

Effect of glove occlusion on the skin barrier

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doi:10.1111/cod.12470

Summary

Wet work tasks are the most common exposures leading to occupational irritant contact dermatitis. Use of liquid-proof gloves is recommended when performing wet work, however, gloves may also contribute to impairment of the skin barrier and development of irritant contact dermatitis. The aim of this study is to review the literature on the effects of glove occlusion on skin barrier function. The PubMed database was searched up to 1 February 2015 for articles on the association between glove occlusion and skin barrier function, including human studies only and in English. Only experimental studies including assessment of the skin barrier function were included in the data analysis. Thirteen articles were identified, 8 with focus on occlusion alone, 7 with focus on occlusion in combination with irritant exposure (some overlapping), and 2 field studies. In conclusion, data from the literature showed that the negative effect of occlusion in itself is limited, and that only extensive and long-term occlusion will cause barrier impairment. However, studies investigating combined effect of occlusion and exposure to soaps/detergents indicate that occlusion significantly enhances the skin barrier damage caused by detergents/soaps in a dose-response fashion.

Key words: gloves; non-invasive measuring methods; skin barrier function; wet work.

The skin barrier is physically located in the stratum corneum, and maintenance of an intact skin barrier is very important to prevent contact dermatitis, and to avoid infections and adverse systemic health effects resulting from contact with chemicals from the outside. Factors causing impairment of skin barrier function resulting from impacts from the environment include exposure to irritants and allergens. Individual differences exist with respect to robustness of skin barrier function, and pre-existing comorbidities, such as atopic dermatitis,

make some individuals more susceptible to the development of irritant contact dermatitis than others, despite identical exposures (1).

Wet work tasks are the most common exposures leading to occupational irritant contact dermatitis (2), and, in 2008, wet work, including the wearing of 'liquid-proof gloves', was added as a risk factor for skin disease in the German ordinance on hazardous substances (3). In order to protect the skin from irritant exposures, the use of gloves is generally recommended when wet work is performed. The specific exposures considered to cause irritant contact dermatitis during wet work are detergents (soaps), water, and glove occlusion, sometimes enhanced by mechanical irritation. The skin barrier damage is related to the frequency and duration of exposures, and might be greater/more pronounced in cases of combined exposure to different irritants than in cases of exposure to a single substance (4). Wet hands or the wearing of

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Accepted for publication 11 August 2015

gloves for > 2 hr during work hours, or hand washing 10–20 times daily, is generally accepted to be quantitatively sufficient for the triggering of irritant contact dermatitis (3). The use of liquid-proof gloves is common in many professions, including cleaning, healthcare, food processing, and hairdressing. The mean time for which nurses wore single-use gloves was reported to be 3.1 min on regular wards and 6.7 min in intensive care units (5).

Whereas the skin-damaging effect of detergents has been verified in numerous experimental and field studies, (6) the impact of occlusion caused by the wearing of gloves is more complex. Thus, the wearing of gloves may also influence the temperature, hydration and pH of the skin (7), and the effect may depend on the occlusive material used (8). On the other hand, occlusion has also been reported to accelerate the healing of certain defects in the barrier (9).

Furthermore, at the workplace, glove occlusion is often accompanied by exposure to detergents, which might negatively affect the skin-damaging effect of gloves.

The aim of this study was to review the literature on the effects of glove occlusion on skin barrier function.

Background

Effect of occlusion on components of the epidermis

The skin barrier is physically located in the stratum corneum, which is composed of protein-enriched cells and lipid-enriched intercellular domains. Lipid synthesis takes place in the lamellar bodies in the keratinocytes, and lipids are secreted into the intercellular spaces of the stratum corneum. Studies in mice have shown that damage of the skin barrier with acetone leads to increased synthesis of lipids and DNA, whereas artificial barrier repair with latex, causing occlusion, prevents increases in lipid and DNA synthesis (10). The effect of the artificial restoration of the skin barrier on epidermal regeneration in human skin *in vivo* remains unsubstantiated (11).

Occlusion of healthy skin was recently reported not to influence or change the ceramide profile or the ceramide/cholesterol ratio significantly (12). Occlusion with polyethylene film followed by removal of occlusion was reported to upregulate the inflammatory cytokines in patients with atopic dermatitis (13), which may affect the inflammatory response. Occlusion has been shown to lead to a significant increase in pH (7), which may have an important impact on the resident microbial flora of the skin. To the best of our knowledge, no effects of glove occlusion on filaggrin expression or filaggrin breakdown products/natural moisturizing factors have so far been reported.

Effect of occlusion on penetration

The effect of occlusion on the percutaneous penetration of different compounds is generally difficult to predict, as hydration of the skin alters diffusion across the skin and the solubility of a penetrant in the stratum corneum (14). Thus, occlusion might have different effects on percutaneous penetration, depending on the penetrating chemical. Occlusion may also alter the effects of moisturizers on the skin. An irritant effect of urea when applied under occlusion has been reported (15). In contrast to what has been found for urea, an increased anti-irritant effect of glycerol (glycerin) has been reported (16) when it is applied under occlusion.

Experimental variables that may possibly influence study results

Anatomical location and type of gloves. The effect of occlusion has been studied in different anatomical locations, including the hands, the backs and the volar forearms of volunteers. Experimental test models involving hands and forearms have previously been compared, and both models were found to be suitable, without significant differences in the results (17).

Liquid-proof gloves are made of different materials, of which the most typical are natural rubber latex, neoprene, elastyrene, nitrile, and polyvinyl chloride (PVC). Breathable, semipermeable glove material has also been introduced (Goretex®; Sympatex®) (8). Glove material type may influence study outcomes, and should therefore be considered when data from occlusion studies are interpreted.

Bioengineering methods used for the assessment of skin barrier function. Bioengineering methods are used in order to achieve an objective assessment of functions related to the skin barrier. Measurement of transepidermal water loss (TEWL) is the most frequently used method (18), and assesses the impairment, which is directly related to the skin barrier function. Timing of the measurement is important, and it has been recommended that TEWL measurements be performed not less than 3 hr after removal of occlusion, particularly when the skin has also been exposed to detergents (19). Other bioengineering methods include the measurement of erythema, which corresponds to the degree of inflammation (20), and electrical capacitance, which indicates the hydration status in the stratum corneum (21). Surface pH is commonly measured with a skin pH meter, and pH is influenced by the levels of free fatty acids and filaggrin breakdown products (22). Timing of the readings obtained with

bioengineering methods varies between studies, and may be a factor causing variation in the obtained results (23).

Methods

Search method

A literature search was performed in the PubMed database up to 15 January 2015, with the following search criteria: [(Glove occlusion) OR (Glove skin barrier)], with a critical preference for articles in English, and only human studies performed with the use of bioengineering methods being considered. Sixty-five studies were identified. Studies on contact allergy, studies on latex allergy, studies on problems related to surgery, case studies, reviews and studies in which occlusion was performed with non-glove material or without the inclusion of a control group were excluded, leaving 11 articles for analysis in this systematic review. Furthermore, the article reference lists were searched for articles not found in the PubMed search, and this provided two additional articles.

Results

Of the identified 13 articles, eight articles (12, 24–30) provided data on the effect of occlusion on normal skin (Table 1), five (8, 12, 25, 30, 31) articles provided data on the effect of occlusion on skin pretreated with an irritant (Table 2), two articles (29, 32) provided data on occlusion of skin followed by exposure to irritants (Table 3), and two articles (33, 34) provided data from field studies evaluating the irritant effect of gloves on the skin (Table 4).

Occlusion on normal skin

The impact of glove occlusion on normal skin was investigated in eight studies, which differed with respect to study set-up, timing, duration, and the material used for occlusion (Table 1).

The effect of wearing of PVC gloves for 2 days was studied by Graves et al. (24). Significantly increased TEWL was observed to last for 1 day after removal of occlusion, and the study indicated a potential skin barrier-harming effect resulting from the use of PVC gloves.

The effect of short-term and long-term glove occlusion with elastyrene glove material was reported in two studies including 20 and 19 healthy volunteers, respectively (25, 26). After 6 hr of occlusion daily for 3 days on uncompromised skin, no significant increase in TEWL, erythema or electrical capacitance was found (Table 1). After 6 hr of occlusion daily for 14 consecutive days, with no weekend break, an increase in TEWL, but not in erythema,

was found, indicating a compromised skin barrier function (26).

In another study, the effects of semipermeable and occlusive gloves on skin barrier function were compared in 20 healthy volunteers (27). TEWL remained stable after 20 min of wearing of semipermeable gloves, in contrast to wearing of gloves made of occlusive materials, after which an increase in TEWL was observed. No significant differences were found between occlusive gloves, that is, powder-free latex, powdered latex, PVC, and nitrile (Table 1).

In a study including 20 healthy volunteers, the effect of a single exposure to occlusion for 4 hr and the effect of repeated exposure to occlusion for 4 hr daily for 7 days were examined for natural rubber latex and PVC gloves (28). No significant change from baseline values was found for any measured parameter (TEWL, electrical capacitance, and erythema) (Table 1), except for pH values, which, after 7 days, showed an increase following occlusion with natural rubber latex but not following exposure to PVC glove material (28).

Jungersted et al. (12) investigated the effect of occlusion with nitrile glove material for 8 hr daily for 7 days, and for 72 consecutive hours as a single exposure, in 20 healthy volunteers. The results showed no increase in TEWL or erythema as compared with baseline, and it was concluded that neither repeated occlusion for 1 week nor occlusion for 72 hr significantly affected the skin barrier (Table 1).

Fartasch et al. (29) investigated the effect of occlusion with PVC glove material in a study including 73 healthy volunteers, with varying exposure periods (2, 3, 4 and 6 hr) over a period of 7 days, and found no significant changes in TEWL, erythema, or electrical capacitance (Table 1). In the same study, water exposure for > 3 hr was found to increase TEWL significantly as compared with baseline (29).

Antonov et al. (30) occluded the skin on the forearms of 20 healthy volunteers for 18 hr with a patch of PVC glove, and observed a significant, although minor ($<1 \text{ g/m}^2/\text{h}$), increase in TEWL as compared with baseline.

Occlusion on pretreated, compromised skin

In most professions in which liquid-proof gloves are used, the exposure to gloves is combined with other exposures, such as water, detergents, chemicals, and mechanical factors. We identified five experimental studies that examined the effect of occlusion on skin that was previously compromised by irritant exposure (Table 2).

Irritation with sodium lauryl sulfate (SLS) followed by occlusion with elastyrene glove material 6 hr daily for

Table 1. Results of occlusion on skin barrier function

Glove material	Occlusion time	Body location	Time after occlusion when measurements were taken	TEWL after occlusion as compared with non-occluded skin	Electrical capacitance after occlusion as compared with non-occluded skin	Erythema after occlusion as compared with non-occluded skin	References
PVC, patch of glove	48 hr	Forearm	20 min/1 hr*	Increase	NS	NA	(24)
Elastyrene, glove	6 hr/3 days	Hand	3 hr	NS	NS	NS	(25)
Elastyrene, glove	6 hr/14 days	Hand	3 hr	Increase	NS	NS	(26)
Semipermeable glove/occlusive gloves (powder-free latex, powdered latex, PVC, and nitrile)	20 min	Hand	30 min	NS (semipermeable glove)/increase (all occlusive gloves)	NS (semipermeable glove)/increase (all occlusive gloves)	NA	(27)
PVC and latex, gloves	4 hr/7 days	Hand	3 hr	NS	NS	NS	(28)
Nitrile, patch of glove	72 hr	Forearm	3 hr	NS	NS	NS	(12)
	8 hr/7 days			NS	NS	NS	
PVC, patch of glove	2–6 hr/7 days	Forearm	24 hr	NS	NS	NS	(29)
PVC, patch of glove	18 hr	Forearm	4.5 hr	Increased	Increased	NS	(30)

NA, not applicable; NS, not significant; PVC, polyvinyl chloride; TEWL, transepidermal water loss.

*Data from two groups with different reading times were combined.

Table 2. Results of occlusion preceded by irritation

Glove material	Occlusion time	Irritant	Time after occlusion when measurements were taken (hr)	TEWL after occlusion as compared with non-occluded skin	Electrical capacitance after occlusion as compared with non-occluded skin	Erythema after occlusion as compared with non-occluded skin	References
Elastyrene, glove	6 hr/3 days	SLS	3	Increased	Increased	NS	(25)
PVC, gloves (filed study, repetitive design)	12 min/34 min/day for 3 weeks	Hand washing and alcohol disinfection	1	NS after 12 min daily ($p < 0.09$)	NA	NA	(31)
Semipermeable, patch of glove/PVC, patch of glove	24 hr	SLS	1	NS after 34 min daily Decreased/increased	NA	Decreased/decreased	(8)
Nitrile, patch of glove	72 hr	SLS-pretreated skin/tape-stripped skin	3	Increased/decreased	NS	NS	(12)
PVC, patch of glove	18 hr	Washing lotion	4.5	Increased	Increased	NS	(30)

NA, not applicable; NS, not significant; PVC, polyvinyl chloride; SLS, sodium lauryl sulfate; TEWL, transepidermal water loss.

3 days was reported to cause a significant increase in TEWL as compared with SLS-compromised skin that was not occluded (25). Skin irritation before occlusion was performed by 2×10 min of exposure to SLS each day for two consecutive days. These results indicate that, in skin pretreated with a detergent, occlusion may increase skin damage and/or delay the healing process.

In an experimental set-up intended to mimic real life-situations, Jungbauer et al. (31) compared two different programmes/schedules for wet work in nurses: a regular set-up including 12 min of glove wear, 10 min of hand washing and 18 alcohol disinfections daily, and a preventive set-up including 34 min of glove wear, 2 min

of hand washing and 30 alcohol disinfections daily. Thirty-nine healthy volunteers participated in the study, for a period of 3 weeks. During the whole study period, PVC gloves were worn on one hand only. After 3 weeks, a significant difference in TEWL was found between the 'regular model' and the 'preventive model', with significantly lower TEWL values in the preventive group. The results also showed that after 3 weeks there was a tendency for there to be higher TEWL values ($p < 0.09$) on the glove hand in the regular set-up, but no difference between the glove hand and the bare hand in the preventive set-up. Although the preventive model implied increased occlusion, the overall result was reduced skin

Table 3. Results of occlusion followed by irritation

Glove material	Occlusion time	Irritant	Time after occlusion when measurements were taken(hr)	TEWL after occlusion as compared with non-occluded skin	Electrical capacitance after occlusion as compared with non-occluded skin	Erythema after occlusion as compared with non-occluded skin	References
Occlusive, patch of glove	30 min	Mechanical irritation	24	Increased	NS	NS	(32)
PVC, patch of glove	2 hr/3 hr/6 hr	SLS	24	NS (2 hr) Increased (3 hr) Increased (6 hr)	NS NS NS	NS NS NS	(29)

NS, not significant; PVC, polyvinyl chloride; SLS, sodium lauryl sulfate; TEWL, transepidermal water loss.

Table 4. Field studies

Glove material	Occlusion time	Profession	Time after occlusion when measurements were taken	Study design	TEWL in the exposed group as compared with the control group	References
Unknown	Whole working day	Cleanroom workers	> 30 min	Cross-sectional	NS	(33)
Latex gloves/ nitrile glove	8 hr daily for 3 months	Dental healthcare workers	No information	Cross-sectional	NS	(34)

NS, not significant; TEWL, transepidermal water loss.

barrier impairment, and an overall positive effect of the increased use of gloves, probably because of there being less exposure to soaps in the preventive model. Owing to the repetitive design in this study, the pre-occlusion and post-occlusion effects could not be distinguished.

Bock et al. reported data from a comparison of the effects of semipermeable and occlusive glove material on pretreated, compromised skin (8). Skin pretreated with SLS was occluded for 24 hr for 3 days with one of three different glove materials: two semipermeable materials (GoreTex® and Sympatex®) and one impermeable material (PVC). On day 3, the semipermeable materials had caused decreases in both TEWL and erythema, whereas the impermeable material had caused further increases in TEWL, indicating enhancement of skin barrier recovery with the use of semipermeable glove material.

The effect of occlusion for 72 hr with nitrile glove material on skin, either pre-irritated with SLS for 24 hr or tape-stripped before occlusion, was recently studied in 20 healthy volunteers (12). Occlusion of the skin following SLS irritation resulted in significantly higher TEWL than in non-occluded control skin, and occlusion of the skin after tape stripping resulted in significantly lower TEWL than in control skin, indicating that occlusion delayed the healing of SLS-damaged skin, and improved the healing of tape-stripped skin (Table 2).

A study evaluated a hand-washing lotion containing SLS and occlusion in combination in 20 healthy

volunteers (30). The experimental set-up was the use of hand-washing lotion for 10 or 30 min, followed by overnight occlusion with vinyl gloves. The study showed that, when the hand-washing lotion was applied alone, the increase in TEWL was significantly lower than when application of the hand-washing lotion was followed by occlusion.

Occlusion before exposure to irritants

We identified two experimental studies that examined the effect of occlusion before the skin barrier had been compromised by detergent exposure or mechanical irritation (Table 3).

Glove exposure followed by mechanical irritation was investigated in an experimental study by Fluhr et al. (32). The volar forearms of 20 healthy volunteers were exposed to glove occlusion for 30 min, and this was followed by mechanical irritation for 5 min, in a repetitive pattern over a period of 4 days. Following mechanical irritation, higher TEWL values were found in pre-occluded than in non-occluded skin, whereas erythema and electrical capacitance were not significantly affected. The study also included test sites exposed to occlusion with water, and water occlusion in combination with mechanical trauma was found to induce more severe impairment of the skin barrier than glove occlusion. Owing to the repetitive pattern in this study, pre-occlusion and post-occlusion effects could not be distinguished.

Fartasch et al (29) studied the effect of occlusion with PVC glove material on the forearms of 73 healthy volunteers. Exposure periods were 2, 3, and 6 hr, respectively, repeated daily for 7 days, and followed by SLS application. Impairment of barrier function after SLS challenge was significantly more pronounced on skin occluded for 3 and 6 hr than on the non-occluded control areas as measured by TEWL, whereas pre-occlusion for 2 hr did not result in a significant difference from control areas.

Field studies

Only a few field studies have evaluated the effect of glove occlusion on skin barrier function (Table 4).

In a recent cross-sectional study (33), skin barrier function was examined in 177 cleanroom workers who had to wear occlusive gloves during the entire workday, and compared with skin barrier function in 146 employees who worked in administration and never wore gloves. When TEWL was measured ≥ 30 min after removal of gloves, no significant difference in TEWL could be detected between the groups; however, for practical reasons, it was only possible to obtain measurement at ≥ 30 min after glove removal in 41 persons. No information about the wearing of cotton gloves beneath occlusive gloves was given, and the occlusive glove material was not specified.

Boyle et al. (34) examined 50 dental healthcare workers who wore gloves during dental treatment procedures for a minimum of 8 hr daily for at least 4 days/week for 3 months. Twenty-six wore a latex glove, and 24 wore a nitrile glove. The control group comprised 25 subjects who did not routinely use occlusive/liquid-proof gloves. Skin barrier function was assessed by TEWL measurement at baseline, and after 1 and 3 months. No significant differences in TEWL were found between the glove groups and the control group, or between the two glove groups. The study design was cross-sectional.

Discussion

Understanding the effect of glove occlusion on the skin is important in relation to 'wet work' and the risk for the development of occupational hand eczema. Prevention and educational programmes for workers engaged in high-risk jobs include recommendations that gloves must be used as skin protection, as do preventive programmes for hand eczema patients. However, possible negative effects of glove occlusion on the skin barrier should be considered. The effect of glove occlusion on the skin barrier in wet work situations is difficult to distinguish from the harmful effects of water, detergents, and mechanical trauma, as these exposures commonly occur together.

Of the eight articles (Table 1) evaluating the effect on the skin barrier of occlusion alone, four articles (12, 25, 28, 29) reported that glove occlusion did not affect the skin barrier, whereas four articles (24, 26, 27, 30) found an increase in TEWL after occlusion, indicating that the skin barrier might have been impaired. It has to be noted that, in two studies (24, 27) that reported a negative effect of glove occlusion on skin barrier function, the TEWL measurements were performed, respectively, 20 and 30 min after the removal of occlusion, and it is known that TEWL values obtained so early after the removal of occlusion are not reliable (23). Thus, the outcomes of these two studies may be biased by the early reading of TEWL, as the increased TEWL values may reflect sweat/skin surface water loss rather than barrier disruption. In another study supporting an increase in TEWL after occlusion (26), increased TEWL was reported only after 14 consecutive days of wearing of elastyrene gloves for 6 hr daily, and no skin barrier damage was observed after 6 or 10 days (26). This might indicate that a long period of occlusion is needed before skin barrier damage occurs. However, in the study by Antonov et al. (30), a minor but significant increase in TEWL was already found after 18 hr of occlusion with PVC gloves. This finding differs from what was reported after long-term occlusion with nitrile gloves (12) and with elastyrene gloves (25, 26), so the question arises of whether differences in material may influence the results. Overall, the data from the included studies suggest that occlusion of skin with glove material does not cause any major impairment of skin barrier function, unless the occlusion is extensive (6 hr daily for >10 days), and when occlusion is not combined with exposure to irritants.

When glove occlusion is applied to pre-irritated skin, the situation seems to change. Four of the five identified studies (Table 2) reported an increase in TEWL after glove occlusion of impaired skin (8, 12, 25, 30), and one study (31) found a tendency for there to be an increase in TEWL (although not statistically significant) after wearing of gloves for 12 min daily when combined with intensive hand washing, whereas wearing gloves for 34 min daily with less intensive hand washing did not cause an increase in TEWL. In experimental set-ups, the effects of occlusion have been studied in skin pretreated with irritants, to mimic the real-life situations at workplaces with wet work. The most frequently used model irritant is SLS. The test models used are characterized by great variations in SLS concentration, method of application (open or occluded, and single or repeated), and duration of exposure. Also, the quality of SLS varies significantly (35), which hampers comparison between the different experimental test models. From the presented data, it can,

however, be concluded that, when the skin is occluded by glove material following detergent exposure, the occlusion increases the damage caused to the skin barrier by the detergent/irritant. In a study by Held and Jørgensen (36), the effect of applying a moisturizer before the wearing of gloves was studied on previously SLS-exposed skin. A control group with non-occluded skin was not included. The irritation resulting from the combined effect of SLS and occlusion was significantly counteracted by the use of a moisturizer immediately before the gloves were put on. Although this observation is interesting, a possible increased risk for sensitization from ingredients in the moisturizer, as well as the fact that a moisturizer may influence glove properties, makes this solution less attractive.

Occlusion prior to irritant exposure may theoretically increase the penetration of at least some irritants, and thus increase the irritant response and the damage to the skin barrier. In two studies (Table 3) that evaluated the effect of occlusion followed by either mechanical irritation or detergent exposure, the impairment of the skin barrier was more pronounced than in non-occluded skin, so it may be concluded that occlusion with glove material may increase the susceptibility to skin irritants.

In exposure to irritants in real life, water, mechanical trauma and occlusion are all combined and repeated over and over again during work hours, and this situation may, of course, differ significantly from the experimental study designs. In the literature, only two field studies on the effect of skin occlusion on skin barrier function were identified (Table 4). Both studies had a cross-sectional design; one study comprised cleanroom workers (33) exposed to glove occlusion, and the other comprised dental health-care workers (34) exposed to a combination of wet work and gloves. Neither of these studies found any impairment of the skin barrier resulting from the wearing of gloves at the workplace as compared with not wearing gloves. The cross-sectional design implies that there could be a 'healthy worker effect' as a possible bias, and prospective field studies should be undertaken in the future before any firm conclusions are drawn.

Most studies examined the effect of occlusive, liquid-proof gloves, that is, latex, PVC, elastyrene or nitrile gloves. A few studies also included semipermeable glove material (8, 27), which is reported to cause no damage to the skin barrier, and even increase the healing after exposure to detergents, probably because of an optimized water vapour gradient during healing (8). The development of new, semi-occlusive materials directed at specific exposure types could be another way to avoid detrimental effects on skin barrier function. However, the protective effect of semi-occlusive gloves against chemicals

and biological hazards should be evaluated before these materials are used in the occupational setting.

Although the data clearly indicate that occlusion following pretreatment of the skin with a detergent increases skin barrier impairment, it is interesting that a positive effect of occlusion was found after tape stripping, whereby occlusion was found to accelerate the healing process (12). In this test model, variables such as the number of strips and the pressure applied on the skin may be speculated to influence the irritant impact on the skin, although more with respect to the magnitude than to the direction of the effect. Interestingly, in a study combining mechanical trauma with occlusion in a repetitive pattern, starting with occlusion followed by mechanical irritation, occlusion was found to increase skin barrier damage (32). In a study of dressing materials (37), the use of a semipermeable dressing following tape stripping was found to cause persistently high TEWL values; however, this was interpreted as a side-effect of the frequent changing of the self-adhesive occlusive material (37). Most studies on the combination of irritants and occlusion have used SLS as a model irritant; however, in the future, it would be of interest to investigate other irritants, and to study the effect of occlusion on standardized mechanical trauma limited to specified depths in the epidermis.

None of the studies on the effect of occlusion on skin barrier function included patients with atopic dermatitis. As atopy affects a fairly large proportion of the population, more studies including individuals with some degree of endogenous impairment of the skin barrier should be conducted.

The use of cotton gloves beneath the occlusive gloves to counteract the negative effects of occlusion was examined in only one study (26), and although this may cause difficulties in performing skilled work and is time-consuming, it is often recommended in preventive programmes, and further studies on this topic are needed.

Conclusion

In conclusion, liquid-proof gloves are necessary to protect the skin from detergents, allergens, harmful chemicals, and biological hazards. The data from the literature presented in this review indicate that the negative effect of occlusion in itself, not combined with other trauma to the skin, is limited, and that only extensive occlusion will cause skin barrier impairment. Combined studies indicate that occlusion significantly worsens the negative effect on skin barrier function of detergents/soaps, and the data also indicate that a dose-response relationship is important with respect to duration of occlusion. This is particularly relevant for workplaces where shifting between wearing of gloves and hand washing is common.

The wearing of 'liquid-proof gloves' is listed as a risk factor for skin disease in the German ordinance on hazardous substances (3). Whenever the wearing of gloves is combined with exposure to detergents, our conclusions in this review strongly support this. However, when the occlusion is not combined with irritant exposures, more evidence is actually needed. Future studies should include examination of occlusion of atopic skin. Combined exposure is a realistic set-up, as workers are most often exposed to multiple potentially harmful substances, and combined studies should include tape stripping and mechanical irritation of the skin, as well as other irritants in addition to SLS. Glove materials should be compared

directly with respect to skin barrier-harming properties. Semipermeable membranes should be further developed, and the effects of cotton-lined gloves should be further examined. As the combined exposures at the workplace are difficult to mimic in experimental studies, prospective field studies and intervention studies would help to clarify the effect of occlusion in real life.

Acknowledgements

This work was supported by H2020 COST Action TD1206 'StanDerm'.

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