

CLINICAL REPORT

Skin Surface pH, Stratum Corneum Hydration, Trans-epidermal Water Loss and Skin Roughness Related to Atopic Eczema and Skin Dryness in a Population of Primary School Children

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Non-invasive investigations of skin morphology and function are standard tools to study the pathophysiology of several cutaneous disorders, yet they have not been used in population-based epidemiological studies. Here we examined skin surface pH, stratum corneum hydration, trans-epidermal water loss (TEWL) and skin roughness by profilometry in a study population comprising 377 primary school children (8–9 years old) as part of a multicentre survey on risk factors for allergic diseases in school children. Skin surface pH showed significant higher values ($p=0.029$) in the group with atopic eczema ($n=45$) compared with the group without atopic eczema; all other parameters did not differ significantly between children with and without atopic eczema. With increasing skin dryness there was a significant increase in pH values ($p=0.004$). Stratum corneum hydration showed a significant decrease with increasing dryness ($p<0.001$). Measurement of skin roughness also revealed a significant linear relationship with skin dryness ($p=0.02$). It is concluded that measurement of skin surface pH, corneometry and profilometry are useful non-invasive techniques to objectively assess skin dryness in epidemiological studies regarding atopic skin disease. *Key words: skin morphology; epidemiological study; MIRIAM (Multicentre International Study for Risk Assessment of Indoor and Outdoor-Air Pollution on Allergy and Eczema Morbidity); non-invasive technologies; cutaneous properties.*

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A variety of non-invasive technologies has been developed to investigate and assess physical properties of the skin and provide objective functional estimates of pathological skin conditions. The instrumental evaluation of skin morphology and functions, e.g. trans-epidermal water loss (TEWL), stratum corneum hydration, skin surface pH, skin roughness and sebum content are established techniques. They are often used in controlled studies to define objective differences between patients with and without atopic eczema or to estimate the effects of environmental influences on these parameters (1–18). Data are based mainly on investigations in adults, rarely in children (1, 9, 15, 16). In 1998 a population-based epidemiological study was carried out in 377 primary school children with emphasis on stigmata of

atopic constitution (19) and on the prevalence of atopic eczema (20). It was the objective of the present study to determine the practicability of these non-invasive techniques and to assess quantitatively changes of biophysical conditions related to atopic eczema and dryness of the skin in this epidemiological setting.

MATERIAL AND METHODS

Study population

This study was part of a German multicentre survey on risk factors for allergic diseases in primary school children (MIRIAM, Multicentre International Study for Risk Assessment of Indoor and Outdoor-Air Pollution on Allergy and Eczema Morbidity). The study population, evaluated between March and May 1998, comprised 377 children (178 males, 199 females). These children were examined for the first time in summer 1996, when they were 6 years old (mean age 6.4 ± 0.31 years): 64 (5.5%) out of 1173 German children who participated in the study 1996 had a doctor-diagnosed atopic eczema at the day of examination, 148 did not have an atopic eczema at this day, but had a history of doctor-diagnosed eczema. In 1998, these 2 groups were asked to participate in another detailed study, together with 300 matched controls. 73% did participate, i.e. 45 out of 64 of the first group, 119 out of 148 of the second group and 213 out of 300 of the third group. Studies were performed following the medical school entrance examination at the local health departments. Written parental consent and the permission of the ethics committee were obtained before the study.

Atopic eczema and skin dryness

The children received a full, standardized dermatological examination. The diagnosis of atopic eczema according to the criteria of Hanifin & Rajka (21) and the assessment of skin dryness were made on a clinical basis by an experienced physician of the Department of Dermatology and Allergy Biederstein, Technical University, Munich. Independent of the clinical examination, 2 other physicians measured the physiological parameters of the skin. Skin dryness was graded from 0 to 3 points according to a previously described study (14): absent (0)=no symptoms of dry skin; mild (1)=ashiness, but no discernible flakes; moderate (2)=small to medium flakes; severe (3)=large flakes and prominent "cracked glass pattern". Investigations with the different instruments were performed on non-inflamed skin.

Skin surface pH

Skin surface pH was measured with a pH meter (SKIN-pH-METER PH 900, Courage and Khazaka electronic GmbH, Cologne, Germany) with a flat glass electrode on the flexor side of the

forearm. The standard deviation of all measurements was ± 0.43 ($n=375$; mean=5.19).

Stratum corneum hydration

Measurements of stratum corneum hydration were performed on the flexor side of the forearm with a corneometer (CORNEOMETER CM 825, Courage and Khazaka electronic GmbH, Cologne, Germany) that registered the electrical capacitance of the skin surface as an indicator of stratum corneum hydration. This parameter depends on the high dielectric constant of water content relative to other skin components. The capacitance was expressed digitally in arbitrary units. The standard deviation of all measurements was ± 6.46 ($n=377$; mean=62.21).

TEWL

The TEWL was recorded on the flexor side of the forearm using an Evaporimeter (Evaporimeter EP-1, ServoMed, Stockholm, Sweden). The measurement was performed in a closed room with an ambient air temperature of about 22°C. The gold-plated probe protection cover without the screen and grid was used and held on the skin surface until stable TEWL was established. The standard deviation of all measurements was ± 2.16 ($n=377$; mean=3.30).

Measurement of skin roughness by profilometry

Replicas were taken from the skin with silicone rubber dental impression material (Permadyne Garant 2:1, ESPE, Seefeld, Germany). A slide frame (50×50 mm) was placed on the skin surface (volar forearm) in order to keep the semi-liquid material within a given space and to allow hardening. A thin layer of the impression material was applied to the surface with a commercially available "pistol" mixing the 2 components of the material without bubbles. The polymerized impression material was lifted from the skin after about 5 min. The orientation of the replica with regard to the arm axis was marked, and the replica was put in a plastic bag to avoid desiccation. Measurements were made within 24 h after application of the impression material.

A standard stylus profilometer (Hommeltester, Hommel-Werke, Villingen-Schwenningen, Germany) was used to assess the negative replicas. With this instrument, profiles of the skin's surface are obtained by tracing the surface on skin replica with a stylus instrument. As the stylus is moved across the replica's surface, its vertical motion is converted into electrical signs. Positive casts are not necessary, since the instrument can invert the profile. The scan length was 15 mm, the cut-off for filtering waviness profile 0.8 mm. For each test site we performed 10 scans in parallel at a distance of 1 mm. The data were recorded and processed electronically to yield the roughness parameter R_a , the mean arithmetic mean roughness value, and R_{max} , the maximum individual peak-to-valley-height. The standard deviation of all measurements for R_a was ± 2.28 ($n=372$; mean=15.49), for R_{max} ± 12.13 ($n=372$; mean=94.41).

Statistical analysis

If not mentioned otherwise, mean values \pm SD are given. For global differences of skin parameters related to atopic eczema the variance analysis was used. Student's *t*-test for independent samples was used for comparisons between the group of children. Linear regression techniques were performed to determine associations between grades of skin dryness and continuous outcomes of the skin physiology measurements. The α -level was set at 5% for a 2-sided test.

RESULTS

Atopic eczema was diagnosed in 45 (11.9%) of the children. 39.2% of the children without actually present eczema had a

Table I. Mean values \pm SD of different skin parameters related to atopic eczema in school children (* $p < 0.05$)

Parameter	Eczema	
	Present ($n=45$)	Absent ($n=327-332$)
Surface pH	5.32 \pm 0.43	5.12 \pm 0.43*
Stratum corneum hydration	61.40 \pm 7.15	62.29 \pm 6.34
TEWL (g/h.m ²)	3.22 \pm 1.1	3.32 \pm 2.27
Skin roughness R_a (μ m)	15.30 \pm 2.74	15.52 \pm 2.22
Skin roughness R_{max} (μ m)	93.69 \pm 14.65	94.48 \pm 11.77

history of doctor-diagnosed eczema. The skin surface pH was significantly higher ($p=0.029$) in the group with atopic eczema (5.32 \pm 0.43) than without atopic eczema at the time of examination (5.12 \pm 0.43). All other measured parameters did not differ significantly between the children of the 2 groups (Table I).

At the time of examination, dryness of the skin was diagnosed in 283 (75.1%) of the children. 178 (47.2%) showed mild dryness, 93 (24.7%) moderate and 12 (3.2%) severe dryness. Children with skin dryness grade 0, 1, 2 or 3 had a history of doctor-diagnosed eczema in 22.3%, 39.9%, 57.0% or 66.7%, respectively.

According to linear regression analysis there was a significant increase ($p=0.004$; $r=0.147$) in pH values in dependence on the skin dryness with a value of 5.12 \pm 0.45 in the group without skin dryness and a value of 5.4 \pm 0.35 in the group with severe skin dryness (Fig. 1). Stratum corneum hydration measured with the corneometer showed a decrease with severity of dryness ($p < 0.001$; $r=0.290$). A value of 64.43 \pm 6.3 was obtained in the group without skin dryness 62.67 \pm 6.47 in the group with mild skin dryness, 59.69 \pm 5.45 in the group with moderate skin dryness and 57.58 \pm 6.60 in

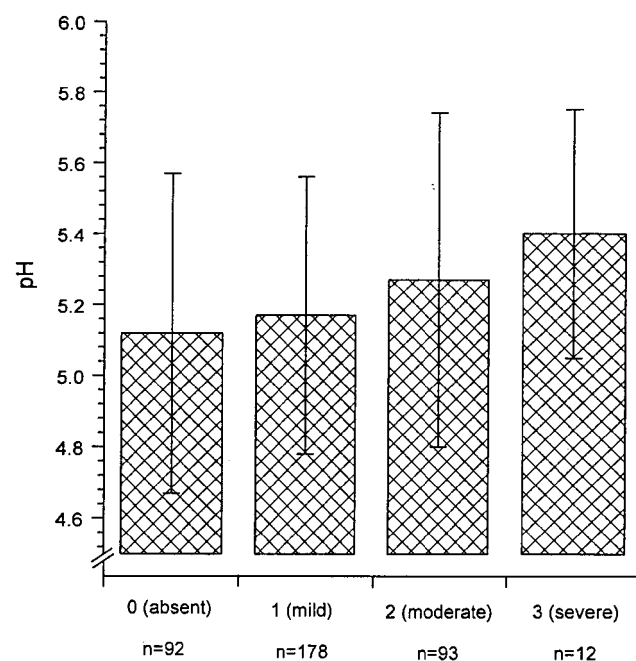


Fig. 1. Mean values \pm SD of skin surface pH related to dryness of the skin; $p=0.004$; $r=0.147$ (linear regression analysis).

the group with severe dryness. The TEWL did not differ significantly between the groups. Measurement of skin roughness (highest mean value R_{\max}) showed a significant linear association ($p=0.02$; $r=0.120$) with skin dryness: $91.08 \pm 12.84 \mu\text{m}$ in the group without skin dryness and $96.24 \pm 11.27 \mu\text{m}$ in the group with moderate skin dryness.

DISCUSSION

pH

The homeostasis of skin surface pH has been an essential part of the "acid mantle" concept created by Marchionini & Hausknecht (22). Its mean value ranges from 5.4 to 5.9 on the skin of the lower arm of healthy adult male Caucasians (23). The mean surface pH of small infants (aged 2 weeks to 16 months) is higher than in adults (16). In a study group of 303 8–9-year-old school children without eczema at the time of investigation and 6 months before a mean pH value of 5.18 was demonstrable at the volar forearm (24). Studies showed that several kinds of skin inflammation or a standardized trauma (tape stripping) can cause an increase in skin surface pH (25, 26). pH values of the volar forearm in children ($n=100$, mean age 4.66 years) affected by atopic eczema were 5.23 in uninvolved skin and 5.54 in involved skin (1). Both values were significantly higher than the value (4.86) of healthy skin in control subjects ($n=21$, mean age 5.75 years). Similarly, the pH values of uninvolved skin in children with eczema in our study population showed a shift towards alkalinity (5.32) compared with children without eczema (5.12; $p=0.029$). Dryness of the skin led also to an increase of pH values with significant differences in dependence on the clinical severity. It is tempting to speculate that the increase of the pH values reflects cutaneous irritation and may influence the bacterial flora of the skin (22), especially in patients with atopic eczema (27, 28).

Stratum corneum hydration

In most studies, the water content of the stratum corneum on normal-looking skin of adult patients with atopic eczema showed decreased values compared with controls and compared with dry, xerotic skin of elderly patients (2, 3). In children, only the involved skin of patients with atopic dermatitis had significantly lower values than uninvolved skin and healthy skin of control subjects (1). In addition, in our study, values obtained from clinically normal skin of children with eczema did not differ significantly from the values for children without eczema. In contrast, in adult patients with atopic eczema the stratum corneum in dry skin had a lower water content than that of clinically normal skin (4). In accordance with these results, in our study hydration of the stratum corneum was related to the dryness of the skin, with decreasing values with severity of dryness.

TEWL

In adult patients with atopic eczema, TEWL as a parameter of skin barrier function has been found to be increased, not only in eczematous skin lesions, but also in dry and clinically normal skin (2, 5–8, 29). In studies with smaller numbers of children similar results were obtained (1, 9). In our study

population, neither children with atopic eczema nor children with different grades of skin dryness showed abnormal values. Probably due to the short acclimatization period and possible air convection (30) the results did not reflect the disturbed barrier function in the present study population.

Skin roughness

Dry skin, defined as a rough, finely scaling, non-inflamed skin surface, in adult patients with atopic eczema showed significantly increased skin roughness parameters compared with controls (13). Also, clinically dry skin on the lateral surface of the lower leg compared with non-dry skin showed significantly higher numbers of peaks in the profile (14). In contrast, clinically normal skin in adult patients and children with atopic eczema did not differ from controls (10, 15). Similar to the results in adults, skin roughness increased with increasing skin dryness in children. The lower value in the highest dryness category could be due to the rather small number of subjects in this group.

Concerning pH, stratum corneum hydration and skin roughness, our results are in accordance with the published studies on dry skin. Furthermore, it is possible to objectively quantitate properties of inflamed and dry skin in large-scale studies, although the measurement of the TEWL might raise some problems. In conclusion, the use of most non-invasive techniques in assessing skin morphology and function is applicable to groups of selected patients and controls in population-based epidemiological studies.

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