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ORIGINAL ARTICLE

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Occupational exposure to epoxy components and risk of dermatitis: A registry-based follow-up study of the wind turbine industry

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Abstract

Background: Allergic contact allergy and dermatitis are frequently reported among epoxy-exposed workers.

Objectives: To determine the risk of dermatitis associated with epoxy exposure.

Methods: We followed 825 epoxy-exposed and 1091 non-exposed blue-collar workers, and 493 white-collar workers of a Danish wind turbine blade factory during 2017–2022 with linked data from national health registers on diagnoses, patch testing, or fillings of prescriptions for topical corticosteroids. Incidence rate ratios of dermatitis or a first-time topical corticosteroid prescription were estimated with Poisson regression using non-exposed blue-collar workers as reference. We similarly estimated incidence rate ratios for the duration of epoxy exposure and current epoxy exposure.

Results: Epoxy-exposed blue-collar workers showed a dermatitis incidence rate of 2.1 per 100 000 person days, a two-fold increased risk of dermatitis and a 20% increased risk of filling a prescription for topical corticosteroids. Incidence rate ratios were higher during early exposure and declined with further exposure for both outcomes. White-collar workers had generally lower risks.

Conclusion: We observed an increased risk of dermatitis following epoxy exposure confirming previous case reports and cross-sectional studies emphasizing the need for intensified focus on preventive efforts for this group of workers.

KEYWORDS
allergic contact dermatitis, epidemiology, epoxy resin systems, occupational

1 | INTRODUCTION

Epoxy resin systems were introduced in the 1940s and shortly thereafter, the first cases of epoxy sensitization and dermatitis were described.[1–4] Epoxy components are now well-known sensitizers of the skin and a common cause of allergic contact dermatitis.[5–7] Contact dermatitis has frequently been observed among workers exposed to epoxy components within construction, electronics, painting and in the manufacturing of aircraft and wind turbines[7–12] and more often among blue than among white-collar workers.[13,14] Due to this, comprehensive protective equipment is required and the Danish Working Environment Authority requires workers handling epoxy components to be certified for this work.[7]

Wind energy is an emerging sustainable energy source and in Denmark, the wind turbine industry is the major consumer of epoxy resin systems.[15] This industry has a high recognition rate for contact dermatitis as an occupational disease.[12,16] In 2004, high prevalences of sensitization and dermatitis were observed among epoxy-exposed workers of the wind turbine industry.[17–19] In a recent cross-sectional study, we observed an 8.9% prevalence of sensitization and a 16.4% prevalence of dermatitis among non-atopic epoxy-exposed workers in the industry.[14] Among office workers, constituting a non-exposed reference group, none were sensitized and 6.5% had dermatitis.

Many of the previous epidemiological studies on this topic are case reports, studies with self-reported exposure information, crude registry-based exposure or outcome information, or cross-sectional designs with voluntary participation and no reference groups.[4,12,16,19]

The objective of this cohort study was to analyse the incidence of dermatitis over time comparing workers with detailed information on epoxy exposure with a reference cohort of non-exposed workers.

2 | METHODS

2.1 | Setting

2.1.1 | Dermatitis diagnoses in the Danish healthcare sector

In Denmark, dermatitis is usually diagnosed and treated by general practitioners, but they do not provide diagnostic information to the national registers.[20] Complicated, occupationally related cases, or cases requiring further diagnostic procedures, such as a patch test, will be referred to a hospital or a private dermatology clinic, where data are routinely collected in the national registers. Mild topical corticosteroids (hydrocortisone) are available over the counter at pharmacies, whereas more potent topical corticosteroids require a prescription from a medical doctor.

2.1.2 | Work procedures in the wind turbine industry

The epoxy-exposed workers of this study were primarily doing lamination or filling procedures. Lamination is characterized by removing large casting defects of the wind turbine blades and re-establishing the surface by hand lamination. Using a handheld roller, fibreglass mats are embedded with clear liquid epoxy. The filling procedure is used to repair smaller defects with a viscous epoxy filler that is smoothened with a scraper. It is mandatory for workers to wear a protective suit with a hood, face shield, protective glasses, safety shoes and often an apron, protective arm sleeves and chemically resistant disposable nitrile-rubber gloves tested for permeability against the relevant product and procedure. Around one third of the non-exposed blue-collar workers handled fibreglass mats manually during a significant part of the work day. Besides this, there is limited exposure to skin irritants in the non-exposed blue-collar workers. The epoxy-exposed work tasks are physically demanding, the worker turnover is high and the workers are young (as shown later).

2.2 | Study population

We established the study population from company files provided by a wind turbine blade factory in Denmark holding information on all workers employed at any time between 1 January 2017 and 1 April 2022. We excluded workers patch tested or diagnosed with dermatitis before the start of follow-up, as defined later, or two or more prescriptions for topical corticosteroids within 5 years before the start of follow-up to avoid including workers with prevalent dermatitis. We excluded workers not included in The Danish Occupational Cohort (DOC*X) cohort because our outcome and covariate data were obtained for members of this cohort.[21] DOC*X includes ever gainfully employed people in Denmark from 1976 to 2019; thus, we did not include workers for the current analyses who first entered the labour market after 2019. We excluded workers with no valid civil registration number, emigrating before begin of follow-up

and women because very few were exposed to epoxy components. Workers first employed in the study factory after 30 June 2021 were also excluded as this was the last date with outcome information.

Using the unique civil registration number assigned to all Danish residents, we linked the study population to individual-level information from the DOC*X,[21] the Civil Registration System, the Danish National Patient Registry,[22] the Danish National Health Service Register,[23] the Danish National Prescription Registry[24,25] and the Population Education Registry.[26]

2.3 | Exposure

The factory provided full employment history for each worker with information on occupational status within the factory (blue- or white-collar worker) and departments (epoxy production, no epoxy production) with starting and ending dates for each assignment. Occupational status and department could change during employment and hence every worker could move in and out of different combinations of occupational status and department over time. In the overall analyses, for each day of follow-up, exposure status was classified as a white-collar worker from the first date as a white-collar worker, as a non-exposed blue-collar worker from the first date of employment in a department with no epoxy production, and as exposed blue-collar worker from the first date of employment in a department with epoxy production. Hence, in the overall analyses, exposed blue-collar employment overruled any subsequent non-exposed blue-collar employment, which overruled any subsequent white-collar employment.

In analyses restricted to blue-collar workers, we recorded duration of exposure as the cumulative number of days in exposed employment. To elucidate the impact of current exposure, we recorded any exposed employment occurring within the previous 60 days, while any exposure outside this window was disregarded.[27]

2.4 | Outcomes

Outcomes were obtained from three national health registers. The Danish National Patient Registry has detailed information on all patients discharged from Danish hospitals since 1977 and outpatient hospital contacts since 1995.[22] For each contact, primary and optional secondary diagnoses are recorded according to the International Classification of Diseases 8th revision (ICD-8) during 1977–1993 and ICD-10 during 1994–2022, as well as information on procedures coded according to SKS, which is a Danish healthcare classification system.

The Danish National Health Service Register contains information on consultations with health contractors in primary healthcare, including private practicing dermatologists, supported by public health insurance since 1990.[23] The register contains information on specialty, the purpose of the consultation and patch testing procedure that were available for this study from 1 April 2017.

The Danish National Prescription Registry contains individual-level information on all prescriptions filled in community pharmacies with information on the Anatomical Therapeutic Chemical Classification System together with the date of filling, since 1994.[24] We had a complete follow-up for the three registers until and including 30 June 2021.

2.4.1 | Dermatitis

We defined dermatitis as having either a primary or a secondary inpatient or outpatient hospital diagnosis of dermatitis, a hospital patch test procedure, a private dermatology clinic consultation for 'atopic dermatitis, hand eczema or psoriasis' (these conditions are not coded separately), or a private dermatology clinic patch test. We defined the onset date as the date of hospital admission, first outpatient visit or dermatology clinic consultation.

2.4.2 | Topical corticosteroids

Topical corticosteroids are the first-line treatment for dermatitis. In an attempt to capture workers who developed contact dermatitis but who had not (yet) received a specialist diagnosis or patch test, we included a secondary outcome defined as filling one or more prescriptions for topical corticosteroids alone or in combination with anti-infectives. Because of our eligibililty criteria, the washout period was 5 years (the 5 years before start of follow-up). We considered the first date of filling to be the date of onset in this analysis. Detailed definitions are provided in Table S1.

2.5 | Other characteristics

Information about educational level and specific occupation at the start of follow-up was provided by DOC*X based on data from Statistics Denmark and coded according to DISCO-88, the Danish version of the International Standard Classification of Occupations, ISCO 1988.[21] If the DISCO-88 code was missing in the first year of employment at the factory, the latest valid code was assigned ($n = 159$ [6.6%]). Educational level was grouped into lower and upper secondary, short cycle tertiary, bachelor, master, doctoral or equivalent based on the international standard classification. Information on age and sex was obtained from the Civil Registration System.

2.6 | Statistical analyses

We followed each worker from 1 January 2017, or the day of first employment until onset of dermatitis, death, emigration, disappearance or end of follow-up by 30 June 2021, whichever occurred first. In the secondary analysis, we followed workers until their first filled

prescription for topical corticosteroids, death, emigration, disappearance or end of follow-up by 30 June 2021, whichever occurred first.

We treated exposure status, duration of exposure and current exposure as time-varying variables and estimated incidence rate ratios (IRR) with 95% confidence intervals (CI) as the number of outcomes per person-days of follow-up with Poisson regression. Analyses were adjusted for age (<30, 30–39, 40–49, ≥50 years). Information on educational level and specific occupation was not included in the statistical analyses due to similar educational level among exposed and non-exposed blue-collar workers (as shown later) and the limited number of events in some of the analyses.

In the overall analyses and analyses of cumulative exposure, we used the non-exposed blue-collar workers as the reference. Five categories of duration of exposure were defined: 0, 1, 2, 3 and ≥4 years, 1 year defined as 365 days. Current exposure was defined as ever versus never exposure within the last 60 days regardless of the duration of exposure.

We fitted restricted cubic splines with 95% CIs for the duration of exposure as a continuous variable, placing the knots at the 5, 50 and 95 percentiles.[28] These analyses only included the blue-collar workers exposed for at least 1 day (excluding the null-exposed blue-collar workers as well as the white-collar workers).

In a sensitivity analysis, we required at least two fillings of a prescription for topical corticosteroids to be classified as an event. The statistical analyses were performed using Stata version 17.0 (StataCorp, College Station, TX).

This study was registered at the repository of the Central Denmark Region (J. no. 2012-58-006/Case no. 1-16-02-125-200). Register studies in Denmark without biological materials do not need approval from the National Committee of Health Research Ethics or informed consent. All data were analysed at the server of Statistics Denmark and we had only access to pseudonymized data that were handled according to the rules of Statistics Denmark. In agreement with the EU General Data Protection Regulations (GDPR), we did not report on groups of three or less persons.

3 | RESULTS

Among the eligible 3459 workers, we excluded 56 workers patch tested or diagnosed with dermatitis before the start of follow-up, 275 with two or more prescriptions for topical corticosteroids within 5 years before start of follow-up, 477 women and 242 for other reasons (Figure S1, Table S2). This left 2409 workers (69.6%) for further analyses.

3.1 | Baseline characteristics

Exposed blue-collar workers were younger than non-exposed blue-collar workers and white-collar workers (Table 1). Specific occupation and highest achieved education were similar for exposed and non-exposed blue-collar workers, the majority being plant and machine operators and assemblers, and having upper secondary education. White-collar workers were more often professionals, technicians and associate professionals and had a bachelor, master or equivalent as the highest achieved education. Excluded and included workers were comparable with respect to specific occupations and educational levels (Table S3). Slightly more blue-collar workers than white-collar workers were excluded because of prior dermatitis or filling a prescription for topical corticosteroids, while little differences were seen between exposed and non-exposed blue-collar workers (Table S2).

3.2 | Dermatitis

We identified 41 dermatitis events during 3 384 675 person-days of follow-up (median 1641 days; interquartile range: 1144–1641 days) at an incidence rate of 1.2 per 100 000 person-days. In the secondary analysis, we identified 353 topical corticosteroid events during 3 115 927 person-days of follow-up (median: 1641 days; interquartile range: 1003–1641 days), yielding an incidence rate of 11.3 per 100 000 person-days. A total of 21 dermatitis events (51.2%) were identified at a hospital. Eight of these (all epoxy-exposed), were diagnosed at a department of occupational medicine. The majority of hospital diagnoses of dermatitis fell within subgroups of 'allergic contact dermatitis' and 'other dermatitis'.

The incidence rates of dermatitis were 2.1, 0.8 and 0.5 per 100 000 person-days for exposed blue-collar workers, non-exposed blue-collar workers and white-collar workers, respectively. With non-exposed blue-collar workers as a reference, we thus observed a two-fold increased IRR (adjusted) for exposed blue-collar workers (IRR: 2.4, 95% CI: 1.2–5.0) but a decreased IRR (IRR: 0.6, 95% CI: 0.2–2.1) among white-collar workers (Table 2).

The blue-collar workers exposed for less than 1 year (1–365 days) showed an IRR of 3.7 (13 events, 95% CI: 1.6–8.6) compared with the non-exposed blue-collar workers (Table 2). The mean time from start of follow-up until onset of dermatitis within the first year was 191 days. The IRR decreased monotonically with a longer duration of exposure (Table 2; Figure 1). The IRR of dermatitis was 2.9 (95% CI: 1.5–5.9) among blue-collar workers with current exposure (during the previous 1–60 days) compared with non-exposed blue-collar workers.

3.3 | Prescribed corticosteroids

We observed IRs for filling a prescription for topical corticosteroids of 13.0, 11.4 and 7.9 per 100 000 person-days for exposed blue-collar workers, non-exposed blue-collar workers and white-collar workers. The IRRs were 1.2 (95% CI: 0.9–1.5) for exposed blue-collar workers and 0.7 (95% CI: 0.5–1.0) for white-collar workers compared with the non-exposed blue-collar workers. The highest IRR of 1.5 (66 events, 95% CI: 1.1–2.0) was seen for those exposed less than 1 year (1–365 days), while no increased risk was seen for a longer duration of exposure. The IRR decreased monotonically with a longer duration of exposure (Figure 2). The mean time from start of follow-up until filling of a prescription for

TABLE 1 Characteristics of the study population by exposure status to epoxy components, male wind turbine blade workers, 2017–2021.

Characteristics	Exposure status		
	Exposed blue-collar worker, *N* = 825	Non-exposed blue-collar worker, *N* = 1091	White-collar worker, *N* = 493
Age, years			
Median, interquartile range	29 (26–37)	40 (31–49)	37 (30–46)
Age group, *n* (column %)			
<30 years	415 (50.3)	207 (19.0)	114 (23.1)
30–39 years	234 (28.4)	334 (30.6)	164 (33.3)
40–49 years	113 (13.7)	284 (26.0)	130 (26.4)
≥50	63 (7.6)	266 (24.4)	85 (17.2)
Occupation (DISCO-88)[a]			
Legislators, senior officials and managers (Major Group 1)	4 (0.5)	5 (0.5)	117 (23.7)
Professionals (Major Group 2); technicians and associate professionals (Major Group 3)	15 (1.8)	16 (1.5)	284 (57.6)
Clerks (Major Group 4)	17 (2.1)	15 (1.4)	35 (7.1)
Service workers and shop and market sales workers (Major Group 5)	43 (5.2)	26 (2.4)	13 (2.6)
Skilled agricultural and fishery workers (Major Group 6); craft and related trades workers (Major Group 7)	95 (11.5)	60 (5.5)	13 (2.6)
Plant and machine operators and assemblers (Major Group 8)	518 (62.8)	865 (79.3)	4 (0.8)
Armed forces (Major Group 0); elementary occupations (Major Group 9)	133 (16.1)	104 (9.5)	27 (5.5)
Highest achieved education			
Lower secondary	214 (25.9)	315 (28.9)	41 (8.3)
Upper secondary	561 (68.0)	703 (64.4)	148 (30.0)
Short cycle tertiary	15 (1.8)	33 (3.0)	35 (7.1)
Bachelor or equivalent	19 (2.3)	17 (1.6)	94 (19.1)
Master or equivalent	6 (0.7)	9 (0.8)	157 (31.8)
Doctoral or equivalent	0 (0.0)	0 (0.0)	18 (3.7)
Missing	10 (1.2)	14 (1.3)	0 (0.0)

[a]Grouped according to International Standard Classification of Occupation, ISCO-88.

topical corticosteroids within the first year was 152 days. Current exposure showed an IRR of 1.3 (95% CI: 1.0–1.7). The sensitivity analysis defining an event as two or more fillings of prescriptions for topical corticosteroids yielded similar results (Table S4).

4 | DISCUSSION

We observed an increased risk of dermatitis or filling a prescription for topical corticosteroids following epoxy exposure, although the association was less pronounced for topical corticosteroids. Both outcomes showed the highest risks during early exposure and declined thereafter despite continued exposure. Exposure within the previous 60 days showed increased risks of dermatitis and filling a prescription for topical corticosteroids, slightly higher than the overall findings for both outcomes. White-collar workers had a generally lower risk compared with non-exposed blue-collar workers.

The results of this longitudinal study are in accordance with the increased risk of dermatitis and skin sensitization observed in non-atopic workers in our recent cross-sectional study of a subsample of the current study population with patch test data on 221 workers.[14] Multiple former studies also reported high prevalences of dermatitis and sensitization among epoxy-exposed workers.[7–13,16,19]

The declining risk of dermatitis and filling of prescriptions for topical corticosteroids with increasing duration of exposure is consistent with our previous as well as other studies.[7,14,29] This indicates a short latency period but also a healthy worker survivor effect. Workers with dermatitis move to other parts of production within the factory without epoxy exposure or leave the factory before consulting a physician or filling a prescription for topical corticosteroids.[30]

TABLE 2 Epoxy exposure, incidence rates (IR) per 100 000 person-days, crude and age-adjusted incidence rate ratios (IRR) of dermatitis and filling of a prescription for topical corticosteroids, male wind turbine blade workers, 2017–2021.

	Dermatitis ($n = 41$)					Prescription for topical corticosteroids ($n = 353$)				
Epoxy exposure	**Person-days**	**Events**	**IR**	**IRR_{crude}**	**IRR_{adj}**	**Person-days**	**Events**	**IR**	**IRR_{crude}**	**IRR_{adj}**
All workers										
Exposed blue-collar workers	1 297 107	27	2.1	2.7 (1.4–5.5)	2.4 (1.2–5.0)	1 188 983	154	13.0	1.1 (0.9–1.4)	1.2 (0.9–1.5)
Non-exposed blue-collar workers	1 442 355	11	0.8	Reference	Reference	1 321 790	151	11.4	Reference	Reference
White-collar workers	645 213	3	0.5	0.6 (0.2–2.2)	0.6 (0.2–2.1)	605 154	48	7.9	0.7 (0.5–1.0)	0.7 (0.5–1.0)
Blue-collar workers only										
Duration of exposure (years)										
0	1 442 355	11	0.8	Reference	Reference	1 321 790	151	11.4	Reference	Reference
1	417 813	13	3.1	4.1 (1.8–9.1)	3.7 (1.6–8.6)	392 219	66	16.8	1.5 (1.1–2.0)	1.5 (1.1–2.0)
2	339 564	5	1.5	1.9 (0.7–5.6)	1.8 (0.6–5.2)	315 733	36	11.4	1.0 (0.7–1.4)	1.0 (0.7–1.5)
3	261 683	5	1.9	2.5 (0.9–7.2)	2.3 (0.8–6.8)	239 952	28	11.7	1.0 (0.7–1.5)	1.0 (0.7–1.5)
≥4	278 047	4	1.4	1.9 (0.6–5.9)	1.8 (0.6–5.6)	241 079	24	10.0	0.9 (0.5–1.3)	0.9 (0.6–1.4)
Current exposure										
Exposure	900 805	23	2.6	3.1 (1.6–6.0)	2.9 (1.5–5.9)	828 344	119	14.4	1.3 (1.0–1.6)	1.3 (1.0–1.7)
No exposure	1 838 657	15	0.8	Reference	Reference	1 682 429	186	11.1	Reference	Reference

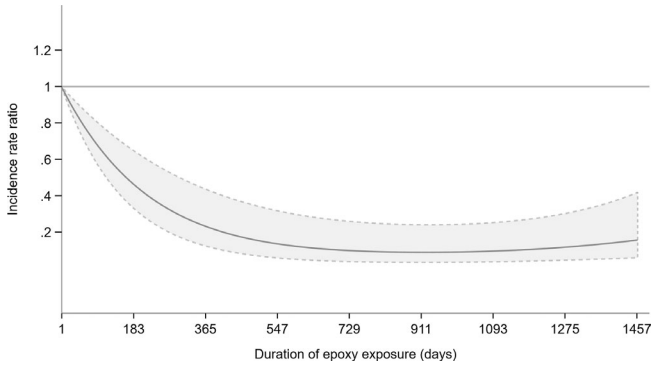

FIGURE 1 Age-adjusted incidence rate ratios of dermatitis associated with the duration of epoxy exposure entered as a restricted cubic spline model, male wind turbine workers, 2017–2021. The solid line represents the point estimate and dotted lines mark 95% confidence intervals.

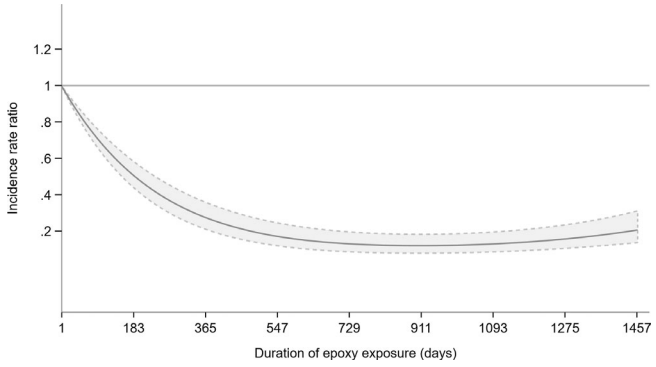

FIGURE 2 Age-adjusted incidence rate ratios of first filled prescription for topical corticosteroids associated with the duration of epoxy exposure entered as a restricted cubic spline model, male wind turbine workers, 2017–2021. The solid line represents the point estimate and dotted lines mark 95% confidence intervals.

4.1 | Strengths and limitations

A major strength of this study is the access to all exposed and non-exposed workers of the study population during the follow-up period. Participation should thus be complete and unaffected by self-selection dependent on a history of dermatitis that may have biased earlier studies relying on voluntary participation.[14,18]

We obtained data on dermatitis and filling of topical corticosteroid prescriptions from national registers with high coverage[22,24] collected within a tax-funded health care system, limiting the impact of social factors on data quality.

No information on dermatitis was available directly from the workers or from the general practitioners. The incompleteness of such cases, which are likely less severe, is indicated by the much higher number of outcome events when using our secondary outcome based on prescriptions for topical corticosteroids. We would expect such under-reporting to affect the exposed and non-exposed blue-collar workers equally unless the threshold for referral to a hospital or dermatology clinic was lower (or higher) for epoxy-exposed patients than for the non-exposed. The high number of exposed dermatitis cases and the lack of non-exposed cases diagnosed at departments of occupational medicine may indicate a lower threshold for the exposed patients because most patients are referred if an occupational cause is suspected. This suggests that we have overestimated the association between epoxy exposure and dermatitis.

Our results for topical corticosteroids should, on the other hand, not be affected by such referral bias and showed weaker associations with epoxy exposure. These results could partly be explained by non-differential misclassification and bias towards the null due to the inclusion of filling a prescription for topical corticosteroids prescribed for other dermatoses than dermatitis, for example, psoriasis.

The access to day-by-day information on epoxy exposure from a company register with high validity allowed analyses of precise exposure timing and exposure–response relations, which to our knowledge have not been done before for epoxy exposure or other skin sensitizers.

The reference group was non-exposed blue-collar workers employed at the same factory and with comparable levels of education and specific occupations as the exposed blue-collar workers. Furthermore, a comparable number of exposed and non-exposed blue-collar workers were excluded because of dermatitis or topical corticosteroid use before the start of follow-up indicating comparable underlying risks of dermatitis for the two cohorts. The exposed blue-collar workers were on average 11 years younger than the non-exposed blue-collar workers, which we accounted for by the age-adjusted analyses. Taken together, we consider residual and unmeasured confounding unlikely in contrast to our recent study that included a reference group of white-collar workers who differed from the epoxy-exposed workers with respect to atopy, sex, age and educational level.[14]

One third of the non-exposed blue-collar workers handled fibreglass mats manually during a significant part of the work day. Glass fibres are well-documented skin irritants[31] and this may have confounded our results towards the null.

4.2 | Putative mechanisms and generalizability

As results from patch tests or other clinical data were unavailable, we could not examine the mechanism behind our findings. Epoxy components have strong sensitizing properties and sensitization is the most likely mechanism of the observed increased risk of dermatitis. However, epoxy components are also irritants, and irritation may also, at least partly, explain our findings.[9,11,13,14,18,32,33] We find that the results should be valid for other worker populations with comparable work with epoxy resin systems.

5 | CONCLUSION

We found an increased risk of dermatitis following epoxy exposure showing an inverse exposure-response relation with increasing

duration of exposure, in accordance with a short latency period and a strong healthy worker survivor effect.

In the short run, industries using epoxy components and occupational health and safety institutions should put increased focus on appropriate training of newly appointed workers including correct use of personal protective equipment. In the long run, they should consider epoxy resin systems with reduced sensitizing potential and improve exposure surveillance by visualizing skin contamination by adding UV tracers to the epoxy components.[34–38]

AUTHOR CONTRIBUTIONS

Alexandra Golabek Christiansen: Conceptualization; formal analysis; funding acquisition; investigation; methodology; project administration; visualization; writing – original draft; writing – review and editing. **Martin Byskov Kinnerup:** Data curation; formal analysis; software; visualization; writing – review and editing. **Ole Carstensen:** Funding acquisition; writing – review and editing. **Mette Sommerlund:** Funding acquisition; writing – review and editing. **Per Axel Clausen:** Writing – review and editing; funding acquisition. **Jakob Hjort Bønløkke:** Funding acquisition; writing – review and editing. **Vivi Schlünssen:** Funding acquisition; writing – review and editing. **Marléne Isaksson:** Funding acquisition; writing – review and editing. **Sigrun Alba Johannesdottir Schmidt:** Methodology; writing – review and editing. **Henrik Albert Kolstad:** Formal analysis; conceptualization; funding acquisition; investigation; methodology; project administration; supervision; writing – original draft; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest. Siemens Gamesa Renewable Energy provided data for this study. The company had no role in study design, data collection and were *not* involved in data analysis, interpretation and conclusion. Only the authors had access to the data in this study and take complete responsibility for the integrity of the data and the accuracy of the data analysis.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Register studies not including biological human material or sensitive bio informative data does not require ethical approvement in Denmark. This study was registered at the repository of Central Denmark Region (J. no. 2012-58-006/Case no. 1-16-02-125-200).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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