

Biophysical changes after mechanical injury of the stratum corneum in normal skin

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Scrubbing off the stratum corneum with a rough towel after soaking in warm water is a bathing custom unique to Korea. However, Korean dermatologists have advised against this practice due to the potential harm that it may cause, though there is little data to support this advice. This study aimed to evaluate the changes in biophysical characteristics after such mechanical injury of stratum corneum, as reflected by water-holding capacity, stratum corneum barrier function, and stratum corneum turnover time (SCTT). 10 Korean female volunteers (aged 19–34 years) were enrolled in this study to investigate the acute effects and 32 volunteers (aged 19–49 years) the chronic effects. After soaking in warm water (36°C) for 5 min, the flexor surfaces of the forearms were scrubbed with a rough towel. The volunteers' forearms were divided into 4 compartments, and each compartment was scrubbed 0, 5, 10, and 15×, respectively. After a single injury of the stratum corneum, there was an initial decrease in water-holding capacity until 6 h. Thereafter, it increased until day (D) 3, when it began to descend to the normal range. The transepidermal water loss (TEWL) values also peaked at D2 and declined thereafter. However, there were no changes in either water-holding capacity or skin barrier function, and only the SCTT was significantly shortened, after chronic injury of the stratum corneum.

Key words: rough towel; corneometer; transepidermal water loss (TEWL); stratum corneum turnover time (SCTT); mechanical irritation; bioengineering methods; irritant contact dermatitis.
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Scrubbing off the stratum corneum with a rough towel after soaking in warm water is a bathing custom unique to Korea. Many Koreans feel refreshed after the removal of *Ttae* (Korean for grime) about 1× a week, and this bathing custom has been popular with all ages for a long time. However, this practice may be harmful to the skin from a dermatologist's point of view because it disrupts skin barrier function. Therefore, Korean dermatologists have advised against this practice due to the potential harm that it may cause. However, there is no supporting evidence that this bathing custom is harmful and no clinical trials aimed at evaluating the acute or chronic effects of mechanical injury of stratum corneum have been attempted.

Therefore the aim of this study was to evaluate the changes in biophysical properties after such mechanical injury of the stratum corneum, as reflected by water-holding capacity, stratum corneum

barrier function, and stratum corneum turnover time (SCTT).

Patients and Methods

Subjects

10 female volunteers (aged 19–34 years) were enrolled to investigate the acute effects and 32 volunteers (aged 19–49 years) were enrolled to study the chronic effects. All patients provided informed consent and none had any dermatological problems. All patients were asked otherwise not to scrub off the stratum corneum during the clinical trial. The study was conducted from winter to early spring. In order to avoid non-physiologic conditions and the influence of excessive sweating, all measurements were performed at a constant room temperature between 20°C to 22°C, and relative humidity between 30% and 32%. Furthermore,



Fig. 1. Scrubbing off the *Ttae* with a specialized rough towel, after soaking both forearms in warm water.

no physical activity was allowed 30 min before each measurement.

Injury of stratum corneum

After soaking in warm water at 36°C for 5 min, the flexor surfaces of both forearms were scrubbed with a commercially-available specialized rough towel (Itaeri Towel®, Songwol, Korea) (Fig. 1). The volunteers' forearms were divided into 4 compartments, and the compartments were scrubbed 0, 5, 10, and 15×, respectively. The compartments were randomly selected and the measurements were made using a single-blind method.

Measurement

Water-holding capacity was measured using a corneometer (Corneometer CM-820 PC®, Courage-Khazaka, Germany), as described by Berardesca et al. (1). The results are expressed in arbitrary

units (a.u). To assess barrier function, TEWL measurements were carried out using a tewameter (Tewameter TM210®, Courage-Khazaka, Germany) (g/m²h), according to the guidelines provided by Pinnagoda et al. (2). To determine acute effects, measurements were performed at 0, 1, 6, 24 h and 2, 3, 5, 7 days (D) after injury of the stratum corneum. To test for chronic irritation, the *Ttae* was scrubbed off 1× a week for 8 weeks, with measurements performed in the 9th week.

In the chronic irritation group, a dansyl chloride staining technique was used to measure stratum corneum turnover time (SCTT). Dansyl chloride (5-dimethylaminonaphthalene-1-sulfonyl chloride, Sigma Chemical Co., USA) was finely dispersed at 5% (wt/wt) in white petrolatum. After 8 weeks' chronic irritation, each of the volunteer's compartments was stained using the method outlined by Jansen et al. (3). 5% dansyl chloride (200 µl) was smeared over a Hill Top Chamber (25 mm in diameter) and fastened to the forearm compartment using occlusive tape. After 24 h, the patches were removed and the residual ointment wiped off. A long-wave ultraviolet lamp (Blak-Ray® B-100A, Ultra-Violet Products, Inc., USA) was used to visualize the fluorescent dansyl chloride stain. The fluorescence grade was scored according to a subjective visual scale of 0–4: 0=no fluorescence remaining; 1=only small areas of fluorescence; 2=moderate areas of fluorescence with noticeable areas of fading; 3=large areas of fluorescence with small areas of fading; 4=whole, even areas of fluorescence present throughout.

Statistical Analysis

To evaluate the differences between the corneometer, tewameter, and SCTT values before and after irritation, statistical analysis using the Wilcoxon

Table 1a. Changes in corneometric values after a single injury of stratum corneum

	Baseline	1 h	6 h	1 day	2 days	3 days	5 days	7 days
0	82.44±9.45	82.77±9.42	8.64±6.17	80.41±3.55	81.45±4.25	80.28±5.06	80.82±6.70	79.83±6.59
5	80.23±6.47	79.60±5.81	73.34±9.30	85.14±8.13	89.90±8.43*	97.52±9.84**	90.71±9.74*	83.52±7.98
10	81.28±10.13	77.85±4.83	75.77±9.88	83.65±6.94	91.69±8.31*	101.24±9.37**	93.87±8.74**	82.54±7.95
15	79.82±6.02	76.87±7.17	72.91±6.55*	85.94±9.29	94.10±9.66**	98.69±8.17**	92.80±9.92*	80.97±9.47

* $p<0.05$, ** $p<0.01$.

Table 1b. Changes in TEWL values after a single injury of stratum corneum

	Baseline	1 h	6 h	1 day	2 days	3 days	5 days	7 days
0	3.38±1.16	3.12±1.02	3.18±1.04	3.08±0.69	3.18±1.12	3.15±1.05	3.13±0.93	3.32±0.89
5	3.14±1.12	6.03±1.85**	5.62±1.94*	6.02±1.11**	8.04±1.19**	5.89±1.46*	4.64±1.14*	3.68±1.36
10	3.49±1.59	5.66±2.23	5.45±1.93*	6.12±1.17**	8.58±1.66**	6.07±1.85**	4.59±1.93	3.04±1.06
15	3.28±0.84	6.13±1.62**	5.90±1.43**	6.38±1.27**	8.99±1.08**	6.31±1.44**	5.00±1.33*	3.15±1.85

* $p<0.05$, ** $p<0.01$.

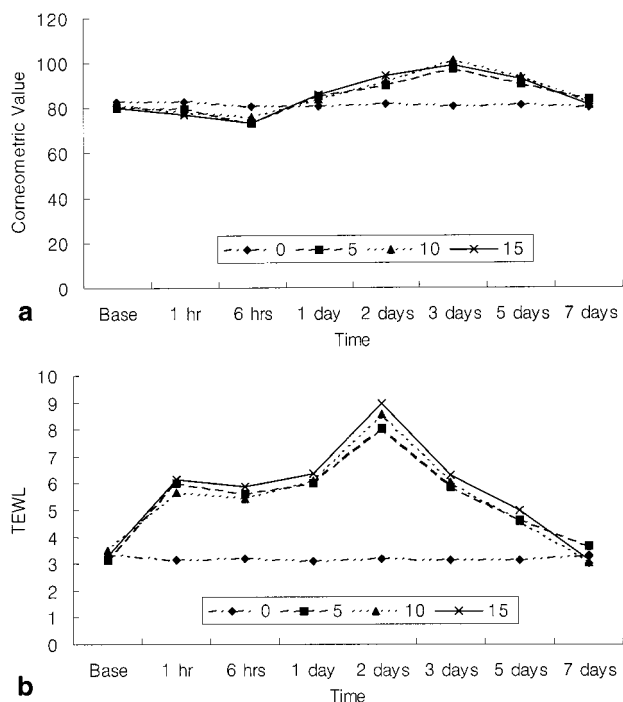


Fig. 2. Changes in biophysical properties after a single injury of the stratum corneum. (a) Corneometric values. (b) TEWL values.

signed ranks test for the acute effects of a single injury was used, because the sample number is insufficient for the parametric analysis. For the chronic effects of regular mechanical injuries, the sample number was sufficient for the repeated measured analysis of variance (ANOVA) to be performed. *P*-values of less than 0.05 were regarded as statistically significant.

Results

After a single injury of the stratum corneum, electrical capacitance measured by the corneometer, which indicates water-holding capacity, initially decreased up to 6 h after the injury. From there, it increased with a decreasing rate reaching a maximum on D3 and descended to the normal range thereafter (Table 1a, Fig. 2a). TEWL values also peaked at D2 and then declined (Table 1b, Fig. 2b).

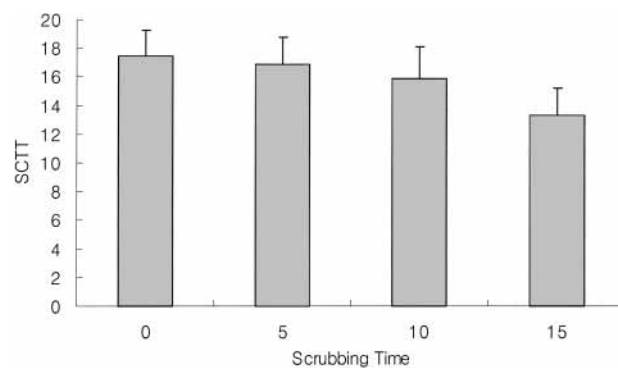


Fig. 3. Stratum corneum turnover time (SCTT) changes after repeated injury of the stratum corneum.

Regular injury of the stratum corneum resulted in no change in either water-holding capacity or skin barrier function. However, the SCTT was significantly shortened (Table 2, Fig. 3).

Discussion

Skin is an important organ that maintains the homeostasis of the human body by buffering mechanical and chemical stimuli. The functions of the stratum corneum, as the outermost layer of the skin, include mechanical protection of the skin, barrier to water loss, and permeation of soluble substances from the environment. Thus, it is natural that many dermatologists have thought that injury to the stratum corneum might be harmful for maintenance of homeostasis of the skin's physical properties.

In spite of the potential harm resulting from this traditional bath custom, there have been few scientific studies on this issue. Lee et al. (4) reported that mechanical injury to the stratum corneum with a rough towel, as used in our clinical trial, decreased the corneocyte count and size immediately, but that this returned to normal within 5 days due to increased epidermopoiesis. However, they did not provide any data that related to chronic irritation or general physiology.

To investigate the biophysical properties of the skin after irritation, chemical irritants like ben-

Table 2. Comparison of corneometric values, TEWL, and SCTT by scrubbing times after chronic injury of the stratum corneum

Scrubbing times	0	5	10	15	<i>p</i> -value ^{a)}
corneometric values	81.63±8.25	81.83±9.09	79.96±9.08	82.66±7.78	ns
TEWL	3.29±1.93	3.37±1.72	3.47±1.79	3.23±1.69	ns
SCTT	17.47±1.81	16.84±1.90	15.84±2.29	13.29±1.90	<0.01
T ^{b)}	a	a, b	b	c	

a) Statistical significances were tested by one-way ANOVA among groups.

b) The same letters indicate non-significant difference between groups based on the Tukey multiple comparison test.

ns: non-significant. TEWL: transepidermal water loss. SCTT: stratum corneum turnover time.

zalkonium chloride, sodium lauryl sulfate, or glycolic acid have frequently been used. In contrast to mechanical irritation, removal of the surface cells by adhesive tape stripping was a most commonly used model. However, the tape-stripping method also has some limitations. Several factors can influence the results of tape-stripping, for instance, the manner, skin hydration, cohesion between cells, body site and individual differences (5, 6). Other investigators have developed their own models for mechanical irritation, such as percussive (7) and abrasive (8) trauma. However, none of these methods appeared to be suited to this study. It is believed that this experimental model using a rough towel is not only more applicable, but is also simple to perform, despite its not being confirmed that the degree of such mechanical injury was equal to that of tape stripping.

Both acute and chronic effects after injury of the stratum corneum were investigated. The results of this study indicated acute changes in the biophysical properties after a single injury of the stratum corneum, TEWL being increased with a maximum on D2 and water holding capacity also increased, reaching a maximum on D3 and slowly returning to normal thereafter. Water-holding capacity immediately decreased and showed an increasing tendency within a day. This acute irritant response was similar to that of chemical irritation or tape stripping (9–11). However, we observed an initial decrease in water-holding capacity, and several possible causes of this phenomenon might be proposed. The Corneometer CM 420® registers the electrical capacitance of the skin surface and depicts changes of hydration to a depth of 0.1 mm (12). A limitation of electrical measurements is that they give only qualitative information on differences in the water content at poorly-defined locations within the skin. Other drawbacks are that skin-surface irregularities and the presence of loose material on the skin, such as scales, may reduce the intimacy of the contact between the capacitance probe and the skin, which may possibly give rise to lower capacitance values. In a recent study, a lack of correlation between TEWL and capacitance was also noted on normal skin (12). A possible reason for this could be that properties at different depths of the stratum corneum contribute to the reading with varying intensity, with difference in the recovery rate of the 2 main components of epidermal barrier, keratinocytes and epidermal lipid. In hairless mice, disruption of barrier function will also induce a burst of epidermal lipid synthesis, recovery of the epidermal lipid layer being 50% within 6 h after injury (13), while keratinocyte repopulation was found far later. Moreover, Bommannan et al. (14) reported that tape stripping re-

duced the amount of lipid content and increased stratum corneum hydration from the surface towards the stratum granulosum interface. We think that all of these may explain why TEWL and water holding capacity show such trends in the acute response model of our study. On the chronic effects, there are no reports that the authors are aware of, and the most interesting result relating to chronic effects in this study was that the SCTT showed remarkable shortening.

There has been improved understanding of the short-term effects of barrier injury in recent years. However, the mechanisms that result in chronic changes are still not fully resolved. Nevertheless, there must be a powerful regulatory mechanism ensuring that mechanical trauma only affecting the stratum corneum has stimulatory effects on the kinetics of keratinocyte proliferation in the basal layer of the epidermis (15, 16). Several mechanisms of SCTT shortening after disturbance of the epidermal barrier all suggest that there is an upregulation of mRNA coding for proinflammatory cytokines, adhesion molecules and growth factors (17), and that the mitotic activity of keratinocytes is increased (18).

Although our results suggest there is no major skin damage after scrubbing off the *Ttae* during bathing, one should be cautious about this interpretation, as all volunteers were healthy with normal skin. Repeated trauma on existing pathologic skin conditions, like psoriasis or atopic dermatitis, might show a different response (19). Further investigation in some pathologic conditions like atopic dermatitis, xerotic eczema, or psoriasis is needed to verify this.

In conclusion, mechanical injury of the stratum corneum in normal skin induces some transitional changes in both water-holding capacity and TEWL values in the acute response. However, major alterations in skin barrier function in the chronic response were not observed in normal individuals, with the exception of a shortening of the SCTT. This implies that regular injury of the stratum corneum may not be as harmful as initially thought.

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