

## Effects of Short-time Hydration on Skin Extensibility

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Vertical cutaneous extensibility was studied before and after 1, 2, 5 and 10 min hydration by application of tap water. After hydration, we noted an increase in all rheological parameters linked to elasticity whereas viscosity and hysteresis parameters were unmodified. These modifications took place from the first minute and increased thereafter. Men and women showed identical values prior to hydration. After hydration, an extensibility gain was noted only in the women, men's extensibility being unmodified. Studying rheological behaviour as a function of age, we showed similar modifications in younger and older groups, the extensibility gain being greater in the older group. Prior to hydration, the stratum corneum was extremely rigid and extensibility was comparable between men and women. Hydration, softening the horny layer, allows a rapid extensibility gain proportional to the reduced thickness of the dermis, especially in women and older subjects. **Key words:** *Stratum corneum; Elasticity.*

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Trials concerning the influence of hydration on rheological properties of the skin are multiple. They have been performed in many ways, using various measurement devices. Therefore, the interpretation of the results obtained is sometimes difficult, highly dependent on the hydration method, intensity and principle of the strain applied on the skin or location and on the area of skin tested. In this study we sought to evaluate this influence with one method of reference, the vertical extensibility measurement, choosing parameters appropriate to the study of the stratum corneum. We also wished to demonstrate the kinetics of the possible modifications, for the matter could depend on hydration duration and few data have been reported on short hydration time.

### MATERIALS AND METHODS

A total of 29 volunteers participated in the study. The population was divided into two sex groups, one consisting of 15 women and the other of 14 men, and two age groups, one consisting of 15 younger subjects (23–49 years) and one of 14 older subjects (60–93 years). All volunteers were Caucasians with no apparent signs of skin disease or therapy affecting the skin.

Measurements were carried out at a temperature of  $23 \pm 1^\circ\text{C}$ , and at a relative humidity of  $37 \pm 10\%$ . Subjects were accustomed to ambient conditions for 10 min prior to any measurement.

Corneous hydration was evaluated before any measurement using the 820 PC corneometer® of Courage & Khazaka (Köln, Germany), a device using an electrical capacitance determination as a reflection of water content of tissue. Three measurements were performed on each forearm, and the mean was used to define basal hydration state of the stratum corneum. In our experimental conditions, the coefficient of variability was determined at about 10%.

Measurements were performed on the flexor side of the forearms in four sites, two on each side of the median of the elbow-wrist line of each forearm. Measurements were performed on supine subjects, with arms extended and palms in supination.

Extensibility measurements were performed with the cutometer SEM 474® suction extensometer of Courage & Khazaka (Köln, Germany). Suction was applied on a 2-mm diameter skin surface, the suction probe acting as a guard ring to preclude outside skin involvement. The probe was fitted to a spring which ensured that it was applied to the skin at a constant pressure. Skin elongation was measured by an optical method using an infra-red diode, with an accuracy of 0.01 mm. The coefficient of variation of the device was previously evaluated at about 15% in our experimental conditions.

The time/strain mode was used with an elementary load cycle consisting of an instantaneous deformation by a 450 mBar strain, maintained for 3 s and then released and followed by a 2 s relaxation period. This elementary load cycle is illustrated in Fig. 1. This cycle was repeated three times successively, the calculations being determined only on the third cycle, to improve the reproducibility (1, 2).

The following main parameters were extracted from this elementary load cycle:

*U<sub>e</sub>* (the immediate extensibility) is the instantaneous deformation following application of the strain. It reflects the elastic properties of the skin.

*U<sub>v</sub>* is the delayed, slower deformation corresponding to intracutaneous movements of the viscous type.

*U<sub>r</sub>* (the immediate retraction) elastic recovery parallel to *U<sub>e</sub>* occurring instantaneously when the strain is released.

The *U<sub>r</sub>/U<sub>e</sub>* ratio, called "biological elasticity", represents the ability of the skin to recover immediately after deformation. This parameter is not linked to skin thickness.

*R* is the residual deformation at the end of the 2 s relaxation period; it may reflect the hysteresis phenomenon (1).

Five sets of measurements were performed, and each measurement was repeated three times to improve the reproducibility of the results, the means of each parameter being recorded. These three successive measurements were performed on areas some millimeters apart, to prevent errors secondary to cutaneous preconditioning (1, 2).

Dry skin measurements were performed on 5 mm distant points at the median of each forearm. Hydrated skin measurements were performed in the four areas previously described, after application of tap water-saturated cotton wool to the whole area.

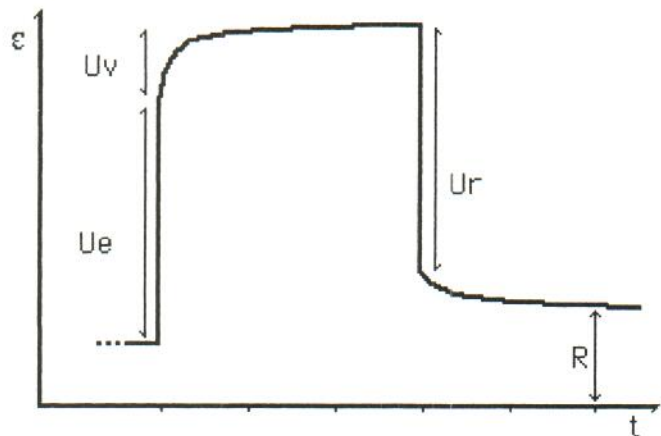


Fig. 1. Elementary load cycle.

Table I. Global results

Mean in  $\mu\text{m}$ . ns: non-significant; +:  $p < .05$ ; ++:  $p < .001$ ; +++:  $p < .0001$ .

	0 mn		1 mn		2 mn		5 mn		10 mn	
Ue	249	(9.9)	271	(.65) +9% ++	268	(.64) +8% ++	278	(.66) +12% +++	282	(.71) +14% +++
Uv	32.4	(1.8)	34.1	ns	32.7	ns	34.1	ns	31.4	ns
Ur	229	(11.5)	256	(.6) +12% +++	253	(.63) +11% +++	264	(.65) +15% +++	263	(.73) +15% +++
Ue/Ur	.91%	(.015)	.936%	(.007) +3% ++	.938%	(.007) +3% ++	.94%	(.007) +3% +++	.921%	(.008) +1% ns
R	67	(.61)	73.9	ns	71.8	ns	69.4	ns	72.5	ns

Cotton wool was applied for 1, 2, 5 or 10 min and then removed, the skin being dried by patting without wiping; measurements were then performed.

The choice of one of the four areas for testing of hydration duration was randomized.

Statistical analysis was performed with Statview II, using Student's *t*-test for paired data to test each extensibility parameter as a function of hydration duration. Data were then studied by an unpaired *t*-test as a function of age and sex. Hygrometry, temperature and basal corneous hydration (corneometry) were studied using a regression method.

An  $\alpha$  risk less than or equal to 5% was considered statistically significant. The  $\beta$  risk was lower than 10% unless mentioned below.

## RESULTS

The main results are shown in Tables I-IV. In the total population (Table I) increases in immediate extensibility (Ue + 14%), immediate retraction (Ur + 15%) and biological elasticity (Ur/Ue + 3%) were observed.

Results varied as a function of sex: before hydration, men and women were not statistically different; after hydration, men (Fig. 2) showed no significant modification in Ue or Ur, but an increase of Ur/Ue, whereas women (Fig. 3) showed increased Ue (+21%) and Ur (+24%) values in comparison with the values before hydration (Table I).

The differences between younger and older subjects are presented in Table II. Before any hydration, we observed a decrease in all the three elasticity parameters with ageing (Ue:

16%; Ur: 25%; Ur/Ue: 11%), and an increased value of R (+105%). After the hydration process elastic differences progressively decreased between age groups, even becoming non-significant for Ue.

On studying corneous hydration, we did not note any correlation basal corneometric results and behaviour during hydration; neither was any difference in behaviour seen when studying groups at high and low ambient temperature or relative humidity (results not shown).

All modifications were observed from the first minute and increased further at other times of hydration.

## DISCUSSION

Recorded differences mainly consisted of an increase in extensibility; however, this global modification masked the heterogeneity of the modification between men and women. Prior to any hydration, the two groups did not show any differences. In the group of men, short hydration did not obviously modify the two extensibility parameters, whereas in the group of women, there was a parallel increase of Ue and Ur. This increase was noted from the first minute and became progressively more pronounced.

Other data studied (temperature, ambient humidity, corneometry) did not seem to influence Ue or Ur in our experimental conditions.

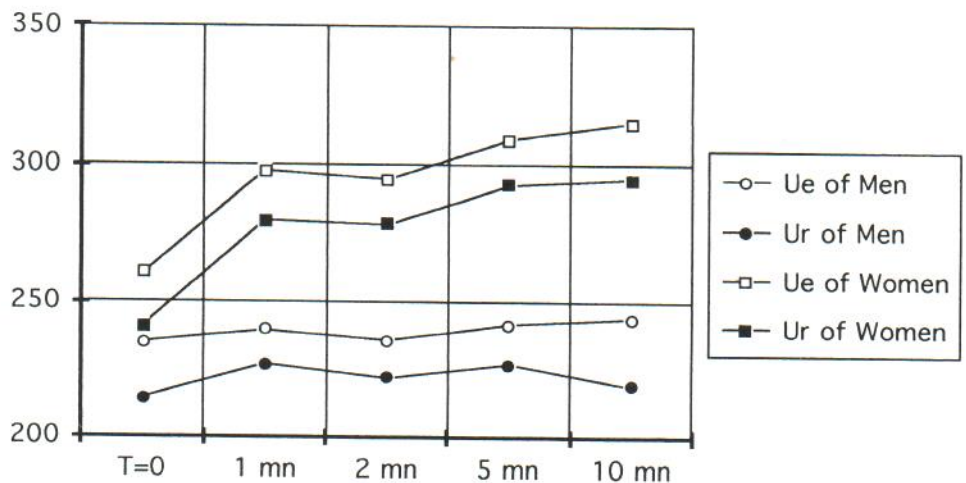


Fig. 2. Extensibility of the group of men vs group of women in  $\mu\text{m}$ .

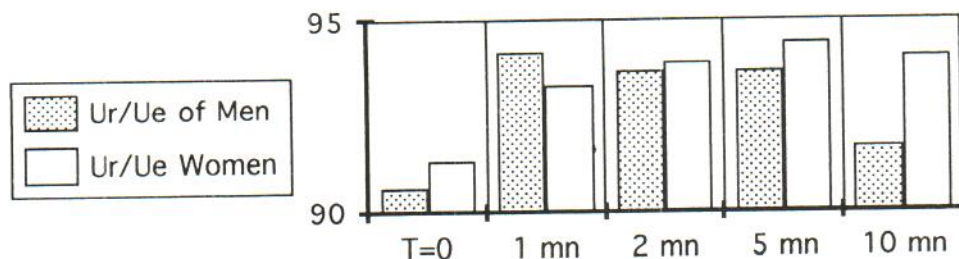


Fig. 3. Biological elasticity of the group of men vs group of women in %.

We have eliminated the possibility of our results being distorted by a "creeping" of the skin which could falsely increase extensibility. We have previously observed this phenomenon only with larger probes and we overcame the problem by using an additional adhesive. In this study, the guard ring of the 2 mm probe (3 cm diameter) was adequate to prevent this error.

Ur/Ue, the "biological elasticity", was increased; we can explain this feature by the equality of absolute gain of extensibility in Ue and Ur. Thus, the skin recovery level is exactly the same as before hydration but, extensibility being increased, the ratio Ur/Ue is artificially increased.

An interesting feature is the increase in Ur/Ue in the group of men, despite the lack of a statistically significant increase in Ue and Ur. This may correspond to a non-statistically perceptible modification of these two parameters, Ur/Ue being a more sensitive parameter to detect effects of hydration. The same feature is observed in Table II, where Ur/Ue between young and older groups remains obviously very different during all hydration times, whereas Ue and Ur, at first different, tend to become statistically identical.

Neither Uv, the delayed deformation, nor R, the residual deformation, shows any modification after hydration and they seem to be correlated with none of the recorded parameters.

There is apparent disagreement in the literature about the effects of corneous hydration on the mechanical properties of the skin. These differences are attributable to various factors, i.e. measuring device, experimental procedure, particularly strain intensity, and the choice of the rheological parameters and their interpretation (1).

Christensen (3) used a tonometer to move the skin parallel to its surface, and records a "hysteresis loop". However, the

parameter he considers to quantify the deformation can be assimilated to an elasticity module. The method can be criticized because of the absence of a guard ring to define the area of skin explored. These results, showing an elasticity module decrease and through it an extensibility increase, closely agree with ours. Another point of agreement is the rapidity of action of tap water, Christensen obtaining results in 30 s.

Using an indirect method, Potts & Buras (4) demonstrated an alteration in the speed of propagation by a 5 min superficial hydration of mechanical wave propagation, which was inversely proportional to corneous water content. This result likewise corresponds to an elasticity module decrease.

Using a torsional device (Twistometer®) but a strain mode similar to ours, De Rigal & Lévêque (5) demonstrated an extensibility increase (Ue) of 15, 30 and 120 min hydrated skin. The maximal increase effect was observed during the first 30 min of hydration. These results are quite consistent with our data, despite the difference in measuring device principle.

In 1990, Jemec & Serup reported two experiments with a suction extensometer (6, 7), Dermaflex® (Cortex technology, Hadsund, Denmark). The first of these experiments showed an increase in hysteresis of more than 100% for 10 and 20 min hydration, extensibility being barely modified (<+4%). The other experiment, with the same duration of hydration, also revealed an increase in hysteresis, but no extensibility variation.

One explanation could derive from differences between technical conditions: whereas strain application modes were identical (instantaneous vertical extensibility by suction), intensity and strain duration and diameters of tested skin (10 mm diameter for Dermaflex®) were different. The structures of the skin mobilised were probably different, particularly in depth.

Furthermore, according to Manschot & Brakee's (8) theory of formalisation, hysteresis is linked to dermal structures, probably related to the orientation of collagen fibres (1), and all the preceding authors (3-7) agree that the site of action of such short skin hydration is the stratum corneum and, less probably, the deeper layers of epidermis. In our study hysteresis was not modified, strain being concerned with superficial layers, whereas hysteresis was involved in the experimentation of Jemec & Serup. Our results, although apparently discordant, are in fact complementary.

Sex-linked differences are not mentioned by any of the other authors. The only data we have found concerning comparison of extensibility between men and women agree with our data concerning the similarity of behavior of the skin in terms of measured extensibility and intrinsic extensibility (i.e.

Table II. Comparisons of younger and older groups

Means - younger vs older, in  $\mu\text{m}$ . % of variation with ageing; ns: non significant; +:  $p < .05$ ; ++:  $p < .001$ ; +++:  $p < .0001$ .

	0 mn		1 mn	
Ue	272	228	292	252
	-16.3%	+		ns
Uv	32	33	35	33
		ns		ns
Ur	264	197	288	227
	-25.4%	++	-21%	+
Ur/Ue	.966	.858	.98	.895
	-11%	+++	-9%	+++
R	44	89	39	81
	+105%	+++	+118%	+++

related to skin thickness (9, 10). These features appear surprising because, according to literature results (10, 11), the dermal thickness of women is less than that of men by about 16%. At the epidermal level there does not seem to be any difference between men and women (12).

We suggest that skin extensibility is the combined result of at least two components: the dermis and the corneous layer (other epidermal structures being considered as rheologically non-existent). Agache et al. (13, 14) showed that their Young's module (elasticity module) was about  $10^5$  N/m<sup>-2</sup> for the dermis and  $10^9$  N/m<sup>-2</sup> for the stratum corneum respectively. Therefore, despite its relative thinness, the stratum corneum is able to alter extensibility of total skin significantly, considerably increasing skin rigidity.

We hypothesize that it is because of this restrictive rigidity that the extensibility of men and women is similar, masking differences in dermal thickness of the dry skin. During the hydration process, we suppose Young's module decreases at the level of the stratum corneum, approaching Young's dermal module; this means a softening of the stratum corneum, to the same order as dermal rigidity, thus allowing the difference in dermal thickness to express itself by a difference in extensibility.

In order to study the influence of age, we divided our population into two groups, younger and older subjects, opting for a critical age of 60 years, because for different authors this age corresponds both to the age when the thickness of the skin starts to decrease (10, 15), and when intrinsic skin extensibility is modified (9, 10). The initial differences we report between these two groups are consistent with results found by earlier authors (9, 10, 16).

The hydration process leads to  $U_e$ ,  $U_r$  and  $U_r/U_e$  increases in both groups, but comparatively greater in the older group, and seems to attenuate age-related differences, even suppressing them in terms of statistics for  $U_e$ .

Lavker (17) demonstrated that age does not alter the thickness or the architecture of the stratum corneum. Here again, we can seek to explain these data by a difference at the stratum corneum layer between younger and older groups.

As for the men/women differences, we suggest that the difference in dermal thickness (10, 11, 17) of older people can explain this phenomenon. Suppression of the limiting barrier represented by the stratum corneum by the hydration process allows the expression of underlying dermal differences.

The influence of temperature and hydrometry on elasticity are well known (4, 14). In our study, we wished to minimise these effects to emphasize the roles of other factors by accustoming the volunteers to a thermal and hydrometrically controlled atmosphere. In our experimental conditions we did not find any significant modification prior to or after hydration.

The corneometer uses a measurement of capacitance to evaluate the water content of superficial layers (19). The principle is recognised as an adequate method (6, 18). A previous study, performed in the same topographic sites and under the same experimental conditions, recorded corneometric results before and after hydration. For all hydration times we ob-

tained a similar result: the initial mean value of 70 was increased to 112 immediately after hydration (arbitrary units).

However, prior to any hydration, this corneometric result was independent of sex, age (consistent with 18), temperature or hydrometry. We did not show any relationship between the initial "dryness" and the amount of extensibility gain. This result agrees with those of Jemec & Serup (7), and we conclude that corneometry cannot predict rheological behaviour.

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