

Comparison between 2 test models in evaluating the effect of a moisturizer on irritated human skin

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The purpose of the present study was to compare 2 experimental models of moisturizer efficacy on the recovery of irritated skin on the hands and the volar forearms. 12 healthy volunteers had their hands immersed in sodium lauryl sulfate (SLS) 10 min 2× daily for 2 days, and at the same time the volunteers had patch tests with SLS (0.125%, 0.25% and 0.5%) applied on their forearms for 24 h. After irritation of the skin, the volunteers had a moisturizer applied on one arm/hand 3× daily for the following 9 days. The other arm/hand served as untreated control. Evaluation was done on days (D) 1, 3, 5, 8 and 12 by transepidermal water loss, electrical capacitance, laser Doppler flowmetry and DermaSpectrometry. Both models were found useful, and the moisturizer was found to accelerate regeneration of the skin barrier function in both the hands (D8, $p < 0.05$) and the volar forearms (0.5% SLS, D5 and D8, $p < 0.01$). When the forearm model is used in the present set-up, a relatively high concentration of SLS ($> 0.25\%$) should be used and evaluation measurements are best performed on D5–D8. The forearm model proved reliable and easy to handle and we suggest that this model is used in future studies on moisturizer evaluation.

Key words: irritant contact dermatitis; skin barrier recovery; moisturizers' efficacy testing; sodium lauryl sulfate; transepidermal water loss; laser Doppler flowmetry; electrical capacitance; DermaSpectrometer; bioengineering methods. © Munksgaard, 1999.

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The benefit of moisturizers used in the prevention and treatment of irritant contact dermatitis (ICD) has been debated during recent decades, and standardized models for the testing of skin care products are necessary to ensure documentation of their efficacy. To investigate this matter, several experimental models have been proposed. Although most cases of ICD are localized to the hands, most studies have evaluated the effect of moisturizer by using the forearm/upper arm (1–7) or the back (8, 9). In a previous study, we evaluated the effect of a moisturizer on irritated human skin on the hands using a hand immersion model (10). This proved to be a realistic exposure model, but is very time-consuming. The purpose of the present study was to compare results obtained in a forearm model with results obtained on the hands, and furthermore to optimize the forearm model with respect to time of measurements and concentration of the irritant (sodium lauryl sulfate-SLS).

Materials and Methods

12 healthy volunteers (11 women, 1 man, median age 38.5 years, range 26–50 years) participated in

the study. Subjects with a history of hand eczema, atopic dermatitis or sensitive skin were not included. The study was approved by the local ethical committee and all participants gave written informed consent.

Study procedure

All participants had both hands and arms exposed to sodium lauryl sulfate (SLS, $> 99\%$ purity, Sigma) on days (D) 1 and 2 (details of the procedures are given later). On D3, evaluation of the irritant skin response was made by 4 non-invasive bioengineering measuring methods, as well as by clinical judgment. After this evaluation, either right or left hand and arm were randomized to have a moisturizer applied 3× daily for the following 9 days. The randomization code was blinded to the investigator. The moisturizer treatment was initiated on D3 just after measurements were made. All volunteers were instructed how to apply the moisturizer on the selected hand and forearm using only the fingertips of the control hand. The moisturizer was applied in a thin layer on the entire hand and forearm (i.e., on the arm, the moisturizer

was applied not only on SLS-irritated skin but on the normal skin as well). Evaluations were done on D5, D8 and D12.

SLS was chosen for induction of skin irritation. It is widely used as a model irritant in experimental studies on ICD and is known to have a marked effect on the skin barrier function even at low concentrations, as well as having a negligible sensitizing potential.

Hand immersion model

In order to elicit an experimental irritation of the hand, all participants had both hands immersed in a 0.5% aqueous SLS solution, temperature 30°C. Immersions took place 2× daily for the 2 consecutive D1 and D2 at the same time as the patch testing. Each immersion took 10 min with an interval of at least 3 h between immersions. After each immersion, both hands were rinsed in lukewarm water and dried with a cotton towel.

The hand immersion model is a standardized irritation model of the hands for eliciting an experimental ICD and has been used in other studies on ICD (10–13). The immersion model of compromised skin was first described by Allenby and co-workers in 1993 (14).

Forearm model

All participants had 3 closed patch tests applied on each volar forearm for 24 h. Each patch contained 120 µl of an aqueous SLS-solution on a filter disc (extra large Finn Chambers, diameter 18 mm, Epitest, Helsinki, Finland). The patches were applied on D1 just after the 2nd hand immersion took place and they were removed the following day. After removal of the patches the forearm skin was rinsed thoroughly with lukewarm tap water and dried with a cotton towel. 3 different concentrations of SLS were used (0.125%, 0.25%, 0.5%). The 3 patch test chambers were placed symmetrically on each forearm ensuring a distance of at least 3.5 cm from the cubital fossa/wrist. Placement of the patches containing different concentrations was systematically varied from one participant to another, always ensuring correspondence of the patches on the 2 arms. Application of the patches was done by a technician and the randomization code was blinded to the investigator. All test areas were marked every day (D3–D12) using a lettering pen.

Moisturizer

The moisturizer used (Locobase®, Yamanouchi Pharma) contains paraffinum molle album, aqua,

paraffinum liquidum, sodium citrate, citric acid, methylparaben, cetomacrogol 1000 and cetearyl alcohol. The moisturizer has a lipid content of 70%, is fragrance-free and has been used in other experimental studies by our group (10, 15) and by others (16). The participants were not allowed to use any other moisturizer on the hands and arms 7 days prior to entering the study nor during the study period. Each participant was given a supply of the moisturizer and a checklist for daily recording of the treatment. The moisturizer tubes were weighed before and after the study period.

Evaluating methods

Evaluations were done on D1 (baseline), D3 (after irritation), D5, D8 and D12. On D5, D8 and D12 measurements were made more than 12 h after application of the moisturizer. The following methods were used for evaluation.

Transepidermal water loss (TEWL) as an indicator of the skin barrier integrity was measured by an Evaporimeter (Servo Med, Stockholm, Sweden), according to the guidelines of the European Standardization Group of Contact Dermatitis ESCDR (17).

Electrical capacitance as an indicator of the hydration level of the skin (18) was measured by a Corneometer CM 820 (Courage and Khazaka, Köln Germany).

Laser Doppler flowmetry is a technique for measurement of blood flow and the monitor was a Laser Doppler blood flow monitor MBF3 (Moor Instruments, England), used according to the guidelines of the ESCDR (19). The blood flow is an indicator of the inflammation level of the skin.

Erythema index was measured with a DermoSpectrometer (Cortex Technology, Hadsund, Denmark). This method is based on the amount of red and green light reflected from the skin (20), and measurements were made according to the guidelines of the ESCDR (21).

Recordings of measurements: on the hands, 3 recordings for evaporimetry, erythema index and laser Doppler flowmetry and 6 recordings of corneometry were performed on each dorsum, and the mean value was used. On the arms, 2 recordings for evaporimetry, 3 recordings of erythema index, laser Doppler flowmetry and corneometry on each test site were performed, and the mean value was used.

Visual score graded for erythema and scaling on the patch test sites and on the hands was registered according to the following scale: 0=no reaction, 0.5=very weak spotty erythema/scaling, 1=slight

erythema/scaling, 2=moderate erythema/scaling, 3=intense erythema/scaling.

All measurements and clinical scorings were done by the same investigator blinded and under controlled environmental conditions. Relative humidity in the room varied between 26–41% and the room temperature was 20–22°. The participants rested for about 30 min before measurements. The study was carried out in the months of January–March.

Statistics

The Wilcoxon test for paired observations was used to compare treated with untreated test sites. All results are given in medians and 25/75 percentiles. A Spearman rank correlation was used for comparison of hand and forearm skin responsiveness to SLS. A significance level of $p < 0.05$ was chosen.

Results

After exposure to SLS, a statistically significant increase was found in TEWL, erythema index, corneometry and laser Doppler flowmetry on D3 compared to baseline values in all patch test sites on the arms. On the hands, a statistically significant increase was also found in TEWL and laser doppler flowmetry on D3 compared to baseline values. A slight increase, though not significant, was found in erythema index. In the electrical capacitance measurement, a statistically significant decrease was found on the hands on D3 compared to baseline values.

Hands (D1–D12)

TEWL. Median values and 25/75 percentiles are shown in Fig. 1. Significantly higher TEWL values were found on the untreated hand on D8 after 5 days of treatment ($p < 0.05$). The electrical capacitance was significantly higher on the moisturizer-treated hand on D5 ($p < 0.02$) and D8 and D12 ($p < 0.05$) (Table 1). A trend towards higher values for both erythema index and laser Doppler flowmetry (Table 1) was found on D5 and D8 on the untreated hand compared to the moisturizer-treated hand.

In 10/12 participants, a variable degree of redness, shininess and scaling, especially on the knuckles and interdigitally, was observed on D3. 2/12 participants did not have any visible skin changes on D3. 1 participant had severe scaling, slight redness and fine cracks on the knuckles and fingerwebs on the untreated hand on D5–12. No significant difference in clinical scoring between

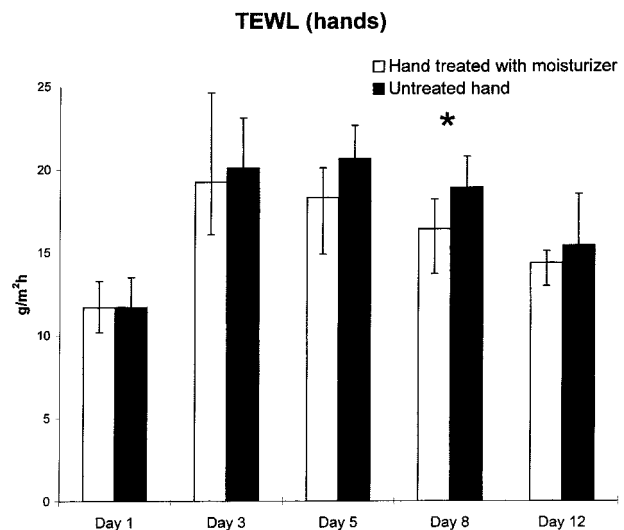


Fig. 1. Hands. Transepidermal water loss (TEWL). Results are given in medians and 25/75 percentiles. * $p < 0.05$.

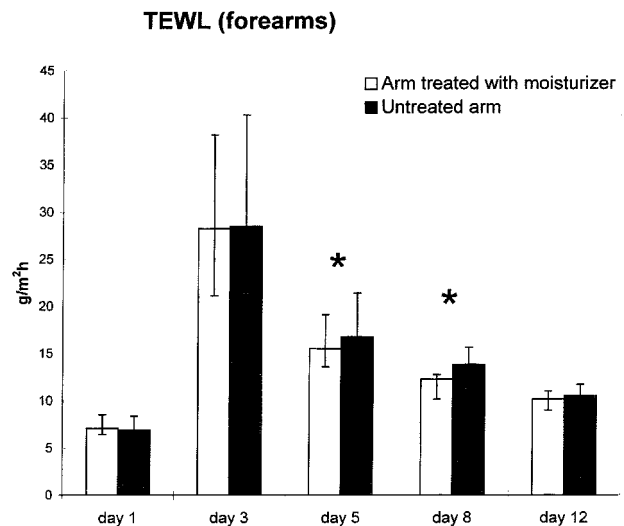


Fig. 2. Arms (0.5 % SLS). Transepidermal water loss (TEWL). Results are given in medians and 25/75 percentiles. * $p < 0.01$.

the moisturizer-treated and untreated hand was observed throughout the study period. The results are summarized in Table 1.

Arms (0.5% SLS) (D1–D12)

TEWL. Median values and 25/75 percentiles are shown in Fig. 2. Significantly higher TEWL values ($p < 0.01$) were found on the untreated arm after 2 and 5 days of treatment (D5 and D8, respectively). The electrical capacitance was significantly higher on the moisturizer-treated arm on D12 ($p < 0.02$) (Table 2). A trend towards higher values for electrical capacitance was found on D5 and D8 on the moisturizer-treated arm compared to the untreated

Table 1. Moisturizer-treated versus untreated hands

	Treated hand	Control hand	
Electrical capacitance			
baseline (D1)	59.5 (53.5–63.5)	60.0 (56–64.3)	n.s., $p>0.2$
irritation (D3)	48.0 (42.8–55.3)	49.0 (41.3–54.5)	n.s., $p>0.2$
moisturizer (D5)	56.0 (51.3–60.0)	48.0 (40–55.8)	significant, $p<0.02$
moisturizer (D8)	60.5 (56.8–85.3)	54.0 (45.5–64.5)	significant, $p<0.05$
moisturizer (D12)	61.5 (58.0–64.8)	57.0 (51.3–61.5)	significant, $p<0.05$
Erythema index			
baseline (D1)	12.5 (10.5–14)	10.0 (8–13)	n.s., $p>0.2$
irritation (D3)	13.5 (10.8–15.3)	13.5 (12–16)	n.s., $p>0.2$
moisturizer (D5)	12.0 (10.8–15.3)	12.5 (9.5–15)	n.s., $p>0.2$
moisturizer (D8)	12.0 (9–13.3)	14.0 (10.8–15)	n.s., $p>0.2$
moisturizer (D12)	13.0 (10.5–14.3)	12.5 (11.8–14.3)	n.s., $p>0.2$
Laser Doppler			
baseline (D1)	23.5 (18.5–25.5)	22.0 (20–27)	n.s., $p>0.2$
irritation (D3)	58.0 (31–62.3)	51.5 (36.8–66.3)	n.s., $p>0.2$
moisturizer (D5)	39.5 (31.8–46.5)	40.0 (28.5–72.3)	n.s., $p>0.2$
moisturizer (D8)	29.5 (25–31.3)	30.5 (25–40.3)	n.s., $p>0.2$
moisturizer (D12)	28.0 (24.8–31.5)	30.5 (23.3–34.5)	n.s., $p>0.2$
Clinical scoring (erythema)			
baseline (D1)	0	0	n.s., $p>0.2$
irritation (D3)	0 (0.4–1.3)	0 (0.4–1.3)	n.s., $p>0.2$
moisturizer (D5)	0.5 (0–1)	1 (0–1)	n.s., $p>0.2$
moisturizer (D8)	0 (0–0.5)	0.5 (0–0.6)	n.s., $p>0.2$
moisturizer (D12)	0 (0–0)	0.5 (0–0.1)	n.s., $p>0.2$
Clinical scoring (scaling)			
baseline (D1)	0	0	n.s., $p>0.2$
irritation (D3)	1 (0.5–1.1)	1 (0.5–1.1)	n.s., $p>0.2$
moisturizer (D5)	0.5 (0–1)	1 (0.4–0.6)	n.s., $p>0.2$
moisturizer (D8)	0.5 (0–1)	1 (0–1)	n.s., $p>0.2$
moisturizer (D12)	0 (0–0)	0.5 (0–1)	n.s., $p>0.2$

Electrical capacitance (arbitrary units) for moisturizer-treated hands and untreated hands D1–D12. Results are given in medians and 25/75 percentiles.

Erythema indices (arbitrary units) for moisturizer-treated hands and untreated hands D1–D12. Results are given in medians and 25/75 percentiles.

Laser Doppler flowmetry (arbitrary units) for moisturizer-treated hands and untreated hands D1–D12. Results are given in medians and 25/75 percentiles.

Clinical scoring (erythema) for moisturizer-treated hands and untreated hands D1–D12. Results are given in medians and 25/75 percentiles.

Clinical scoring (scaling) for moisturizer-treated hands and untreated hands D1–D12. Results are given in medians and 25/75 percentiles.

arm. Erythema index was significantly lower on D8 ($p<0.05$) on the moisturizer-treated arm compared to the untreated arm. A trend towards higher values for laser Doppler flowmetry (Table 2) was found on D5, D8 and D12 on the untreated arm compared to the moisturizer-treated arm.

All participants reacted to the patch tests of SLS with an irritant skin reaction varying from slight spotty erythema to intense redness and infiltration on D3. On clinical scoring, no statistically significant difference was found between the moisturizer-treated arm and the untreated arm throughout the study period (Table 2).

Concentrations of 0.125% and 0.25% SLS

For patch tests containing 0.125% and 0.25% SLS, it was not possible to show any statistically

significant difference between the moisturizer-treated and untreated arm in any of the parameters. Patch tests with 0.5% SLS resulted in statistically significant higher TEWL values than did patch tests with 0.125% and 0.25%, respectively.

Comparison between hand and forearm skin responsiveness to SLS 0.5%

When values (mean values from the 2 corresponding arms/hands) after irritation of the skin on the hands and arms were compared on D3, a statistically significant correlation for laser Doppler flowmetry was found (Spearman rank correlation coefficient, $r_s=0.78$, $p<0.01$). For erythema indices and TEWL no significant correlation was found, ($r_s=0.53$, $p<0.1$) and ($r_s=0.53$, $p<0.1$), respec-

Table 2. Moisturizer-treated arms versus untreated arms

	Treated arm	Control arm	
Electrical capacitance			
baseline (D1)	63.5 (58–63.5)	64.5 (61–67)	n.s., $p>0.2$
irritation (D3)	77.0 (70.3–79)	76.0 (65.8–79.8)	n.s., $p>0.2$
moisturizer (D5)	54.5 (37.8–60.3)	42.0 (39–52.8)	n.s., $p<0.1$
moisturizer (D8)	44.0 (31.8–49)	35.5 (33.5–42.3)	n.s., $p<0.2$
moisturizer (D12)	62.5 (50.8–70)	50.0 (44–62.8)	significant, $p<0.02$
Erythema index			
baseline (D1)	8.0 (7.8–9.3)	8.5 (7–9.25)	n.s., $p>0.2$
irritation (D3)	13.5 (13.5–15)	14.0 (12.5–15)	n.s., $p>0.2$
moisturizer (D5)	11.0 (9.8–14)	12.0 (10.5–13.3)	n.s., $p>0.2$
moisturizer (D8)	11.0 (9–13)	12.0 (11–13)	significant, $p<0.05$
moisturizer (D12)	9.0 (8–11)	10.5 (9.8–11.3)	n.s. $p<0.1$
Laser Doppler			
baseline (D1)	20.0 (16.3–22.3)	19.5 (17–22)	n.s., $p>0.2$
irritation (D3)	83.5 (64.5–121.3)	114.5 (89.8–132)	n.s., $p>0.2$
moisturizer (D5)	39.0 (27–52.3)	41.5 (27.8–51.3)	n.s., $p>0.2$
moisturizer (D8)	25.5 (18.5–32.8)	31.0 (21–31.8)	n.s., $p>0.2$
moisturizer (D12)	24.5 (20.5–27)	25.5 (21.8–28)	n.s., $p>0.2$
Clinical scoring (erythema)			
baseline (D1)	0	0	n.s., $p>0.2$
irritation (D3)	2 (1.8–2.5)	2.5 (1.8–2.5)	n.s., $p>0.2$
moisturizer (D5)	2 (1–2)	2 (1–2)	n.s., $p>0.2$
moisturizer (D8)	1 (0.4–1.3)	1 (0.5–2)	n.s., $p>0.2$
moisturizer (D12)	0.5 (0–1)	0.5 (0–1)	n.s., $p>0.2$
Clinical scoring (scaling)			
baseline (D1)	0	0	n.s., $p>0.2$
irritation (D3)	0	0	n.s., $p>0.2$
moisturizer (D5)	0 (0–0.5)	0.5 (0–1)	n.s., $p>0.2$
moisturizer (D8)	0.5 (0–0.9)	1 (0.5–1.3)	n.s., $p>0.2$
moisturizer (D12)	0 (0–0.6)	1 (1–1)	n.s., $p>0.2$

Electrical capacitance (arbitrary units) for moisturizer-treated arms and untreated arms D1–D12. Results are given in medians and 25/75 percentiles.

Erythema indices (arbitrary units) for moisturizer-treated arms and untreated arms D1–D12. Results are given in medians and 25/75 percentiles.

Laser Doppler flowmetry (arbitrary units) for moisturizer-treated arms and untreated arms D1–D12. Results are given in medians and 25/75 percentiles.

Clinical scoring (erythema) for moisturizer-treated arms and untreated arms D1–D12. Results are given in medians and 25/75 percentiles.

Clinical scoring (scaling) for moisturizer-treated arms and untreated arms D1–D12. Results are given in medians and 25/75 percentiles.

tively. For electrical capacitance ($r_s=0.27$), no correlation was found.

TEWL on D3 was statistically significant higher on the arms compared to the hands. The amount of moisturizer used per volunteer was 11.35 g (7.5 g–14 g) given as median and 25/75 percentiles.

Discussion

The moisturizer tested was found to accelerate skin barrier repair after SLS irritation in both the forearm (0.5%SLS) and the hand immersion model. This result from the hand immersion model corroborated what was found in a previous study by our group where the same moisturizer was tested on deteriorated skin on the hands (10). The forearm model was more sensitive than the hand immersion model: TEWL was statistically signifi-

cantly reduced on the moisturizer-treated arm (0.5% SLS) on both D5 and D8 ($p<0.01$) compared to the control arm, whereas the moisturizer-treated hand had only statistically significantly reduced TEWL on D8 ($p<0.05$) compared to the untreated control hand. In addition erythema index was significantly lower on D8 ($p<0.05$) on the moisturizer-treated arm compared to the untreated arm. The forearm model has some advantages over the hand immersion model because the technical procedure is simpler (1 patch test for 24 h), whereas the hand immersion model is both time-consuming (4 immersions over 2 days) and has a noticeable risk of eliciting an eczema eruption in the volunteers. Furthermore measurements on the volar forearm are simpler and less confounded by variation because of a homogenous skin surface in comparison with the heterogeneity in topography

and vascularization usually found on the back of the hand. It should be mentioned that it is not likely that any residual cream was left on either the hands or the forearms when performing measurements, since all measurements were taken more than 12 h after the last application of the moisturizer and also because the volunteers were encouraged to bath and shower as normal. Blichmann et al. showed that an oil-in-water emulsion applied on forearm skin did not affect the skin barrier function, as evaluated by TEWL after 15 min (22). However, this study was performed on normal non-irritated skin.

The reason that there was no statistically significant effect of the moisturizer treatment when using lower concentrations of SLS (0.125% and 0.25%) on the arms is probably that low concentrations of SLS induce very little skin irritation. The moisturizer cannot therefore make a difference in the recovery phase when compared with untreated control areas. TEWL after exposure to SLS on D3 was significantly lower on the hands compared to the arms (0.5% SLS). This could also be a reason why the forearm model (0.5% SLS) is more sensitive than the hand immersion model. But it does not seem realistic to increase the SLS concentration or the SLS-exposure time in the hand immersion model because of the risk of eliciting a severe eczema eruption in the participants.

Overall the responsiveness on D3 of forearm skin and hands with respect to degree of inflammation and skin barrier function was well correlated. Best correlation was found for laser Doppler flowmetry ($r_s=0.78$, $p<0.01$), which is in agreement with a study reporting that the responsiveness of forearms to surfactants is predictive of the responsiveness of hands (23). The lack of significant correlation between arms/hands with respect to TEWL ($p<0.1$) and erythema indices ($p<0.1$) may be due to different skin qualities. The electrical capacitance showed no correlation ($r_s=0.27$). This was to be expected since patch testing with SLS in relatively high concentrations may produce a "wet" irritant skin reaction in the early phase of recovery (24).

Several in vivo models for testing the effect of moisturizers on prevention and treatment of ICD in both animals (guinea pig, mouse) and in humans have been proposed in the past decades. When the effect of a moisturizer is tested, the time of application of the moisturizer has to be considered: before an irritant trauma to avoid penetration of noxious agents into the skin (barrier creams/protective creams) or after an irritant trauma to affect the recovery phase of the skin (after work emollients, emulsions for eczema-treatment). Moisturizers have also been tested alternating with irritant traumas in dynamic models. An

agreed classification of the different kind of creams/moisturizers/emollients does not exist.

Studies on barrier creams were done by Frosch et al. (1, 8). They used the repetitive irritation test (RIT) to study the efficacy of different creams in protecting against an irritant trauma (SLS, sodium hydroxide, lactic acid and toluene). Protective creams were applied on the human skin (volar forearm (1) and back (8)) and 30 min later followed by an irritant trauma. The procedure was repeated 1× daily for 9 days. It was shown that some barrier creams are effective against some irritants but not against others. In another study using the RIT on human backs, it was shown that some barrier creams could even intensify the irritant skin response (9).

Arguments for using the back as a test region for moisturizers are that the irritants are applied by the investigator (as opposed to self-administered application) and moreover that the back provides a large homogenous test area. Skin barrier properties on the human back, however, may differ significantly from the back of the hands with respect to the thickness of the stratum corneum and sebum production. Experimental studies on barrier/protective creams may provide limited relevant information since it is difficult to simulate real working life, where workers are often handling many different kinds of irritants and allergens in combination.

In a dynamic test model in humans, a repetitive washing procedure was used for 7 days (6). In this model, arms were exposed to both washings and barrier creams 5× daily. In another study, the efficacy of 8 different moisturizers in preventing and treating experimental ICD was studied on humans (2), who for 1 week washed their upper arm 2× daily and after each washing applied moisturizers to small test areas on the upper arm. Blanken conducted a similar study with repetitive irritation alternating with moisturizer treatment for 2 weeks using the volar forearms (3). Since occupational ICD is usually caused by cumulative irritation of the skin because of daily exposure to mild irritants, the dynamic models as mentioned above may imitate daily life well. In these realistic test models, the combined effect of the moisturizer as a barrier cream and an after-work emollient is tested. A critical point, however, is that when using a number of different creams on a number of different test sites on the arm it is possible that volunteers may easily make mistakes and thereby make the study less reliable. In one of the studies, as many as 8 different creams were tested on the upper arm (2). The different test areas may affect each other and thereby affect the results.

Only a few studies have focused solely on the

effect of a moisturizer on the recovery phase of diseased skin. A moisturizer containing urea and canola oil was found to promote barrier recovery in SLS-irritated skin on the forearms when used 2× daily for 14 days (7). In another study, 4 after-work emollients were tested on irritated skin on the volar forearms but no enhanced regeneration of the irritated skin was found (4). However, in this study, no rotation of the test sites was reported, which may have biased the results.

When testing the effect of a moisturizer on the recovery phase of surfactant irritated skin, it is preferable to use the arms or the hands, since the volunteers are able to apply the formulations themselves several times a day, which is a realistic procedure. A simple and reliable method is to test only 1 cream formulation at a time and to apply it on both irritated and normal skin. Symmetrical test areas should always be preferred, since anatomical variations in skin susceptibility may vary even in the same anatomical region, i.e., from the cubital fossa to the wrist (25). The time period of the study is another issue that has to be considered. Some studies have focused on the 24–48 h that follows after an irritant insult of the skin (26, 27). Since irritated/diseased skin has a recovery time of at least 1–2 weeks, it seems relevant to follow the recovering phase of moisturizer-treated skin vs. untreated control skin for at least 3–6 days after irritation (according to the results from the present study). When bioengineering methods are used, evaluations should be done 12 h after application of the cream at the earliest to ensure that there is no residual cream on the test area.

In conclusion, both test models illustrate the enhancing effect of the moisturizer on the barrier function of the skin. The proposed forearm model seemed more sensitive than the more realistic but cumbersome hand immersion model. We conclude that when the forearm model is used in the present set up, a relatively high concentration of SLS (>0.25%) should be used and evaluation measurements should be made on D5–D8. The forearm model could be used in further studies testing the efficacy of moisturizers because it is reliable, easy to handle and involves only a little inconvenience to the participants.

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