

Dermal Exposure, Handwashing, and Hand Dermatitis in the Rubber Manufacturing Industry

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Skin diseases, such as hand dermatitis, are thought to be a common problem in the rubber manufacturing industry, as workers are exposed to a wide range of chemicals with known irritant and sensitizing potential. We conducted a cross-sectional survey of a representative sample of rubber manufacturing workers (N = 202), selected from nine different rubber companies. Prevalence of hand dermatitis ("major" and "minor" dermatitis) and skin injuries was assessed on the basis of a diagnosis by a dermatologist. We investigated the possible relations between actual skin exposure, handwashing practices, and hand dermatitis. Prevalence of major hand dermatitis (7%) was comparable with that in the general population;

however, minor signs of dermatitis were more common among the surveyed population (28%), as were traumata of the skin (17%). Dermal exposure to cyclohexane-soluble agents at work was related to the occurrence of major hand dermatitis, but not to the occurrence of minor hand dermatitis. Moderate and frequent handwashing especially with industrial surfactants containing scrubbing particles were found to be strongly associated with the occurrence of minor dermatitis [odds ratio = 4.27 (95% confidence interval = 0.90–20.27) and odds ratio = 6.38 (95% confidence interval = 1.33–30.17, respectively)]. (Epidemiology 2001;11:350–354)

Keywords: rubber industry, dermal exposure, occupational contact dermatitis, handwashing, industrial surfactants, occupational exposures.

Skin diseases are estimated to account for 9–35% of all occupational diseases,^{1–4} of which allergic and irritant contact dermatitis constitute the majority of occupational cases.⁵ Frequent causes of occupational allergic contact dermatitis (ACD) are rubber chemicals, chromates, and epoxy resins. Detergents; cutting fluids; organic solvents; and environmental factors such as humidity, occlusion, and mechanical friction have been shown to elicit irritant contact dermatitis.^{5–7} Several of these stimuli are present in the rubber manufacturing industry, and as a result, the rubber industry has been considered as a high-risk industry in relation to skin diseases.^{8,9} Most of the data, however, stem from routinely collected governmental statistics or clinical series.^{5,10} Epidemiologic investigations identifying particular occupational processes are scarce and have focused on working conditions en-

countered in large rubber tire companies.^{11–13} Rubber manufacturing in the Netherlands is predominantly a small-scale industry producing mainly custom-made technical rubber goods.

The focus of most of these industry-based epidemiologic studies has been on the occurrence of ACD due to exposure to chemical substances with great sensitizing potential, such as thiuram-, carbamate, paraphenylene, and mercapto- compounds.^{14,15} A recent study has indicated that not only are rubber additives an important risk factor for allergic reactions, but so is natural rubber, as allergenic natural rubber latex (NRL) proteins have been detected in extracts from rubber products.¹⁶ On the other hand, scant data are available on irritant contact dermatitis and skin trauma related to working conditions in the rubber manufacturing industry. Furthermore, none of the epidemiologic studies controlled for potential confounders or effect modifiers such as past or present atopic dermatitis, handwashing practices, and domestic exposures.

We conducted a cross-sectional study of rubber manufacturing workers to investigate the prevalence of skin disorders and the possible relation between dermal exposure and hand dermatitis. We obtained detailed information on actual skin exposure, handwashing practices, personal characteristics, and domestic exposures to identify specific risk factors asso-

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TABLE 1. General Characteristics of the Surveyed Plants, Production Functions, and Prevalence of "major" and "minor" Dermatitis and Traumatata at the Hands of Workers in the Rubber Manufacturing Industry per Company and Production Function

Factory (SBI code)*	No. of Workers†	Subjects‡		Production	Major Dermatitis		Minor Dermatitis		Traumatata	
		No.	%		No.	%	No.	%		
1 (3112)	25	19	76	Mold and extruding articles, rubber foils	0	0	10	53	4	21
2 (3112)	35	17	49	Mold and extruding articles, roller covering, metal to rubber, bonded articles	1	6	3	18	3	18
3 (3112)	40	16	40	Mold articles	4	25	0	0	1	6
4 (3112)	50	18	36	Mold and extruding articles, metal to rubber-bonded articles	0	0	2	11	7	39
5 (3112)	150	15	10	Mold and extruding articles, metal to rubber-bonded articles	1	7	4	27	2	13
6 (3111)	190	34	17	Bicycle and moped tires	4	12	7	21	5	15
7*3111)	150	32	21	Belting, hose	1	3	10	31	6	19
8 (3111)	660	31	5	Industrial and passenger car tires	1	3	10	32	3	10
9 (3121)	55	20	36	Retreading truck and industrial tires	2	10	10	50	3	15
Production function										
Compounding and mixing	125	19	15	Raw material handling, weighing, mixing and milling	2	11	6	32	2	11
Pretreating	160	29	18	Degreasing, spraying, and repair buffing	2	7	10	35	4	14
Molding	380	52	14	Extruding and calendering, component, assembly and building	3	6	18	35	10	19
Curing	295	48	16	Curing	3	6	7	15	10	21
Finishing	155	18	12	Inspection and finishing	2	11	4	22	2	11
Shipping	85	14	16	Storage and dispatch	1	7	5	36	2	14
Engineering	135	14	10	Engineering services	1	6	6	33	4	22
laboratory	20	4	20	Laboratory	0	0	0	0	0	0
All	1,355	202	15		14	7	56	28	34	17

* Dutch Standard Industrial Classification: 3111 rubber tire; 3112 general rubber goods; 3121 retreading.

† Number of workers directly involved in production.

‡ Number of selected subjects participating in the study.

ciated with increased likelihood of work-related skin disorders.

Subjects and Methods

STUDY POPULATION

We conducted the study from January through July 1997 as part of a large cross-industry survey to evaluate the possible role of dermal exposure on the total genotoxic dose of workers in the rubber manufacturing industry in the Netherlands. We randomly selected subjects among those employed in nine companies (three rubber tire, five general rubber goods, and one retreading company), based on their production function (compounding and mixing, pretreating, molding, curing, finishing, shipping, engineering service, and laboratory), to cover a variety of production processes and exposures.¹⁷ Table 1 presents general characteristics of the companies and production functions. Total workforce in the surveyed companies was 1,355 subjects, of which 225 subjects were selected. Two hundred two (90.2%) subjects took part in the medical evaluation and exposure survey and successfully completed a self-administered questionnaire. The self-administered questionnaire included detailed questions concerning demographics (age, ethnicity, etc), known risk factors of skin complaints and diseases, atopic dermatitis, and absenteeism and medical consultation due to skin complaints. All 202 subjects were male, between 19 and 60 years of age, with a mean age of 37.6 years (standard deviation = 9.1).

HAND DERMATITIS

Two dermatologists conducted a medical evaluation of current skin condition. Their classification was based on objective skin symptoms: active hand dermatitis ("major" dermatitis), the first symptoms of dermatitis ("minor" dermatitis), and skin injuries (traumatata). Major dermatitis was defined as erythema, papules, vesicles, and fissures, composing a clear eczematous picture. Minor dermatitis was exhibited as erythema, slight chapping, and scaling of the skin. Traumatata of the skin comprised cuts and burns. No distinction was made between irritant and allergic dermatitis, as morphologic characteristics of these skin disorders are similar.^{18,19}

HANDWASHING

Dermatologists asked subjects standardized questions regarding handwashing frequency and type of surfactant used during the workday. Contents of identified surfactants were subsequently verified and categorized as mild surfactants (normal household soaps) and industrial surfactants (soaps containing scrubbing particles with or without the addition of an organic solvent).

DERMAL OCCUPATIONAL EXPOSURE

Personal dermal exposure to cyclohexane-soluble matter (CSM) was measured with a dermal pad sampler on 3 consecutive days (Tuesday through Thursday). The pad sampler consisted of 24 layers of cotton surgical

gauze with a surface of 9 cm², worn on the volar forearm (wrist) of the hand of preference throughout the 8-hour working period.^{20,21} CSM content of the pad sampler was determined by means of the National Institute of Occupational Safety and Health P&CAM 217 method.²²

NATURAL RUBBER LATEX ALLERGY

Plasma of all subjects was analyzed for anti-NRL IgE by enzyme immunoassay.²³ Flat-bottom 96-well polystyrene microtiter plates with high binding capacity were coated overnight at 4°C with latex allergen dilution (10 µg/ml) (*Hevea brasiliensis*, ALK Benelux, Houten, the Netherlands). Sera diluted 1/10 in phosphate-buffered saline containing 0.5% (weight/volume) Tween were added to the wells and incubated for 2 hours at 37°C. Bound IgE was measured in a four-step procedure consisting of three 1-hour incubations at 37°C with monoclonal mouse anti-human IgE, biotinylated rabbit anti-mouse immunoglobulins, avidin-peroxidase, and finally an incubation for 30 minutes with *o*-phenylenediamine containing 0.015% (volume/volume) H₂O₂. The reaction was stopped after 30 minutes by the addition of 50 µl 2N HCl, and the absorption was read at 492 nm. All sera were tested in duplicate wells on the same microtiter plate. Each plate included a positive control serum tested in duplicate and two reagent blanks (no-serum controls). Sera were considered positive if the mean absorption at 492 nm was 0.05 units higher than the reagent blanks.

CALCULATIONS AND STATISTICAL ANALYSES

We calculated mean individual dermal exposure levels from the repeated individual measurements. We used the median of the aggregated exposure distribution as the cutoff point to classify exposure dichotomously as low/high. We evaluated use of protective gloves on the basis of the actual use of gloves during the exposure survey. If subjects wore gloves during more than 50% of the measurement days, we classified them as "frequent" glove users. Two of us (R. V. and D. P. B.), blind to outcome, evaluated reported domestic activities and hobbies, such as gardening and car maintenance, that are known to irritate skin and classified such exposures dichotomously (yes/no).

We initially evaluated possible relations between personal and work-related determinants and hand dermatitis by computing crude prevalence odds ratios (ORs) from univariate logistic regression analyses. We further conducted multiple logistic regression analyses comparing subjects with a particular skin condition (for example, major and minor dermatitis) with subjects without any adverse skin condition (N = 113). In evaluating major hand dermatitis, we adjusted for reported past or present atopic dermatitis.

Results

Among the 202 subjects, 14 were diagnosed with major hand dermatitis. Twenty-eight per cent showed symptoms of minor hand dermatitis, and 17% were di-

agnosed with traumatized skin at the time of the study (Table 1). Subjects with major hand dermatitis had erythema and papules with vesicles and sometimes fissures on the palms and the palmar sides of the fingers and fingertips. The subjects with minor dermatitis had erythema, almost exclusively, with occasional scaling and chapping of the hands. We observed large differences in the prevalence of skin disorders among the different companies, but smaller variation in prevalence among different production functions (Table 1).

Of the subjects with skin disorders, 34.8% attributed their adverse skin condition to working conditions encountered in the rubber manufacturing industry; 41.6% claimed relief of skin problems when not working for several days. We observed a clear trend between the severity of skin disorders and the proportion of subjects who claimed beneficial effects from a few days off work: 64.3% of those with major dermatitis, 42.9% of those with minor dermatitis, and 29.4% of those with trauma. Only two subjects reported having had an allergic reaction due to contact with rubber goods and/or chemical additives. None of the 202 workers showed a class II or higher positive anti-NRL IgE reaction. Although skin disorders were prevalent in this population, only in seven instances did the occurrence of hand dermatitis result in a subject's absenteeism from work during the previous 12 months.

We used the median (31.7 µg/cm²) of the aggregated personal dermal CSM exposure distribution as the cutoff point to classify dermal exposure as low or high. Subjects without any skin disorders (N = 113) had a median dermal CSM exposure concentration of 31.2 µg/cm² (Q1-Q3 = 19.1-57.7 µg/cm²), which was similar to subjects with major or minor hand dermatitis (median = 31.3 µg/cm²; Q1-Q3 = 14.9-70.5 µg/cm²). In Table 2, we present crude prevalence ORs and ORs estimated from the multiple logistic regression analyses. Crude ORs did not differ much from the ORs derived from the multiple logistic regression analyses, except for dermal CSM exposure and handwashing. High dermal exposure levels measured at the wrist were associated with major hand dermatitis [OR = 2.15, 95% confidence interval (CI) = 0.58-7.95]. Other determinants under consideration suggested an overall protective effect in relation to major hand dermatitis, especially for domestic activities suspected of causing skin irritation (OR = 0.33, 95% CI = 0.10-1.10). In contrast, minor hand dermatitis was positively associated with the studied determinants except for glove use (OR = 0.58, 95% CI = 0.27-1.23). Moderate and frequent handwashing during the workday showed a strong positive effect: OR = 3.09 (95% CI = 1.16-8.21) and OR = 2.27 (95% CI = 0.92-5.56) after adjustment. The use of industrial surfactants seemed to augment the occurrence of minor hand dermatitis (OR = 1.92, 95% CI = 0.91-4.02). Domestic activities with potential skin-aggravating potency were found to be one of the major risk factors for the occurrence of minor dermatitis (OR = 4.33, 95% CI = 1.72-10.92). Little association was observed between age and major or minor dermatitis (data not shown).

TABLE 2. Associations between Hand Dermatitis and Personal and Work-Related Determinants, Presented as Prevalence Odds Ratio with 95% Confidence Intervals from Multiple Logistic Regression Analyses

	Controls (N = 113) N	Major Dermatitis*† (N = 14)			Minor Dermatitis (N = 56)				
		N	Crude OR‡	OR	95% CI	N	Crude OR	OR	95% CI
High dermal exposure§	56	8	1.36	2.15	0.58–7.95	26	0.88	0.82	0.40–1.69
Handwashing¶									
5–9	33	3	0.72	0.53	0.11–2.66	18	1.68	3.09	1.16–8.21
>10	40	6	1.20	1.18	0.30–4.62	25	1.92	2.27	0.92–5.56
Industrial surfactant use	60	7	0.88	0.64	0.19–2.21	35	1.47	1.92	0.91–4.02
Glove use	51	5	0.68	0.61	0.18–2.11	19	0.62	0.58	0.27–1.23
Domestic activities	71	6	0.44	0.33	0.10–1.10	46	3.40	4.33	1.72–10.92

* Regression analyses adjusted for atopic dermatitis (OR = 6.6, $P = 0.07$).

† Number of subjects with particular determinant.

‡ Odds ratio derived from the univariate logistic regression analyses.

§ Tested against low dermal exposure to cyclohexane-soluble matter.

¶ Tested against low hand-washing frequency (0–4).

|| Domestic activities with potentially skin-aggravating potency.

The relation between handwashing frequency, surfactant use, and minor hand dermatitis was further investigated in a stratified analysis according to the type of surfactant used. A clear dose-response relation was found between the frequency of industrial surfactant and the prevalence of minor dermatitis (Table 3). This trend between handwashing frequency and minor dermatitis was not observed among the subjects using only mild surfactants during the workday.

Discussion

As we did not design the study primarily to assess the occurrence of skin disorders in this particular industry, selection bias is not likely to have occurred. As the relative sample size per production function and company was not equal, the prevalence of skin disorders could have been biased by the relative overrepresentation of a particular production function or company. Adjusted prevalences were similar when compared with crude prevalences for major and minor dermatitis and traumata of the skin (7.2% vs 6.9%, 29.0% vs 27.7%, and 17.8% vs 16.8%, respectively). Therefore, the observed prevalence of skin disorders and associated risk factors is representative for the rubber manufacturing industry in the Netherlands. Although some authors^{24,25} have argued for the use of prevalence ratios, the standard effect measure in prevalence studies is the prevalence OR,^{26,27} because, in a stable population, this measure provides an estimate of the ratio of the products of disease incidence and average disease duration in the two populations being compared. Thus, if an exposure

does not affect disease duration, then the prevalence OR directly estimates the incidence rate ratio.²⁸

Prevalence of major hand dermatitis (7%) was similar to that in previous reports from the rubber manufacturing industry.^{12,29,30} Although 27% of the subjects with major hand dermatitis attributed their skin condition to the working circumstances encountered in the rubber industry, the reported prevalences of hand dermatitis in the general population are nevertheless comparable (2–10%).³¹ Minor signs of dermatitis, however, were more common in the rubber workers (28%). Although symptoms were mild, irritated and damaged skin is a precursor to eczema.¹⁹ The overall absence of self-reported allergic reactions due to contact with rubber goods or chemical additives suggests that irritant contact dermatitis is the predominant form of hand dermatitis observed in this industry. Nevertheless, as morphologic characteristics of allergic and irritant contact dermatitis are similar,^{18,19} only application of diagnostic patch tests could have ruled out with certainty the presence of allergic contact factors.

The present results could have been prone to selection bias in the form of a healthy worker effect owing to the cross-sectional character of the survey. As not many people seek employment elsewhere because of skin disorders (except in the case of proven ACD), this phenomenon is not very likely to have occurred.³²

We observed a large difference in prevalence of all skin disorders between companies and production functions. As variation in prevalence between production functions was lower than between companies, company-

TABLE 3. Relation between Minor Hand Dermatitis and Handwashing Frequency Stratified for Industrial and Mild Surfactant Use,* Presented as Prevalence Odds Ratios with 95% Confidence Intervals

Handwashing Frequency	All Detergents (N = 167)		Industrial Surfactant (N = 76)†		Mild Surfactant (N = 71)‡	
	OR	95% CI	OR	95% CI	OR	95% CI
5–9	3.09	1.16–8.21	4.27	0.90–20.27	2.38	0.52–10.95
>10	2.27	0.92–5.56	6.38	1.35–30.17	1.17	0.28–4.80

* Analyses adjusted for personal dermal exposure, glove use and domestic exposures (model table 2).

† Exclusive use of industrial surfactants.

‡ Exclusive use of mild surfactants.

specific production characteristics and/or working conditions (including handwashing) probably play an important role in the occurrence of skin disorders. Nevertheless, we did not observe a consistent picture among rubber tyre, general rubber goods, and retreading companies. Investigation of possible underlying risk factors for major hand dermatitis showed an overall protective effect with the exception of dermal CSM exposure. Damage to the skin can be repaired, at least in part, when the interval between individual damaging processes is sufficiently long and when the damage is not too extensive.³³ This rehabilitation was demonstrated in our study, as 42% of all subjects with diagnosed skin disorders claimed relief of their complaints when not working for several days. Thus, it is likely that subjects with diagnosed major hand dermatitis consciously try to avoid skin-damaging activities, which leads to the observed reversed relations with, for example, industrial surfactant use and domestic activities. Because symptoms for minor dermatitis are mild, they are seldom considered as an adverse health effect by the subjects themselves.¹⁸ Consequently, subjects do not change their working habits and domestic activities accordingly.

Handwashing practices (frequency and soap use) were found to be an important risk factor for minor hand dermatitis. Even though the mechanisms of skin irritation due to surfactants are not fully understood, it is well documented that repetitive handwashing can lead to irritant contact dermatitis.^{34,35} Industrial surfactants were available in all companies, and although differences in average use per day between companies were observed (range 0.9–7.1), this difference did not account fully for the observed differences in prevalence of minor dermatitis between these companies. Therefore, additional unidentified company-related risk factors may be associated with the occurrence of contact dermatitis in this industry.

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