kneeling and standing were inversely related to each other, whereas the other two posture pairs were related directly.

DATA ANALYSIS

To compare the prevalence of various knee problems among the three "occupational activity groups," we first excluded from the analysis the single woman and the 34 subjects with a history of sports injuries to the knee. We then computed the age adjusted prevalence of each of the seven knee conditions in each of the three occupational activity groups. The age distribution of the entire study group provided the standard population. The prevalence in millwrights and bricklayers (MWBL) was used as the denominator in computing the prevalence ratio for "reported knee conditions" (table 2) and the prevalence in the NHANES sample of United States men was used as the referent value in computing prevalence ratios for

Table 2 Age adjusted prevalence and prevalence ratio of reported knee conditions in floor layers and tilesetters relative to millwrights and bricklayers (MWBL)

Knee condition	Occupation	Prevalence (%) [*]	Prevalence ratio [†]	90% CI [‡]
Knee "taps"	Floor layers	31.5	5.0	3.2- 7.8
	Tilesetters	31.0	4.9	2.7- 8.7
	MWBL	6.3	1.0	NA
Bursitis	Floor layers	20.0	3.2	1.9- 5.4
	Tilesetters	11.2	1.8	0.8- 3.9
	MWBL	6.2	1.0	NA
Arthritis	Floor layers	14.3	1.1	0.7- 1.8
	Tilesetters	25.7	2.0	1.2- 3.3
	MWBL	12.9	1.0	NA
Skin infections of knee	Floor layers	7.0	4.1	1.5-10.8
	Tilesetters	2.6	1.5	0.3- 8.2
	MWBL	1.7	1.0	NA
Fractured patella	Floor layers	0	0.0	—
	Tilesetters	0	0.0	—
	MWBL	3.7	1.0	NA
Knee surgery	Floor layers	2.4	0.4	0.1- 1.1
	Tilesetters	7.6	1.3	0.5- 3.4
	MWBL	6.1	1.0	NA
Other knee conditions	Floor layers	19.1	2.0	1.3- 3.1
	Tilesetters	16.2	1.7	0.9- 3.3
	MWBL	9.5	1.0	NA

^{*}Age adjusted prevalence directly standardised using the age distribution of the entire study group as the standard population.

[†]Ratio of age adjusted prevalence in the exposed relative to millwrights and bricklayers.

[‡]90% confidence intervals for the directly standardised prevalence ratio using method from Kleinbaum and Kupper.¹¹

the NHANES questions (table 3). The age distribution of the NHANES weighted sample of men was used as the standard population for direct standardisation. Ninety per cent confidence intervals were computed around the directly standardised prevalence ratios using the standardised risk ratio.¹¹

MULTIVARIATE ANALYSES

Unconditional logistic regression (SAS Logist) was used to identify those personal and occupational characteristics that best predicted any of the seven reported knee conditions. Variables considered in the model included age, usual occupation, duration of employment, the self reported score for use of the knee kicker, postural factors 1-3, and all two way interactions. Main effect variables and interaction terms were retained if the p value was less than 0.05.

Odds ratios and 90% confidence intervals were calculated from the model using the lowest use category as the referent.¹¹ We report only the final and most parsimonious models for bursitis, knee taps, and skin infections, the three conditions for which the floor layers reported a significant excess.

USE OF THE PHYSICAL AND XRAY EXAMINATIONS TO VALIDATE THE QUESTIONNAIRE DATA

Physical examination and radiological findings were used to validate the questionnaire responses. Although we expected only certain findings such as arthritis, history of knee surgery, or fractured patella to be documentable on the medical examination, we also included bursitis in the validation study.

Table 3 Prevalence of seven NHANES knee symptoms* in the three occupational groups interviewed and prevalence ratios relative to United States white men, aged 25-74

Symptom*	Occupation	Prevalence (%)†	Prevalence ratio	90% CI‡
Knee pain for at least one month	Floor layers	33.4	3.5	2.8- 4.5
	Tilesetters	34.1	3.6	2.1- 6.1
	MWBL	23.1	2.4	1.9- 3.0
Swelling and painful to touch	Floor layers	15.4	8.4	5.6-12.7
	Tilesetters	5.6	3.1	1.3- 7.0
	MWBL	7.2	4.0	2.6- 6.2
Locking of the knee	Floor layers	6.8	7.0	3.6-13.9
	Tilesetters	5.3	5.5	2.1-14.3
	MWBL	5.4	5.6	3.1-11.2
Knee "gives away"	Floor layers	17.0	4.9	3.4- 7.3
	Tilesetters	9.7	2.8	1.3- 6.1
	MWBL	11.2	3.2	2.1- 4.6
Pain at rest	Floor layers	22.1	5.0	3.6- 6.9
	Tilesetters	28.8	6.5	3.5-12.2
	MWBL	13.9	3.1	2.3- 4.3
Swelling of knee joint	Floor layers	19.2	4.9	3.4- 7.0
	Tilesetters	19.7	5.0	2.2-11.7
	MWBL	12.7	3.2	2.3- 4.6
Morning stiffness	Floor layers	22.7	3.8	2.8- 5.3
	Tilesetters	14.5	2.4	1.4- 4.3
	MWBL	22.2	3.7	3.0- 4.7

*Symptoms were those used in the NHANES standardised supplemental questionnaire on arthritis.

†Prevalence has been age adjusted using direct standardisation, with men in the NHANES sample as the standard population.

‡90% confidence intervals for the directly standardised prevalence ratio using the method described for the standardised risk ratio.¹¹

Table 4 Participation in knee disease study by union membership

Union	No of members	No sampled for study	Participation	
			Questionnaires No (%)	Medical No (%)
Resilient floor layers and decorators	170	170	132 (78%)	47 (28%)
Bricklayers, terrazo, mosaic, and tilelayers	440	190	146 (77%)	40 (21%)
Millwrights and machinery erectors	420	202	154 (76%)	21 (10%)
Totals	1030	562	432 (77%)	108 (19%)

VALIDATION USING PHYSICIAN'S RECORDS

We attempted to contact the physicians of workers reporting specific knee conditions in order to validate their diagnoses.

Results

Table 4 shows the number of workers participating in the questionnaire and medical phases of the study, categorised by union membership. Participation could be assessed only by union membership rather than "usual occupation," since the latter was determined only on participants in the questionnaire study. Almost identical proportions of workers sam-

Table 5 Demographic characteristics of workers participating in the questionnaire survey, grouped by usual occupation

	Carpet and floor layers (floor layers) (n = 112)	Tile terrazo marblesetters (tilesetters) (n = 42)	Millwrights, bricklayers, decorators (MWBL) (n = 243)
Age:			
Mean	50.7	57.8	53.9
SD	15.1	15.8	16.0
Range	23-79	24-86	19-87
Retired	31%	36%	38%
Years employed:			
Mean	25.0	31.2	24.3
SD	12.1	14.1	12.8
Range	1.5-47.6	5.3-61	1.2-61
Height (inches):			
Mean	70.0	70.0	70.0
SD	2.7	3.3	2.6
Range	64.0-81.0	63.0-81.0	64.0-77.0
Weight (kg):			
Mean	80.1	80.7	81.3
SD	12.7	11.1	13.4
Range	47.6-113.4	59.0-115.7	45.4-117.9

Table 6 Selected job characteristics of participants in the questionnaire survey, by usual occupation

	Carpet and floor layers (floor layers) (n = 112)	Tile terrazo marblesetters (tilesetters) (n = 42)	Millwrights, bricklayers, decorators (MWBL) (n = 243)
Knee kicker score*			
Mean	3.9	1.0	1.1
SD	1.8	0.0	0.6
Range	1-6	1-1	1-6
Kneeling score*			
Mean	5.5	4.9	2.9
SD	6	5	3
Range	1-6	1-6	1-6
Any kneeling			
No (%)	111 (99%)	41 (97%)	210 (83%)
Regularly use knee pads†	57 (51%)	34 (97%)	31 (15%)
% of time using knee pads† (mean)	43.4%	83.4%	29.9%

*Self assigned qualitative score from 1 (never) to 6 (always).

†Analyses restricted to workers who kneel at work.

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pled from the three unions participated in the questionnaire phase of the study (76-78%); only 19% of workers sampled participated in the medical examination.

Table 5 shows some demographic characteristics of the participants in the questionnaire survey. In this and subsequent tables the study subjects are classified by "usual occupation" instead of by union membership. Slight differences in age and employment status are evident between the three groups. Floor layers were on average younger and less likely to be retired than either of the two other groups. The tile terrazo and marblesetters (n = 42) were slightly older and had been employed the longest; they included the largest proportion of retired workers.

Table 6 summarises some of the job practices of the three occupational groups. As may be seen, only floor layers used a knee kicker frequently. Over 80% of workers in all three groups stated that their work entailed some kneeling, but floor layers and tilesetters reported substantially higher kneeling scores than the MWBL. Among workers who knelt regularly in their job, tilesetters were far more likely to use knee pads (97% v 51%).

Table 2 shows the prevalence of reported knee conditions among floor layers and tilesetters compared with the MWBL. Floor layers more frequently reported a history of knee tap (needle aspiration of the knee), bursitis, skin infections of the knee, and "other knee disease" than the MWBL. Other knee conditions included miscellaneous conditions such as ruptured cartilage, strained ligament, or puncture wounds from kneeling on sharp objects. Nearly half (47%) of the floor layers reported having had at least one episode of either knee aspiration or bursitis, compared with only 11% of the MWBL. For knee taps, arthritis, and knee surgery, the small group of tile terrazo and marble setters reported prevalences that were equal to or greater than those of the resilient floor layers. Arthritis was the single condition that tilesetters reported statistically more frequently than did the MWBL, but floor layers did not.

A similar pattern was evident when comparing the age adjusted prevalence of the seven NHANES symptoms among these workers with that of the NHANES sample. Table 3 shows the age adjusted prevalence of these symptoms in each occupational group. Here each occupational group is compared with men of comparable age in the NHANES sample of the United States population rather than with the MWBL. Relative to United States men, floor layers reported three to four times the age adjusted prevalence of all seven symptoms, with the highest prevalence ratios for swelling and tenderness to touch and locking of the knee joint. Symptom reporting was highest among carpet layers but also significantly

higher among tilesetters and even among the millwrights and bricklayers than that of United States men. The millwrights and bricklayers reported a two to sixfold higher prevalence of all symptoms than men in the NHANES sample.

USE OF THE PHYSICAL AND XRAY EXAMINATIONS TO VALIDATE THE QUESTIONNAIRE DATA

Low participation in the physical and x ray examinations precluded comparison of medical findings between the occupational groups. The physical and x ray data did allow validation of some questionnaire responses, however. Table 7 shows the correspondence between a questionnaire report of bursitis or arthritis and the physical or x ray findings. In these analyses the questionnaire report is considered the screening test; the physical or radiological signs of disease are accepted as the confirmatory "gold standard." For both bursitis and arthritis, the questionnaire response shows low (38–44%) sensitivity but moderate (82–89%) specificity.

For arthritis, the radiologists classified many more subjects as having joint changes consistent with "arthritis" than did the questionnaire or the physical examination. The radiologist identified 32 subjects with some degree of osteoarthritis compared with the physical examination finding of 12 and the questionnaire report of 22. Although more subjects may have reported symptoms of arthritis on questionnaire, only 22 responded positively to question 3, appendix A. A

Table 7 Correspondence between the questionnaire report and summary impression of bursitis and arthritis on physical or x ray examination

<i>Bursitis</i>				
<i>Physical examination: summary impression</i>				
	Bursitis	Bursitis	Total	
Questionnaire response:	+	–		
Bursitis +	8	14	22	Sensitivity = 38%
Bursitis –	13	73	86	Specificity = 84%
Total	21	87	108	
<i>Arthritis</i>				
<i>Physical examination: summary impression</i>				
	Arthritis	Arthritis	Total	
Questionnaire response:	+	–		
Arthritis +	5	17	22	Sensitivity = 42%
Arthritis –	7	79	86	Specificity = 82%
Total	12	96	108	
<i>X ray examination: summary impression</i>				
	Arthritis	Arthritis	Total	
Questionnaire response:	+	–		
Arthritis +	14	8	22	Sensitivity = 43.8%
Arthritis –	18	67	85	Specificity = 89.3%
Total	32	75	107	

positive questionnaire response detected only 44% of subjects with radiological changes of osteoarthritis; positive findings on physical examination detected only 19%.

On physical examination, bursitis was observed more often over the infrapatellar than the prepatellar bursa. The criteria used to define bursitis on physical examination included detectable swelling or tenderness to palpation, or both. Such findings concerned the infrapatellar bursa in 62% of cases and the prepatellar bursa in 38%. This finding contrasts with the reported preponderance of prepatellar bursitis in housemaid's knee.¹

VALIDATION USING PHYSICIAN'S RECORDS

The attempt to contact physicians to document past episodes of knee disease met with limited success. For example, of 35 floor layers reporting knee tap, we were able to contact the physicians of only 16. In many cases the physician was dead or had retired or the record could not be found. Of the 16 physicians contacted, records were obtained from 12, all of which confirmed that the patient had undergone needle aspiration of the knee. In seven responses the physician specified that the prepatellar bursa had been aspirated. These limited data suggest that some unquantified fraction of the cases of knee taps among the floor layers represent effusions of the bursae rather than of the joint space.

MULTIVARIATE ANALYSES

Tables 8, 9, and 10 show the results of stepwise logistic regression analyses to identify those demographic and occupational characteristics that best predicted a history of bursitis, knee taps, and skin infections. Table 8 shows the optimal model for bursitis. Only the self reported score for use of the knee kicker achieved statistical significance in the overall model. The odds ratio was 5.3 when frequent users were compared with non-users. Table 9 shows the corresponding logistic model for knee taps. The two important main effect terms were years of employment and the factor representing kneeling/standing. The negative relation between the kneeling/standing factor and knee taps indicates that the probability of knee taps decreases with standing and increases with kneeling.

The statistically significant interaction term between age and the kneeling/standing factor reflects a pronounced difference in the prevalence of reporting knee taps between young and older workers. The probability of knee taps actually decreased with age among workers reporting frequent kneeling (a negative kneeling/standing score), whereas it increased with age among those reporting rare kneeling (a high kneeling/standing score). Such a pattern is consistent with a survivorship phenomenon, workers with knee

Table 8 *Logistic regression model for history of bursitis*

Variable	Coefficient (β)	Standard error	Odds ratio	90% CI
Knee kicker	0.33	0.080	5.3	2.8-10.3

Odds ratio and CI computed for heavy users (score = 6) versus non-users (score = 1).

Table 9 *Logistic regression model for history of knee taps*

Variable	Coefficient $\beta \times 10^{-2}$	Standard error $\times 10^{-2}$	p Value
Years employed	4.5716	2.054	0.026
Factor 2*	-2.2275	0.634	0.0004
Age	0.0185	1.859	0.99
Age \times factor 2	0.0230	0.011	0.03

Variable	Odds ratio†	90% CI†
Employment for 20 years	2.5	1.3- 4.9
Age \times factor 2		
Low kneeling: age 25	1.0	(Referent group)
Low kneeling: age 65	6.3	0.8- 50.2
High kneeling: age 25	142.3	44.1-459.0
High kneeling: age 65	56.8	7.5-427.3

*Factor 2, the kneeling/standing factor, becomes more strongly negative with increased kneeling.

†p values apply to the overall terms in the model. Odds ratios and CIs were computed from the model using the actual scores of study participants with extreme combinations.

Table 10 *Logistic regression model for skin infections of the knee*

Variable	Coefficient $\beta \times 10^{-2}$	Standard error	p Value
Factor 1	-0.4145	0.0040	0.30
Factor 2	-1.0923	0.0038	0.004
Factor 1-2	-0.0073	0.00003	0.035

Factor 1 (bending/lifting)	Factor 2 (kneeling/standing)	Odds ratio*	90% CI*
Low bend & lift	Low kneeling	1.0	(Referent group)
Low bend & lift	High kneeling	0.3	<0.1 - 1.9
High bend & lift	Low kneeling	0.03	<0.01- 0.3
High bend & lift	High kneeling	5.0	1.1 - 22.7

*Odds ratios and CIs were computed from the model using the actual scores of study participants with extreme combinations.

disease tending to self select out of jobs that require extensive kneeling.

Frequent kneeling was also a statistically significant predictor of skin infections of the knee (table 10), but only among workers who also reported a high score for bending and lifting (factor 1). A high kneeling score was not a risk factor among workers with low bending/lifting scores (OR = 0.1). The possible importance of the interaction between factors 1 and 2 is discussed below.

Discussion

Carpet and floor layers report substantially more

Thun, Tanaka, Smith, Halperin, Lee, Luggen, Hess knee morbidity than either the general United States white male population or a blue collar working population of comparable age, sex, and race. In particular, floor layers describe more frequent bursitis, needle aspiration of knee fluid, skin infections of the knee, and miscellaneous other knee conditions. Frequent reporting of knee problems by carpet layers has been noted in a previous survey of musculoskeletal complaints among carpet layers in Sweden and is evident in the disproportionate number of disability claims for knee injury observed among United States carpet and floor layers.^{9 12}

To our knowledge, the only previous data about knee symptoms in floor layers comes from a Scandinavian study of 125 000 construction workers.¹² This study, as yet unpublished in English, included, in a lengthy interview, one question about pain and stiffness of the knee. Floor and parquet workers reported the highest prevalence of knee symptoms among construction workers, 3.3 times higher than that of clerks. Knee disorders have also been studied in concrete reinforcement workers.¹³ No increase in physical or x ray abnormalities was found among the reinforcement workers relative to painters. The concrete workers typically stand rather than kneel, however, and their work practices have little in common with floor layers.

Our study provides some rather limited information about the clinical features of "carpet layer's knee." Although we could not define the precise nature and magnitude of the knee disease, we did determine that effusions are an important component. About one third of floor layers reported needle aspiration of the knee at some point in their career. It is not clear whether these effusions involve predominantly the bursae or the joint space. Our limited follow back to the medical records of workers reporting knee tap found that the effusion involved the prepatellar bursa whenever a specific diagnosis was mentioned.

The bursitis identified by the rheumatologists in our medical study concerned the infrapatellar bursa in nearly two thirds of cases. The criteria used for infrapatellar bursitis were tenderness or swelling in the infrapatellar area or both. Pre- rather than infrapatellar bursitis is reported to be the characteristic feature among other workers who kneel—namely, in housemaid's knee, the beat knee of coal miners, and the bursitis of clergymen and nuns.¹

It remains unclear whether carpet layer's knee is also associated with more serious types of knee disease, such as osteoarthritis or injury to cartilage and ligaments. That the carpet layers did not report a more frequent history of arthritis and reported less frequent knee surgery than the other trades is not reassuring. Workers with disabling knee disease

would be likely to leave the trade and be lost from a cross sectional study such as ours. There are three lines of indirect evidence that floor layers with serious knee morbidity may indeed leave the trade. Firstly, symptoms of knee disease increase with age in the general population but decrease with age among floor layers, suggesting that symptomatic floor layers change their occupation. Secondly, there is a 100-fold increase in compensation claims among floor layers over other trades, but only a three to six fold increase in symptom prevalence in our study. This difference may be explained by floor layers leaving because of disability. Thirdly, and finally, there is anecdotal reporting by floor layers that colleagues with serious knee problems leave to find other work. Although we attempted to deal with this problem of selective retirement by including former workers, we were only able to locate retired workers who continued to pay union dues. The motivation to pay such dues is directly related to seniority—for example, only one of the retired floor layers in our study had stopped work prematurely with less than 20 years seniority. Thus the retired study participants are a “survivor” population and may not include workers of shorter tenure who left prematurely due to knee disability.

We were partly successful in identifying the occupational determinants of carpet layer's knee. Multivariate statistical analyses of the questionnaire data showed that a worker's self reported score for using a knee kicker, an instrument used only by the carpet layers, was the single important determinant of bursitis. Kneeling, and its interaction with age, were predictors of knee tap. The distinction between knee taps and bursitis is interesting but difficult to interpret. We cannot determine whether knee taps represent aspiration of bursae in cases of severe bursitis or aspiration of the joint space.

A second interesting finding of the regression analyses is the interaction between factor 2 (kneeling/standing) and factor 1 (bending/lifting) in the model for skin infections of the knee (table 10). It seems biologically plausible that workers who kneel frequently and bend and lift, particularly while kneeling, might be at high risk of skin infections. It is not clear why bending and lifting should be protective in workers who kneel infrequently. We suspect that this finding, if real, is due to some unidentified correlate of bending and lifting rather than these activities per se.

The prevalence of many reported knee problems was as high or higher among the small group of tile terrazo and marble workers than among the carpet layers. Despite the small study population, tilesetters reported conditions such as arthritis significantly more frequently than did the MWBL. The tilesetters, or non-resilient floor layers, spend their workdays kneeling on hard, unyielding surfaces. Although they

do not use the knee kicker, these workers undoubtedly experience occupational knee trauma.

Similarly, the comparison population of millwrights and bricklayers kneel frequently in their work (table 4). Such kneeling may account for some of the increased symptom reporting (table 6) and workers' compensation claims (table 1) filed by these workers. Knee trauma occurs in many construction trades and it is difficult to find an unexposed yet comparable comparison group.

The implications of carpet layer's knee are clearly most immediate for the 80–100 000 carpet and floor layers (SOC 6162) for whom it carries both medical and economic consequences.¹⁴ The number of these workers is substantial, although small in relation to the general population. Of potentially larger public health consequence are the incompletely understood effects of chronic kneeling in a variety of trades.

In summary, a cross sectional questionnaire study of knee symptoms among three groups of current and retired construction workers showed that carpet and floor layers report an increased frequency of bursitis, needle aspiration of knee fluid, skin infections of the knee, and a variety of knee symptoms compared with millwrights and bricklayers. Tile terrazo and marble setters report similar problems. Medical examinations on a subset of subjects served to validate the questionnaire data. Further research is needed to (1) characterise the nature and extent of knee disease in workers who incur chronic knee trauma, and (2) develop an effective, ergonomically suitable substitute for the knee kicker for stretching carpet.

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Appendix A

QUESTIONS CONCERNING PAST KNEE CONDITIONS, NIOSH QUESTIONNAIRE*

- (1) Have you ever had your knee tapped for an accumulation of fluid or blood in the knee joint?
- (2) Have you ever had bursitis (inflammation of a joint sac) of the knee?
- (3) Have you ever had arthritis of the knee?
- (4) Have you ever had a skin infection in the knee joint area?
- (5) Have you ever had a broken knee cap?

- (6) Any other illness or injury to the knee joint?
- (7) Have you ever had any operation (surgery) of the knee joint?

*For each positive response, the subject was asked in what year the condition first occurred, last occurred, in which leg it occurred, and the name of the physician treating the problem.

Appendix B

The questions adopted from the National Health and Nutrition Survey included:

- (1) Have you had pain in or around the knee on most days for at least one month?
- (2) When this knee pain is present, does it hurt at rest as well as moving?
- (3) When this knee pain is present, is there also swelling of the knee joint?
- (4) When this pain is present, have you ever had "locking" of the knee?
- (5) Has either knee "given away" under you?
- (6) Have you ever had any swelling of joints with pain present when the joint was touched on most days for at least one month? (This is a two step question. The second part asks which joint is affected.)
- (7) Have you had stiffness in your joints and muscles when getting out of bed in the morning on most mornings for at least one month? (This is a two step question. The second part asks which joint is affected.)

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