

## The Water Barrier Function of the Skin in Relation to the Water Content of Stratum Corneum, pH and Skin Lipids

### *The Effect of Alkaline Soap and Syndet on Dry Skin in Elderly, Non-atopic Patients*

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Clinical dryness of the skin is a common problem among elderly, dermatological patients. In the present investigation, hydration, surface lipids, skin pH and water barrier function as expressed by the transepidermal water loss (TEWL) were studied in both dry and normal skin. Using these parameters, a comparison of the local effects of acid and alkaline cleansing products was made. In non-atopic elderly patients with dry skin, the TEWL values were lower than in the younger control group but higher than in the older controls. Following one week's topical therapy, the TEWL values in the patient group decreased further and approached the lower values of the older control group. At the same time the skin hydration values increased, indicating a beneficial effect on the skin barrier. An inverse relationship was demonstrated between TEWL and skin hydration. The study indicates that high TEWL values are frequently correlated with high pH, low hydration of the stratum corneum and reduced skin surface lipid content. Despite the intensive use of an acid syndet and lotion, the pH-readings increased but were still within the 'confidence limits' of the control groups. *Key words:* TEWL; Hydration; Age; Cleansing. (Received June 1, 1987.)

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Dry and cracked skin caused by atmospheric fluctuations in humidity and temperature is a common problem among dermatological patients. But it is difficult to describe the condition of dry skin adequately in terms of altered morphology, biochemistry or physiology, as the skin does not always lack moisture or sebum as evaluated by usual methods. The causes are often multifactorial and in some cases external injury and desiccation as well as inherent defects in intercellular lipids and cellular structural proteins (keratins) may be precipitating factors.

The symptoms are usually treated with hydrating or moisturizing agents, since it is generally assumed that roughness and visible scaling are associated with increases in transepidermal water loss (TEWL) due to a defective water barrier and reservoir function in the stratum corneum (1). According to several investigators (1, 2, 3), individuals with dry skin show higher values of TEWL than those with normal-appearing skin. Under normal circumstances, higher TEWL values are associated with greater hydration of the stratum corneum. But this is not always the case in abnormal skin (1). Since TEWL cannot be regarded as a reflection of water content in the stratum corneum, the hydration of the skin has to be measured separately. Only a few in vivo studies using such measurements have been reported (1, 4, 5, 6).

The technical development of new and more sophisticated measuring devices has made it

possible to evaluate *in vivo* not only the water content of the upper part of the stratum corneum but also the ability to take up water, i.e. its hygroscopicity, as well as the water-retaining capacity. These parameters have been shown to be clearly related to dry skin conditions, even if there is only inconspicuous, fine scaling (7). It seems that the hygroscopicity is more dependent on natural moisturizing factor components, i.e. the presence of hygroscopic substances of small molecular weight, whereas water retention requires a stratum corneum with an intact structure (7).

The use of syndets (synthetic detergents) and creams with low pH (5.5) has been enthusiastically advocated as being more 'skin friendly' and physiologically effective, since under normal circumstances the pH varies between 5.4 and 5.9 (8). It is kept within these limits by the 'functional buffer capacity' of the skin, mainly a lactate-bicarbonate buffer system. The buffering capacity is of crucial importance in neutralizing small amounts of alkali and acids as encountered during work and leisure activities. Theoretically one might think that the pH of a topical vehicle or soap could modify skin keratin, but under physiological conditions the vehicle's pH has little effect on hydration (9).

The purpose of the present study was to investigate 1) the local effect of acid products, compared with an alkaline soap, on the pH of dry and normal skin; and 2) the possible relationship between water-barrier function as expressed by TEWL, the skin hydration and the surface lipids. These lipids are mostly of sebaceous origin and consist of triglycerides, squalene and wax esters (10). The stratum corneum lipids, present in lesser quantities, are derived from the lamellar bodies and contain neutral lipids such as ceramides, sterols and sterol esters, and free fatty acids (10, 11). These structural lipids are essential for the water-retaining capacity of the stratum corneum, the hydration state and the barrier function.

## MATERIALS AND METHODS

Fifty subjects suffering from dry skin with no or only minimal scaling and with no history of atopy, were initially included in the study. Ten patients were later withdrawn from the investigations because of compliance failure. Their median age was 65 years (95% confidence interval 60–73 years). The subjects washed (for 1 min) one arm with alkaline soap (pH 9.5) while the other arm was washed with Sebamed compact (pH 5.5) followed by application of Sebamed lotion (also pH 5.5). This treatment was performed twice daily. All investigations were performed on the lateral aspect of the upper arm about 10 cm above the elbow and at an ambient room temperature of about 20°C and relative humidity at 50%. Measurements were performed after one week of therapy and about 3 h after the last application.

Normal values were obtained from: 1) 23 young subjects without skin symptoms and with clinically normal skin and who did not undergo premeasurement treatment. The median age in this control group was 29 years (confidence interval 24–40 years); 2) 15 older subjects without skin symptoms and with a median age of 81 years (range 67–95 years).

Measurements of the pH were performed with a new type of glass electrode SMT-pH-90 (Schwarz-haupt), which is based upon the electrochemical method. The instrument was calibrated before use. The skin surface lipids were measured using the Sebumeter SM 420. This method is based upon photometric measurements of light transmission through a transparent plastic foil which is pressed (6 N) against the skin for 30 s, to allow adhesion of skin lipids. The sebumeter readings were converted into  $\mu\text{g}/\text{cm}^2$ . This instrument has previously been compared with the lipometer of l'Oreal and yields corresponding values (12). The barrier function, as expressed by TEWL, was measured using the evaporimeter (13) and the results were expressed in  $\text{g}/\text{m}^2/\text{h}$ . The skin surface hydration state was evaluated by use of the Corneometer CM420 (6). This instrument measures the electrical capacity of the stratum corneum which is dependent upon the water content and the high dielectric constant of water relative to other skin components.

## RESULTS

All parameters except the pH values varied greatly from one individual to another. Dry-looking skin could have normal or even high lipid and hydration values, whereas normal-looking

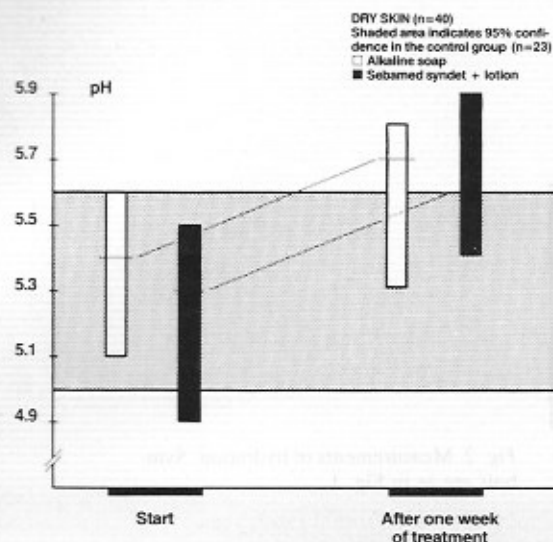


Fig. 1. pH measurements. The shaded area indicates the 95% confidence area for the younger control group ( $n=23$ ). Vertical range bars indicate the 95% confidence interval of the median values in the dry-skin group ( $n=40$ ). □: alkaline soap; ■: sebamed.

skin with low values were also observed. It seemed as though the TEWL decreased with age, while the hydration remained fairly constant. The values obtained in the older control group are illustrated in Table I. Higher pH and hydration values were observed in that group than in the other groups. The TEWL values were significantly lower ( $p<0.01$ ), while there was no significant difference with regard to the surface lipids. Nor was there any difference between the right and the left side.

The median pH values of all groups were within the range 4.9–6.3 (Fig. 1). A slight increase in pH was observed in the dry-skin group after one week of treatment, both on the test sites treated with acid products and on those washed with alkaline soap ( $p<0.03$ ). There was a slight increase in moisture on both test sites after one week's treatment (Fig. 2). At the same time there was a bilateral decrease in TEWL, indicating a beneficial effect on the barrier function (Fig. 3). The obtained pretreatment TEWL values in the dry-skin group were significantly lower on both sides than in the younger control group ( $p<0.01$ ), but not as low as in the older control group. During treatment, the hydration and the TEWL values both approached those of the older control group. The skin surface lipid readings in the treatment group showed a significant increase ( $p=0.01$ ) (Fig. 4).

A correlation analysis of the obtained values is illustrated in Table II. A strong negative correlation between TEWL and hydration is evident. This correlation disappears if we correct for the variables pH and lipid, which can be explained by a positive correlation between surface lipids and hydration and a negative correlation between lipids and TEWL. pH is positively correlated to TEWL and high age and negatively to hydration. The apparently positive

Table I. Measurements of pH, hydration, TEWL and surface lipids; older control group;  $n=15$ ; Results from one side

	pH	TEWL	Hydration	Lipids
Median, with 95% confidence interval	5.9 (5.32–6.15)	3.8 (2.1–5.6)	79 (71–91)	7 (6–12)
Mean $\pm$ SE	5.7 $\pm$ 0.15	4.6 $\pm$ 1.14	80.7 $\pm$ 2.7	15 $\pm$ 4.4
Range	4.17–6.50	1.2–19.2	67–106	6–57

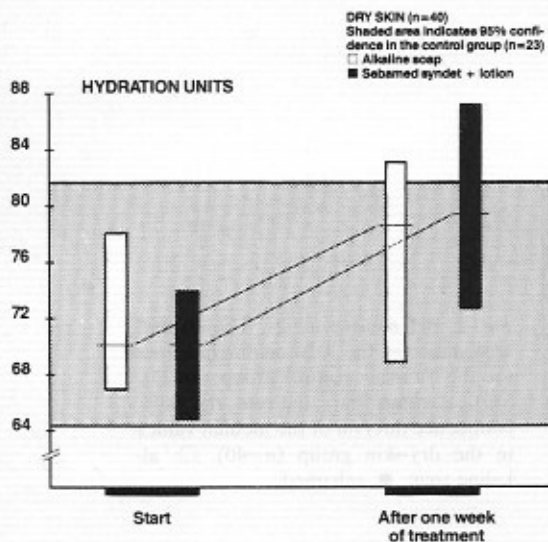


Fig. 2. Measurements of hydration. Symbols are as in Fig. 1.

correlation between pH and skin lipid levels is actually false. Thus high TEWL values are frequently correlated with high pH, low hydration of the stratum corneum and depressed lipid levels in the skin.

## DISCUSSION

It is an accepted fact that age appears to be an important factor in the dry-skin syndrome. Structural and biochemical changes in the stratum corneum would seem to be more important than changes of sebum excretion, which accounts for most of the skin surface lipids. In fact it has been stated that sebum is of very questionable importance (14). Still it may be misleading to regard sebum merely as a remnant of earlier primate development and dismiss it as a factor which can affect both the appearance and the pliability of the skin by a smoothing or lubricating effect.

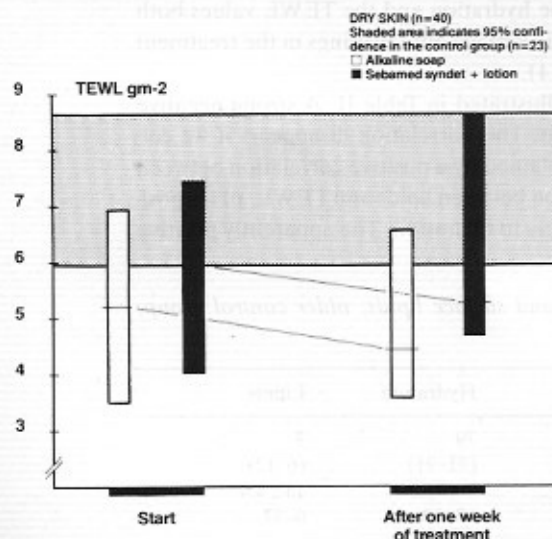


Fig. 3. TEWL measurements. Symbols are as in Fig. 1.



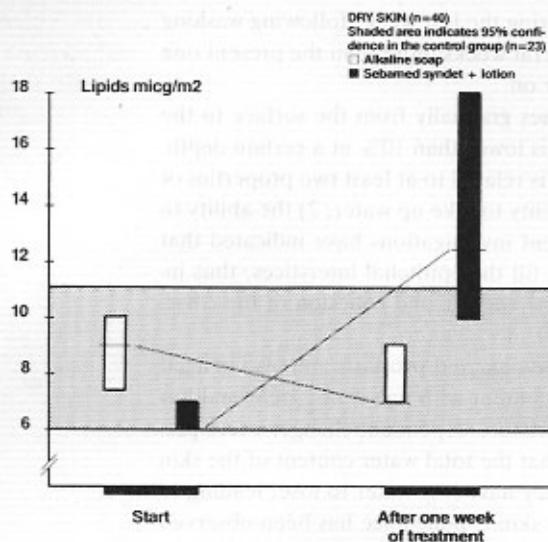


Fig. 4. Measurements of the skin lipids. Symbols are as in Fig. 1.

An increase in surface lipids occurred on the test-site which was treated with the lotion. This probably reflected the lipid compounds which were derived from the lotion itself, but could also be due to a modification of the natural moisturizing factor components and epidermal skin lipids, manifested as an increase in the stratum corneum hydration. It has been demonstrated that the application of moisture-containing emollients can cause changes similar to those induced by artificial hydration (4, 15) but there are no published reports on in vivo measurements correlating TEWL, hydration and skin lipids.

The present investigation indicates that daily washing with alkaline soap and syndet increases the hydration state and has a beneficial effect on the skin barrier in dry, elderly skin. No deleterious effects whatsoever were observed and one might imagine that the vigorous application of water twice daily altered the water content and function of the stratum corneum and perhaps other structures of the skin. The application of an acid lotion on one test site increased the skin surface lipids significantly. At the same time, corresponding changes in pH, TEWL and hydration occurred on both test sites, i.e. also on the one which was only treated with alkaline soap. This indicates that water was the main factor responsible and concurs with other opinions regarding the minor importance of skin surface lipids (14, 16). Despite the intensive use of an acid syndet and lotion, the test-site pH readings increased in the dry-skin group but were still within the confidence area of the control groups. Most probably this reflects the neutralizing effect of water. The application of an acid cream after washing with the acid syndet did not alter the tendency to alkalinity, but one should bear in mind that these results cannot be directly transferred to conditions with eczema or infected skin. In one

Table II. Correlation analysis

Kendall's correlation					
Age	1	0.41*	-0.33*	-0.26*	0.44*
TEWL		1	-0.40*	-0.32*	0.60*
Hydration			1	0.34*	-0.55*
Lipids				1	-0.23*
pH					1

\* Significant coefficients.

recent study, a slight decrease in skin pH was noted during the last weeks following washing with the same acid product (17). That study lasted several weeks more than the present one and it might be that the acidifying effect appears later on.

The hydration state of the stratum corneum increases gradually from the surface to the deeper layers and one assumes that when the content is lower than 10% at a certain depth, the skin appears dry and chapped. The hydration state is related to at least two properties of the stratum corneum: 1) the hygroscopicity, i.e. the ability to take up water; 2) the ability to retain water, or the water-retaining capacity (1). Recent investigations have indicated that the epidermal lipids derived from the lamellar bodies fill the epithelial interstices, thus influencing the barrier function, permeability as well as dyshesion and cohesion of the cornified cells (11, 14, 16, 18).

It has been shown that the water content is low in eczema and psoriasis and also in aged skin (1, 7, 19). The magnitude of change in moisture content with age is not great and has been attributed to a decrease in skin thickness. The moisture-dependent changes occur predominantly in stratum corneum, but it might also be that the total water content of the skin is reduced in elderly patients and that, accordingly, they have less water to lose, leading to low TEWL values as a logical consequence. A normal skin conductance has been observed in xerotic skin (3), although the skin surface appeared abnormal on biopsy. But neither the hygroscopicity nor the water-retaining capacity, which were demonstrably abnormal in xerotic skin (1, 7), was measured. In vitro, the secondarily bound water of the horny layer from elderly skin has been found less than normal, whereas no differences were detected in primarily bound water (20).

In the present study an inverse relationship was demonstrated between TEWL and skin surface hydration. High TEWL and low hydration values are changes which are characteristic of a defective barrier function and are typical findings in atopic dermatitis (5, 6). The patient material in this study consisted of non-atopic, elderly patients with dry-appearing skin. Their TEWL values were in between those measured in the younger and the older control groups, respectively, whereas the hydration values did not differ significantly between the same groups. As a result of the therapy, the TEWL values decreased and approached the low values of the older control group. This suggests an underlying defect unlike that seen in atopic dermatitis. Additional measurements of the hygroscopicity and the water-retaining capacity may well have elicited more information and such studies are now under way.

In conclusion, the frequently diagnosed condition 'clinically dry skin' is apparently not always justified by measurements of the hydration alone but calls for further investigation of the structural and chemical factors leading to abnormal cohesion and water-binding capacity. Abnormal TEWL values may be an indication of such alterations.

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## MATERIALS AND METHODS