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Temperature Dependency of Skin Susceptibility to Water and Detergents

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Exposure to water and detergents is an important factor for development of irritant contact dermatitis. The aim of the present study was to investigate the effect of temperature on the damaging effects of water and detergents on the skin.

Twenty healthy volunteers participated in the study. Ten participants had right and left forearms immersed into a detergent (soap) solution for 2 days twice daily for 10 min. Another 10 participants had both forearms immersed into sterile water. Right and left forearms were randomized to immersion into 20°C and 40°C solutions, respectively. Reactions were evaluated clinically, and by measurement of transepidermal water loss, electrical capacitance and erythema.

Immersions into 40°C sodium lauryl sulphate solution caused significantly increased transepidermal water loss as compared to immersion into 20°C sodium lauryl sulphate solution. Electrical capacitance and erythema were not significantly influenced by temperature. Immersion into water caused no significant changes in any observed parameter.

Water temperature influences the irritant capacity of a detergent. Change of temperature may be a simple but important means for prevention of irritant contact dermatitis. ***Key words: TEWL; electrical capacitance; erythema; skin barrier function; wet work.***

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Long-lasting exposure to water and detergents frequently precipitates irritant contact dermatitis (ICD). ICD, in its chronic form, is common in employees in wet occupations (1). Physical and thermal elements may be additional traumatic factors. Since healing may be prolonged and relapse is common, prevention is rewarding. Prevention includes limited exposure to irritants, choice of detergents with minor irritating abilities, and careful skin care. Whether water alone may cause ICD is not yet proven, but recent studies indicate an irritant effect of water itself (2). Hot water is usually considered as more harmful to the skin than cold water, and regulation of water temperature could be a simple means of prevention. However, only few scientific reports address this subject (3, 4). The present study was undertaken to further study the relationship between temperature and degree of skin irritation. Effects of a detergent solution and of sterile water of different temperatures were studied, aiming at experimental conditions simulating daily life situations.

MATERIALS AND METHODS

Twenty healthy volunteers participated in the study. Informed consent was obtained from all participants, and the study was approved by the local ethical committee. Subjects with a history of atopic dermatitis, with previous hand eczema and persons sensitized to ubiquitous allergenes were not included. Participants were divided consecutively into the two following groups:

Group A included 10 volunteers, 6 females and 4 males (median age 30 years, range 25–50). Each person had one forearm immersed into a hot 0.5% sodium lauryl sulphate (SLS) solution (40°C), and the other forearm into a cold 0.5% SLS solution (20°C) (SLS Sigma, 99% purity). This immersion took place for 10 min twice daily for 2 days, with at least 3 h between two succeeding immersions. Right and left arms were randomly selected for exposure to hot and cold solutions. If clinical signs of irritation appeared, further immersions were refrained from. SLS is an anionic detergent frequently used in experimental studies to elicit irritant skin reactions (5), and the immersion model used was recently described as a useful model to imitate cumulative irritant skin reactions (6). The temperature of the bath was checked at start of the immersion.

Group B included 10 volunteers, all females (median age 35 years, range 21–49). Each person had one forearm lowered into a hot solution of sterile water (40°C), and the other forearm into a cold solution of sterile water (20°C). Procedures of immersions were similar to those of group A.

Evaluation of skin reactions was performed by *clinical examination* for signs of irritation (erythema, scaling), and by the following non-invasive measuring methods:

Transepidermal water loss (TEWL) was measured using an Evaporimeter (Servo Med, EP1, Stockholm, Sweden) (7). The sensors of the Evaporimeter determine the water vapour pressure gradient of the boundary layer between the skin surface and ambient air in order to quantify the diffusion of water through the skin as the TEWL. Measurements were performed according to the guidelines of the Standardization Group of the European Society of Contact Dermatitis (8). The measuring method is highly sensitive and reproducible (9, 10).

Electrical capacitance was measured by a Corneometer CM 820[R] (GmbH, Köln, Germany) (11). The Corneometer measures the electrical capacitance of the outer epidermis. The probe of this instrument is a plastic-foil-covered brass grid, which functions as one electrode while the skin functions as the other, and registers hydration down to a depth of about 0.1 mm (11).

Erythema index was measured using a DermaSpectrometer (Cortex Technology, Hadsund, Denmark). This method is based on a quantitative comparison of the reflection of green and red light from the skin (12). The spectrometer was placed in contact with the skin with minimal pressure on the skin.

Evaluations were performed prior to immersions (day 1), and 24 h after the last immersion (day 3). The site for measurement was chosen as a 1×1 cm area symmetrically placed on the mid-volar side of the forearms, 10 cm proximal to the distal wrists flexorline. The skin temperature of the participants was measured in relation to TEWL measurements and varied between 29.3°C and 32.8°C. The ambient relative humidity varied in the test period between 26% and 48%.

During the 10-min immersions the temperature of the 40°C bath dropped by 1°C, and the temperature of the 20°C bath increased by 1°C.

Statistics

A Pratt modified Wilcoxon test for paired observations (13) was used to compare median values. A significance level of $p < 0.05$ was chosen. The results are given as median, 25 and 75 percentiles. Values for erythema and electrical capacitance represent an average of 3 measurements, and for TEWL an average of 2 measurements.

RESULTS

Group A (SLS immersion)

Clinical observations. Clinical signs of irritation on the forearm exposed to 40°C SLS solution appeared in one volunteer after two immersions, and further immersions were refrained from. The remaining 9 volunteers were all able to fulfil the planned four immersions. Discrete, fine scaling appeared in 4 volunteers on the forearm exposed to 40°C SLS solution, while no reaction appeared on the other arm.

TEWL. The results are shown in Table I. No significant difference was found between basal TEWL values on the two arms. Comparing basal values and values after exposure to 20°C SLS solution, no statistically significant difference in TEWL ($p>0.05$) was found. Comparing TEWL basal values to values after exposure to 40°C SLS solution, a statistically significant difference for TEWL was demonstrated ($p<0.01$), with increased values after immersions. Comparing TEWL for test sites exposed to 20°C to test sites exposed to 40°C SLS solution, a statistically significant difference was demonstrated, with increased TEWL values for test sites exposed to 40°C solution ($p<0.01$).

Electrical capacitance. The results are shown in Table I. No significant difference was found between basal electrical capacitance values on the two arms. Comparing basal values and values after exposure to 20°C and 40°C SLS solution, a statistically significant decrease in electrical capacitance was found ($p<0.05$ and 0.01, respectively). No statistically significant difference in electrical capacitance was found between test sites exposed to 20°C and 40°C solution.

Erythema index. The results are shown in Table I. No significant difference was found between basal erythema values on the two arms. Comparing basal values and value after exposure to 20°C and 40°C SLS solution, no statistically significant difference in erythema was found ($p>0.05$). No statistically significant difference in erythema was found between test sites exposed to 20°C and 40°C solution ($p>0.05$).

Group B (sterile water)

Clinical observations. None of the participants in group B had subjective or objective signs of irritation after the immersions.

TEWL, erythema and electrical capacitance. No statistically significant difference between basal values for TEWL, erythema and electrical capacitance was found.

No statistically significant difference between values for TEWL, erythema and electrical capacitance between basal values and values after the immersions, was found either for 20°C or 40°C (Table II).

No statistically significant difference between values for TEWL, erythema and electrical capacitance for test sites exposed to 20°C compared to test sites exposed to 40°C was found.

DISCUSSION

The present results demonstrate a significantly increased impairment of skin barrier function after immersions into hot SLS solution (40°C) as compared to SLS solution with room temperature (20°C). Impairment of skin barrier function following exposure to detergents is well known (5), and SLS exposure is commonly used in experimental studies of irritant contact dermatitis. The temperature dependency of the irritant

Table I. *Baseline values (day 1) and values after SLS immersions (day 3) for TEWL, electrical capacitance and erythema index for group A, for immersions into 20°C and 40°C, respectively*

n.s. indicates $p>0.05$.

TEWL, g/m^2h	Day 1 (baseline)	Day 3 (exposed)	*p*-value
20°C	6.9	8.4	n.s.
	(6.8–8.1)	(6.7–10.0)	
40°C	7.3	10.2	$p<0.01$
	(6.5–7.7)	(8.8–12.8)	
p-value	n.s.	$p<0.01$	

Electrical capacitance, a.u. (arbitrary units)	Day 1 (baseline)	Day 3 (exposed)	*p*-value
20°C	70	64	$p<0.05$
	(69–74)	(62–73)	
40°C	73	66	$p<0.01$
	(69–76)	(63–71)	
p-value	n.s.	n.s.	

Erythema index, a.u. (arbitrary units)	Day 1 (baseline)	Day 3 (exposed)	*p*-value
20°C	9.2	8.0	n.s.
	(7.9–10.2)	(6.7–10.2)	
40°C	8.5	9.0	n.s.
	(7.0–10.9)	(7.5–12.8)	
p-value	n.s.	n.s.	

Table II. *Baseline values (day 1) and values after sterile water immersions (day 3) for TEWL, electrical capacitance and erythema index for group B, for immersions into 20°C and 40°C, respectively*

n.s. indicates $p>0.05$.

TEWL, g/m^2h	Day 1 (baseline)	Day 3 (exposed)	*p*-value
20°C	8.6	7.2	n.s.
	(5.7–9.5)	(6.6–8.4)	
40°C	7.5	7.0	n.s.
	(6.3–8.6)	(6.3–8.3)	
p-value	n.s.	n.s	

Electrical capacitance, a.u. (arbitrary units)	Day 1 (baseline)	Day 3 (exposed)	*p*-value
20°C	73	75	n.s.
	(62–76)	(63–81)	
40°C	70	76	n.s.
	(64–77)	(72–79)	
p-value	n.s.	n.s.	

Erythema index, a.u. (arbitrary units)	Day 1 (baseline)	Day 3 (exposed)	*p*-value
20°C	8.9	9.7	n.s.
	(7.6–12.9)	(8.2–12.0)	
40°C	8.5	9.2	n.s.
	(7.8–10.2)	(7.9–11.4)	
p-value	n.s.	n.s.	

effect of SLS has, however, only been investigated in a few earlier studies. Rothenborg et al. (3) in 1977 reported of temperature-dependent ICD from the lemon perfume component Citral. When patch testing with this substance no reactions appeared after exposure to 23–25°C test solution, but irritant reactions appeared after exposure to 43°C test solution (3). In a recent study Berardesca et al. (4) treated 4 × 4 cm areas on the forearm with 5% SLS once daily for 5 days, using solutions at 3 temperatures: 4°, 20° and 40°C. Skin damage was augmented in sites treated with high temperatures, and a highly significant correlation between irritation and temperature was found (4). Previous investigations of workers in the fish industry have demonstrated that exposure to cold water throughout the day does not compromise the skin barrier function significantly (14). These studies all indicate an effect of temperature on skin susceptibility and are in agreement with our present findings. In the present study an experimental set-up similar to the daily life situation was achieved.

Immersions were found to decrease electrical capacitance, reflecting the hydration state of stratum corneum, independently of temperature. This is in agreement with the findings of Berardesca et al. (4), who reported no significant difference in skin hydration after patch testing with 20° and 40°C test solution. Skin dryness, caused by detergents, apparently cannot be prevented by decrease of temperature.

Immersions did not cause significant erythema, independent of temperature. Immersions into sterile water for the same period, independently of skin temperature, did not influence either skin barrier function, hydration state of stratum corneum or erythema.

The accentuated irritant effect of SLS solution at 40°C compared to 20°C could be explained either as an effect of temperature on the irritant capacity of SLS, or as an effect of temperature on the skin barrier function. An increased irritant capacity of SLS itself, due to increased temperature, is not very likely to occur, since temperature has a comparatively small effect on the micellar properties of SLS in the range 20°–40°C (15). Effects of temperature on the lipids of stratum corneum constitute a more likely explanation. Increased temperature is known to increase the water flux through stratum corneum (16), and increased percutaneous absorption due to increased temperature of SLS and nickel was recently reported (17). This increased water flux at higher temperatures may cause increased penetration of SLS, and subsequently increased impairment of the skin barrier function. Results from group B, which had immersions into sterile water only, illustrate that water alone, independent of skin temperature, cannot elicit similar reactions. However, more prolonged immersions may lead to another result.

This investigation has demonstrated that temperature plays an important role in the deteriorating effect of a detergent on the skin barrier function in the temperature range 20°–40°C. Effects of temperature outside this range are not deducible from this study, and also the shape of the irritant capacity curve between 20°C and 40°C has yet to be studied. Whether the temperature dependency is a general phenomenon for irritants or is restricted to detergents only is not known. Both occupationally and domestically, knowledge about the influence of temperature on the irritant effect of detergents in water is important, and regulation of water temperature could be an effective prevention of ICD in some occupations.

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