Epidermal Hydration and Skin Mechanics

The Relationship between Electrical Capacitance and the Mechanical Properties of Human Skin In vivo

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The possible relationship between skin capacitance and the mechanical properties of the skin was studied using non-invasive techniques. Skin hydration was changed by soaking skin with tap water. Hydration of the skin increased the capacitance significantly ($p < 0.01$) and hysteresis (creeping phenomenon) ($p < 0.01$). The elasticity of the skin was reduced by hydration ($p < 0.01$). Capacitance was found to be a poor predictor of the mechanical properties of untreated skin; while increases in hysteresis (creeping phenomenon) and decreases in elasticity were significantly ($p < 0.0001$) related to changes in the capacitance of hydrated skin. *Key words: Rheology; Bioengineering; Emollients.*

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Moisturizers improve the subjective perception of the mechanical properties of human skin. After using a moisturizer the skin is often felt to be more supple and elastic. Previous studies have shown that application of a moisturizer increases the capacitance and hydration of the skin (1, 2, 3). Water can be regarded as the ultimate moisturizer, although its effects are short-lived. Hydration increases skin capacitance as well. The electrical capacitance of the epidermis is strongly correlated to the water content, although it may also be influenced by other polar substances contained in moisturizers. Capacitance is therefore not a specific measure of hydration.

Superficial hydration with plain tap water has been shown to affect the mechanical properties of human skin in vivo (4). Especially the hysteresis, representing the creeping phenomenon, is increased.

This study was undertaken in order to establish whether capacitance measurements are related to the mechanical properties of the skin.

MATERIALS AND METHODS

Studies were carried out in 17 healthy volunteers, 4 men and 13 women. Their median age was 46 (range 22–62 years). There was neither history of nor current skin disease among the volunteers.

The flexor side of the underarms was used exclusively in

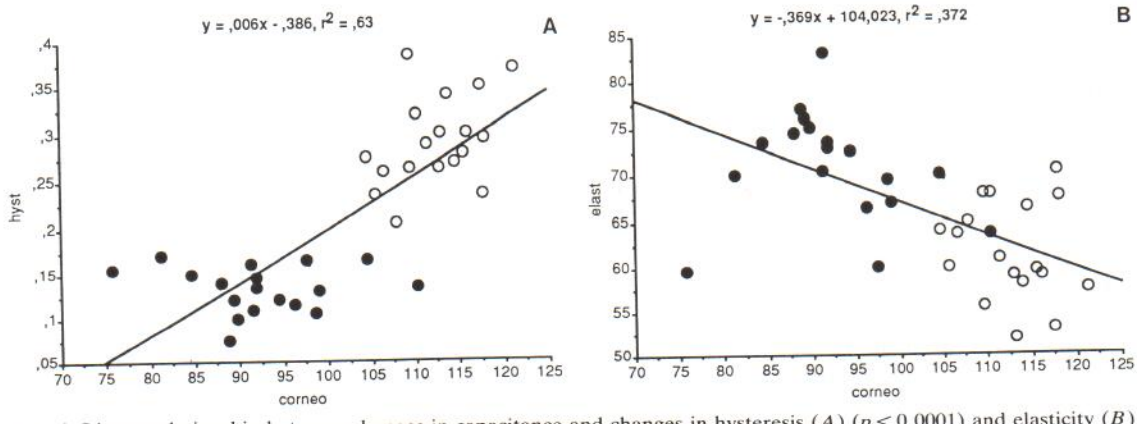

Fig. 1. Linear relationship between changes in capacitance and changes in hysteresis (*A*) ($p < 0.0001$) and elasticity (*B*) ($p < 0.0001$). ●, Values before hydration. hysteresis (*hyst*, ○ in (*A*)) measured in mm; elasticity (*elast*, ○ in (*B*)) measured in %; capacitance (*corneo*), measured in arbitrary units.

Table I. *Changes induced in the skin by hydration with tap water*

Parameter	Pre-hydration	Hydration	
		10 min	20 min
Capacitance (arbitrary units)	92.40	111.90*	
	92.60		113.10*
Hysteresis (mm)	0.14	0.28*	
	0.14		0.31*
Distensibility (mm)	1.52	1.55	
	1.40		1.53*
Elasticity (%)	69.60	61.60*	
	70.40		62.20*

Two pre-hydration values are given, one for each arm. The appropriate post-hydration values are lined up with pre-hydration values for comparison. * $p < 0.01$.

the study. A comparable area 5 cm distal to the elbow was studied. All measurements were repeated three times with the Corneometer® and twice with the Dermaflex®, and the means were used in subsequent calculations. In 9 persons, skin hydration was changed by applying paper towels soaked in tap water. The towels were applied for 10 or 20 min, under occlusion with cling foil (PVC) to reduce evaporation. The surface was wiped dry before any measurements were made.

The Corneometer CM 420® (5) measures the electrical capacitance of the skin surface. The capacitance is expressed in arbitrary units. The Dermaflex® (4) measures elevation of the skin in a sealed chamber during suction. The machine operates in repeated cycles, each cycle lasting 4 s and applying 0.3 Bar of suction. After six cycles, the following parameters are presented: hysteresis, reflecting the creeping phenomenon of the skin; distensibility, reflecting the maximum distention achieved; and elasticity, reflecting the ability of the skin to return to its original position after being stretched.

The Spearman test was used to compare changes in skin capacitance with changes in mechanical parameters, and the paired Wilcoxon test was used to compare pre-hydration and post-hydration values.

RESULTS

In untreated skin the capacitance was not significantly related to skin hysteresis ($r^2 = 0.091$), skin distensibility ($r^2 = 0.068$) or skin elasticity ($r^2 = 0.003$).

Hydration caused significant changes, as is evident from the values in Table I. Changes in hysteresis ($p < 0.0001$) and elasticity ($p < 0.0001$) were significantly correlated to changes in capacitance. See Fig. 1A, 1B. There was no correlation between skin distensibility and capacitance in the hydrated skin ($r^2 = 0.001$).

DISCUSSION

Previous studies have suggested that skin capacitance could be a predictor of the mechanical properties of skin in vivo. This study has shown that skin capacitance is not correlated to the mechanical properties of untreated skin. Changes in the capacitance are, however, significantly correlated to the changes in the mechanical properties of the skin following the application of water.

Two things are suggested by this. Firstly, although many factors play a role in determining the mechanical properties of the human skin, the hydration of the superficial epidermis seems to play a measurable part. Secondly, although capacitance does not in itself seem related to the mechanical properties of the skin, it can be used to monitor changes following increased skin hydration in the individual patient.

The effect of moisturizers on skin capacitance is limited however (3), suggesting that the mechanical changes induced are similarly limited. The subjective perception of what moisturizers do to the skin, may therefore be more dependent on changes in skin surface and friction (6).

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