

Skin Effects of Occupational Kneeling

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To evaluate chronic knee trauma associated with kneeling, we conducted a cross-sectional questionnaire survey among floorlayers and tilelayers, two trades that require kneeling. Bricklayers and millwrights were studied for comparison. Approximately 28% of the 432 questionnaire respondents volunteered for a subsequent medical examination. Ultimately, data were analyzed for 112 floorlayers, 50 tilesetters, and 235 "comparison" workers.

We found that the history of past skin infection in the knee area was about four times more prevalent among floorlayers (7.1%) than among workers in the other two categories combined (1.8%). Unilateral or bilateral patellar skin thickening and erythema were found to be more prevalent among those who kneel: 79% of floorlayers and 98% of tilelayers vs 35% of the control group were found to have skin thickening; 52% of floorlayers and 49% of tilelayers vs 24% of the control group were found to have erythema on the frontal aspect of the knee.

Key words: floorlayers, carpetlayers, kneeling workers, occupational knee infection, erythema, thickening of the skin

INTRODUCTION

Workers who kneel to perform their work tend to develop certain knee abnormalities. Classic examples are "housemaid's knee" [Hunter, 1978], a prepatellar bursitis from scrubbing floors, and "beat knee," a combination of cellulitis and bursitis in the knee of British coal miners who work in low seam mines [Roantree, 1957; Williamson, 1972].

In the United States, carpetlayers, tilelayers, and floorlayers are at substantially increased risk of filing worker's compensation claims for "knee joint inflammation attributed to kneeling, leaning, repetition of pressure, or striking against a stationary object" [Tanaka et al, 1982]. Carpetlayers also use a "knee kicker," a device used for stretching the carpet for wall-to-wall installation, which is kicked with the supra-patellar segment of one knee while kneeling on the other (Fig 1).

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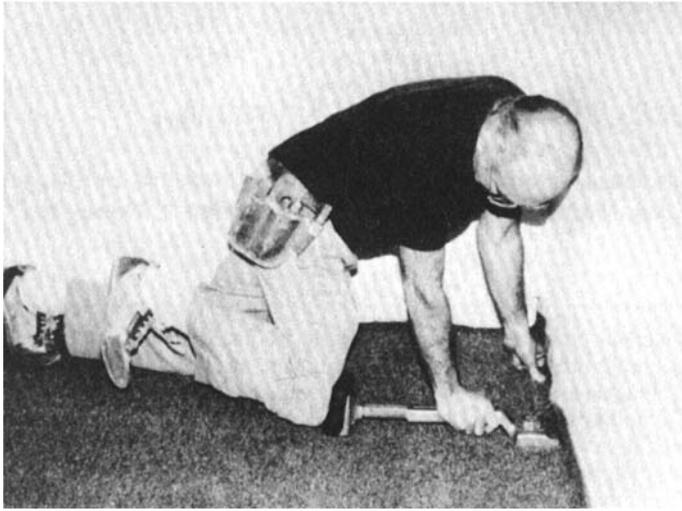


Fig. 1. Carpetlayer using knee kicker.

A cross-sectional questionnaire and medical survey was conducted to (a) characterize the spectrum of disease of the knee in two groups of workers who kneel while working, floorlayers and tilayers, and (b) compare these findings to those of workers who do not kneel at work. This report is limited to the skin findings on the frontal aspect of the knee.

PARTICIPANTS AND METHODS

All active and retired members of the floorlayers union, one of every three active members of the bricklayers and millwrights unions, and all retirees of the bricklayers and millwrights unions in the Cincinnati, Ohio area were asked to respond to a self-administered questionnaire. Information was collected regarding age, years in the trade, occupation, working postures (work standing, sitting, kneeling, etc), history of knee problems including skin infection in the knee area, use of the knee kicker and knee pads, and knee symptomatology. On the basis of pain, swelling, locking, and/or "given way" in the knee, the knee symptoms were graded as none, mild, moderate, and severe. Participants judged relative frequency of various working postures and the use of a knee kicker on a scale of 1 (never), 2, 3, 4, 5, and 6 (always).

Participants in the physical examination and X-ray component of the study were randomly assigned to one of eight physicians who were not informed regarding history or union membership. Skin changes looked for were erythema, folliculitis, eczema, thickening, excoriation, and psoriasis in the frontal aspect of the knee. No specific definitions of skin lesions were used. Physicians recorded the presence or absence of skin lesions and its location as supra-, mid-, and/or infrapatellar segment.

For data analysis, participants were classified by occupation as follows: (A) floorlayers who kneel and use a knee kicker in their work ("kick and kneel"); (B) tilayers (including terrazzo, marble, and stone layers) who kneel but do not use a knee kicker; and (C) bricklayers, millwrights, and decorators who neither kneel nor

use a knee kicker (Table I). Sampling framework and response rates are shown in Table II.

We recognized the possibility that symptomatic individuals would be more likely to respond to the questionnaire or participate in the knee examination. Also, union members of nonkneeling trades might not have been recruited with the same enthusiasm as those of the kneeling trades. To adjust for these potential biases, the proportion of questionnaire respondents who participated in the knee examination was calculated for the contingency tables of occupation and severity of knee symptoms (Table III). The reciprocal of these proportions was used to adjust for response bias [Cochran, 1966; Kleinbaum et al, 1982]. Thus, the prevalence of clinical findings was analyzed using contingency tables with adjusted frequencies, and the historical data were analyzed using contingency tables without adjusted frequencies. Pearson's chi-square

TABLE I. Use of Occupation to Classify Workers by Kneeling and Knee Kicker Usage

Union membership	Occupation	Activity category
Resilient floorlayers and decorators (union)	Floorlayers	Category A: "kick and kneel" (kneel and use knee kicker)
Bricklayers, terrazo, mosaic, and tilelayers (union)	Tilelayers, terrazzo, and stonelayers	Category B: "kneel only" (kneel but do not use knee kicker)
Millwrights and machinery erectors (union)	All millwrights, decorators, and bricklayers	Category C: "comparison" (neither kneel nor use knee kicker)

TABLE II. Sampling Framework for the Study by Union Membership

	Total (Active; retired)		
	Floorlayers	Bricklayers	Millwrights
1. Membership	170 (126; 44)	440 (375; 65)	420 (327; 93)
2. Sampled for questionnaire	170 (126; 44)	190 (125; 65)	202 (109; 93)
3. Completed questionnaire	132 (93; 39)	146 (104; 42)	154 (84; 70)
4. Response rate (%)	78 (74; 89)	78 (83; 65)	76 (77; 75)
5. Used in statistical analysis ^a	122 (87; 35)	137 (97; 40)	138 (71; 67)
6. Participated in physical exam	47 (39; 8)	40 (33; 7)	21 (13; 8)

^aOne female and those who reported a history of sports knee injury were excluded from statistical calculation.

TABLE III. Proportion of Questionnaire Respondents Who Participated in the Knee Examinations*

Occupational group	No knee symptoms (%)	Knee symptoms positive			Total (%)
		Mild (%)	Moderate (%)	Severe (%)	
A. Floorlayers	28/80 (35)	5/8 (63)	4/11 (36)	8/13 (62)	45/112 (42)
B. Tilelayers, etc	9/37 (24)	2/5 (40)	1/3 (33)	4/5 (80)	16/50 (32)
C. "Comparison"	29/178 (16)	5/15 (33)	10/24 (42)	3/18 (17)	47/235 (20)
Total	66/295 (22)	12/28 (43)	15/38 (39)	15/36 (42)	108/397 (27)

*Categorized by occupation and severity of knee symptoms. Severity of knee symptoms was graded by presence, absence, and combinations of pain, swelling, locking, and "given way" in the knee joint. Denominator is the number of persons who responded to the questionnaire in that category. Numerator is the number of persons who participated in the knee examination in that category. Since participants were regrouped by their occupation (not by union membership) the total numbers do not necessarily match those reported in Table I.

test was used to test differences among the three exposure categories for each of the variables: occupation, frequency of kneeling, and use of knee kicker or knee pads. Test for trend was conducted using the GSK method [Grizzle, Starmer, and Koch, 1969].

RESULTS

Of 562 individuals in the study, 432 (76.9%) responded to the questionnaire. Thirty-four (34) who had a history of knee injury from sports, 1 female, and 16 who had moved were excluded. The remaining 381 respondents were asked to participate in the physical and X-ray examinations of the knee joint, of whom 108 (28.3%) were examined. Thus, only 21.6% of the originally sampled population received the knee examination. All but two of the examinees were nonblacks. Tables II and III indicate participation by union membership, by occupation, and by severity of knee symptoms, respectively.

Table IV shows the number of people who gave a history of skin infection of the knee. When compared by occupation, workers who kick and kneel (carpetlayers) had a significantly higher rate (7.1%) of skin infection than the combined group of all other occupations (1.8%). When the prevalence of skin infection was examined by the frequency of kneeling, there was no statistically significant difference among the three kneeling categories, although there was a nonsignificant increased trend as the frequency of kneeling increased. When the prevalence of knee infections was examined in relation to the frequency of using the knee kicker, the intermediate users reported the highest rate of infection.

Table V shows the number of individuals who had thickened patellar skin by the three exposure categories. In view of the limited participation in the knee examination, interpretation of the data has to be cautious. When examined by occupation, workers who both kneel and kick, and those who only kneel had a higher prevalence of skin thickening. Also, as the frequency of kneeling increased, so did

TABLE IV. History of Skin Infection in the Knee Joint by Occupation, Frequency of Kneeling, and Knee Kicker Use (Questionnaire Response)*

Exposure category	Positive		Total n	Test for equality			Test for trend		
	n	%		df	χ^2	p	df	χ^2	p
Occupational group									
Carpetlayers	8	7.1	112						
Others ^a	5	1.8	284	1	7.367	0.01			
Work kneeling ^b									
5, 6 (frequent)	9	5.5	165						
3, 4 (intermediate)	2	1.8	114	2	4.202	0.12	1	3.290	0.07
1, 2 (seldom)	2	1.7	117						
Use of knee kicker ^b									
5, 6	3	5.8	52						
3, 4	5	14.7	34	2	16.606	0.0002	1	4.72	0.03
1, 2	5	1.7	294						

*df, degree of freedom; χ^2 , chi-square.

^aTotal of "kneel only" and "comparison" (bricklayers, tilayers, decorators, millwrights, etc).

^bAmount of kneeling or knee kicker use at work as estimated by participants: 1 (never), 2, 3, 4, 5, 6 (always).

TABLE V. Thickening of Patellar Skin by Occupation, Frequency of Kneeling, and Knee Kicker Use (After Adjustment for Nonparticipation Biases)*

Exposure category	Thickening				Total n	df	χ^2	p
	Positive bilateral		Positive unilateral					
	n	Row (%)	n	Row (%)				
Occupational group								
A. Floorlayers	80	71.3	9	7.7	112			
B. Tilelayers, etc	43	84.3	7	13.2	51	4	110.85	0.0001
C. "Comparison"	60	25.6	21	9.0	235			
Work kneeling								
5, 6 (frequent)	108	65.4	21	13.0	165			
3, 4 (intermediate)	35	32.5	6	5.7	109	4	62.41	0.0001
1, 2 (seldom)	39	31.7	9	7.0	124			
Use of knee kicker								
5, 6	19	51.4	0	0.0	37			
3, 4	36	89.1	0	0.0	41	4	42.95	0.0001
1, 2	118	38.0	36	11.7	311			

*Percentages were calculated before rounding weighted total into integers.

TABLE VI. Erythema in the Frontal Knee by Occupation, Frequency of Kneeling, and Knee Kicker Use (After Adjustment for Response Bias)*

Exposure category	Erythema				Total n	df	χ^2	p
	Positive bilateral		Positive unilateral					
	n	Row (%)	n	Row (%)				
Occupational group								
A. Floorlayers	48	42.8	10	9.1	112			
B. Tilelayers, etc	25	48.7	0	0.0	51	4	43.39	0.0001
C. "Comparison"	54	22.9	2	1.0	238			
Work kneeling								
5, 6 (frequent)	68	40.6	7	4.4	167			
3, 4 (intermediate)	32	29.0	5	4.8	109	4	19.40	0.0007
1, 2 (seldom)	27	22.1	0	0.0	124			
Use of knee kicker								
5, 6	18	47.6	4	12.0	37			
3, 4	22	54.4	3	7.0	41	4	33.33	0.0001
1, 2	27	27.8	5	1.7	313			

*Percentages are calculated before rounding weighted total into integers.

the prevalence of knee skin thickening. Use of the knee kicker was also significantly related to thickening of the patellar skin. However, the highest prevalence of thickening was found in the "intermediate" (rather than "frequent") users of the knee kicker. Patellar thickening was not significantly related to age ($p = 0.12$, by GSK method).

With regard to erythema of the frontal knee (Table VI), a statistically significant difference was found among the three occupational categories and by the frequency of kneeling and use of knee kicker. By occupation, both groups of workers who kneel had significantly higher rates of erythema compared to the nonkneeling group. Also,

the prevalence of erythema was proportionately related to the amount of kneeling. While the prevalence of erythema was related to the frequency of knee kicker use, the highest rate was found again among the intermediate users of knee kickers.

No workers were found to have psoriasis on the knee. Folliculitis, eczema, or excoriation were reported by only a few workers.

We also examined the protective value of using knee pads. There was a positive correlation between the frequency of kneeling and the use of knee pads (Spearman correlation coefficient: $r = 0.378$, $p = 0.0001$). Table VII presents the relationship between patellar skin thickening and use of knee pads. Although we found a statistically significant association between them, the trend was unexpected in that the knee pad wearers had more patellar skin thickening. This is probably because those who kneeled more used knee pads more.

DISCUSSION

We became interested in knee diseases of carpetlayers after observing a worker repetitively striking a knee kicker while installing wall-to-wall carpet. Using worker's compensation data, we found that the carpetlayers had a 108-fold excess of claims for "knee joint inflammation attributed to kneeling, leaning, repetition of pressure, or striking against a stationary object" [Tanaka et al, 1982]. Also, carpetlayers told us of episodes of skin puncture and infection in their knees, since they kneel inadvertently on sharp objects hidden under the carpet, particularly nails in the tacks.

We decided to conduct a questionnaire and medical survey. Unfortunately, the interpretation of the medical examination data is limited, since only a fraction of the questionnaire respondents were examined. The extent of bias was reduced somewhat by means of statistical adjustment.

From our questionnaire data, 8 (7.1%) of 112 responding floorlayers reported past skin infection; this is four times as high as other groups (1.8%) in this study. This may be extrapolated to 71.4 per 1,000. The time span was not specified in our questionnaire, but if we use the average years of work (24.3 years) for floorlayers, this represents 2.9 cases per 1,000 floorlayers per year. Although such infections are not life-threatening, they may cause temporary disability and may be preventable.

The findings of patellar skin thickening and erythema among carpetlayers and tilelayers were considered to be physiological responses to frequent pressure and friction of kneeling work.

TABLE VII. Thickening of Patellar Skin and Use of Knee Pad

Knee pad use ^a (percent of time)	Patellar skin thickening		Total ^a
	Bilateral thickening (%)	Unilateral thickening (%)	
1-20	24 (43.6)	4 (7.3)	55
21-60	14 (73.7)	0 (0)	19
61-100	15 (62.5)	5 (20.8)	24
Total	53 (54.1)	9 (9.2)	98

^aOnly those who reported the use of knee pads are included. Test for association of knee pad use and patellar thickening = 13.763, (df = 4), $p = 0.0081$.

It is puzzling to note that for either thickening or erythema, the highest rate was found among the "intermediate" users of the knee kicker, rather than among the "frequent" users. This is probably due to the fact that among those examined, all of the "intermediate" users of the knee kicker were active workers, while 43% of "frequent" users were retired workers whose thickening or erythema might have regressed. Furthermore, we suspect that some of the frequent users might have developed certain knee joint impairment and left the trade (thus not appearing in a large number in our study). However, we have not been able to examine this speculation systematically.

A question of whether or not skin thickening and erythema might serve as markers of potentially damaging trauma to the knee joint was not addressed in this report, although it is possible that such dermal signs may be related to trauma via the acts of kneeling and knee kicking.

We found that wearing knee pads was positively associated with thickening of the knee skin. We had expected that wearing knee pads would reduce skin thickening. A possible explanation may be that those who kneel more tend to use knee pads more. Even if knee pads are worn, the knee skin is still rubbed against the trousers. We feel, however, that this does not negate the protective role of wearing knee pads.

The "beat knee," once prevalent among British coal miners who worked in low seam mines, has declined because of two factors: first, increased mechanization has reduced the need for manual shoveling of coal in a kneeling position; second, and probably more important, improved design and quality of knee pads, including the material for the inner lining as well as for the outer shell, strap size, and positioning [Archibald, 1982].

It is unlikely that kneeling can be eliminated from the work of floorlayers or tilelayers. Therefore, there is a legitimate need for the development of good quality knee pads. These pads should offer a high degree of protection, durability, comfort, ease of wear, low weight, and low cost. One promising approach proposed by Swedish researchers [Ekstrom et al, 1981] is to place a rectangular piece of highly resilient foam rubber in a knee pocket attached to the work trouser. Such a device will prevent not only penetrating wounds but also provide a cushion for the knee joint of kneeling workers.

With regard to carpet stretching, a device called a "power carpet stretcher," which is operated by hands, is available. However, it has not eliminated the use of the knee kicker among carpetlayers. Many still prefer to use the knee kicker for quick installation. Also, it is difficult to use the power stretcher in small areas or on stairs. Additional research is needed to improve protective devices for kneeling workers.

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QUESTIONS AND ANSWERS

Ms. Fineman (Consumer Products Safety Commission): We are interested in this subject (of carpet laying) from a viewpoint of sensitization from formaldehyde resins, which are sometimes used either in the carpeting or in the backing of the carpeting, and to which people would be more exposed because of the friction from rubbing the knee. Would it be possible to incorporate in the study of the carpet workers some questions about this type of contact dermatitis, and even about lung reactions also in that group while you are studying them?

Dr. Tanaka: It is my understanding that if formaldehyde resins are used in the manufacturing of carpet, its backing, or the padding material, it must all be cured and there would be no or minimal release of formaldehyde. Although we did not include a question about formaldehyde per se, we did include dermal findings of erythema, eczema, and thickening in the frontal knee. In later analysis (as reported in the text) there were no statistical differences in the incidence of eczematous skin lesions in the knee among the three groups. In addition, carpetlayers reported to us that they were concerned about the health effects of carpet cement they used. As a result, we decided to study these problems from two directions: one is a study of their knee joint and the other is an industrial hygiene study to determine what agents are being used and how much.

Dr. Rycroft: From my experience, carpet installers are a highly paid group of workers for what they do. I wonder which comes first, these terrible knee conditions, or the pay, or are we paying them a lot for getting the conditions?

Dr. Tanaka: I am not sure whether or not it is a specifically highly paid group. Neither do I know whether or not they consider that their wages are high enough to take these risks (of knee injury). I am told that the unionized floorlayers are probably a little more protected because they are paid by the hour. In contrast, nonunion floorlayers are usually hired by carpet dealers and paid by the job or on an incentive basis. So the latter group may impose more impacts on their knees in a day. I am also told that in the installation works performed by unionized workers, customers often require the use of power stretchers for better installation, while nonunionized workers are hired by carpet dealers and are sent on many small

residential jobs in which knee kickers are mostly used. In either case, it may be said that they are using a part of their body as an impacting tool, which incurs some resultant damages.

Dr. Rycroft: They do not have to do a quick job. They are doing a quick job to earn more money. Correct?

Dr. Tanaka: I suppose that may be the case for most of these workers. (We did not have an opportunity to study a group of nonunionized floorlayers.)

Dr. Adams: It is not only for laying the carpet, but they also have to remove the old carpet and the old pad. There are mites, fleas, dirt, and dust, and everything else in there, which may pose health hazards.