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Seasonal Variations in Skin Temperature, Skin pH, Evaporative Water Loss and Skin Surface Lipid Values on Human Skin¹⁾

TAKASHI ABE, JUNKO MAYUZUMI, NORIKO KIKUCHI, and SEIICHI ARAI

*Cosmetics Laboratory, Kanebo Ltd.*²⁾

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The seasonal variations of skin temperature, skin pH, evaporative water loss (EWL) and skin surface lipid values were determined in the forearm skin of 24 healthy Japanese adults at four different periods over one year.

The results provide new information on the changing systemic patterns of the four skin parameters. It was found that EWL, total lipid and squalene values in July were approximately 2–3 times those in January. On the other hand, the skin pH was significantly lower in July than in January, April or October. However, the extents of change of skin pH and cholesterol values were less than those of EWL, squalene and total lipid values on the basis of statistical analysis.

Furthermore, significant correlations were observed between skin temperature and EWL, total lipid and squalene values. On the other hand, significant inverse correlations were found between skin pH and skin temperature and EWL values. On the basis of these results, the dependence of sebaceous lipids on skin temperature and the contribution of eccrine sweating to the skin pH are discussed.

Keywords—seasonal variations; skin temperature; skin pH; evaporative water loss; skin surface lipids; squalene; cholesterol; sebaceous lipids—skin temperature; eccrine sweating—acidic skin pH

The human skin surface is in a constant state of flux due to its interaction with seasonal external factors such as the temperature, relative humidity, *etc.*³⁾ Protection of the skin surface against undesirable consequences of seasonal changes is an important function of cosmetics or external preparations.⁴⁾ In this regard, it is important to investigate the patterns of human skin parameters and their relationships under actual seasonal changes.

In previous studies,⁵⁾ skin surface lipids and evaporative water loss (EWL) were shown to be important parameters for the barrier and hydroregulatory systems. Although the acidity of the skin surface (*i.e.* its buffering system) is assumed to depend on several parameters, such as skin pH, EWL, skin surface lipids, skin temperature, *etc.*,⁶⁾ statistical relationships between these parameters are still uncertain. There have been several reports on seasonal

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2) Location: 3-28, Kotobuki-5-chome, Odawara, Kanagawa.

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variations in skin temperature,^{3b)} skin pH,^{3c)} and EWL^{3c)} in normal Japanese adults. However, few comparable data are available on the changing patterns of these parameters in the same skin site of the same subjects.

Therefore, in this study the seasonal changes in skin temperature, skin pH, EWL and skin surface lipids were determined using twenty-four healthy volunteers at four different periods over one year.

This paper describes novel quantitative studies on the changing systemic patterns of four important skin parameters in the forearm skin. Furthermore, the dependence of the amount of sebaceous lipids on skin temperature and the contribution of eccrine sweating to the acidity of the skin surface, *etc.*, are discussed on the basis of a statistical consideration of these parameters.

Experimental

Subjects—The twenty-four healthy adult subjects were of both sexes (12 females and 12 males) ranging in age from 19 to 55 years. Most subjects took a bath on the day before measurements.

Measurement Period and Conditions—Skin surface temperature, skin pH, EWL and skin surface lipid values were measured during the following periods: October 18—20, 1976; January 11—13, 1977; April 12—14, 1977 and July 11—13, 1977. These measurements were usually carried out before noon in a non air-conditioned room. The subjects rested for half an hour before measurements. For reference, the average temperature (°) and relative humidity (%) in the room at each period were recorded. They were as follows: 21.6°, 57.4% (October); 15.1°, 35.1% (January); 19.9°, 65.4% (April) and 27.5°, 70.5% (July).

Skin Temperature Measurements—Skin temperature was measured with an infrared thermometer (Mikron® 25 ABS, Mikron Instrument Co., New Jersey) on the right forearm skin.

Skin pH Measurements—A pH meter (Beckman® SS-2) with a flat surface electrode (model 39182) was used to measure the skin pH. The electrode combines glass and reference electrodes into a single probe for pH measurement on paper, culture media, skin surface, *etc.* The meter was calibrated before use on each subject, using standards at pH 4.0 and 7.0. The electrode was dipped in ion exchange fluid⁷⁾ (pH 6.08—6.25) and applied to the right forearm skin surface. The measurement was taken after the pH reading stabilized. The final pH value used was the mean of three measurements.

EWL Measurements—EWL was measured electrohygrometrically as described previously.⁵⁾ Measurements were performed on the right forearm skin (in an area of 7 cm²) and the data were expressed in mg/cm²/hr.

Skin Surface Lipid Measurements—Casual total lipids were extracted with acetone by the cup method (12.56 cm² in area) from the left forearm skin. The collection procedure was as described previously.⁵⁾ Total lipids were measured gravimetrically. Squalene was chosen as a marker of sebaceous lipids and cholesterol as a marker of epidermal lipids.⁵⁾ Free and total cholesterol and squalene were measured by gas chromatography.⁵⁾

Results

Seasonal Variations in Skin Temperature, Skin pH and EWL Values

The results are summarized in Table I. The skin temperature was highest in July and lowest in January. The difference in skin temperature between July and January was significant ($p < 0.001$). Thus, the skin temperature in the forearm skin was graded in the following order: July > April = October > January.

On the other hand, it appeared that the skin pH value was significantly lower in July than in the other three months ($p < 0.01$ in each case). The pH values in the forearm skin were in the following order: January = April = October > July.

The maximum EWL occurred in July and the minimum in January. The EWL value in July was 1.8 times ($p < 0.001$) that in January. The order of EWL value in the forearm skin was as follows: July > April = October > January.

Seasonal Variations in Lipid Values

Table II shows the results of seasonal changes in total lipid, free and total cholesterol and squalene values.

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TABLE I. Seasonal Variations in Skin Temperature, Skin pH and EWL Values

Skin parameter	1976		1977	
	October	January	April	July
Skin temperature ^{a)} (°C)	31.8±1.7 ^{d)} (18) ^{e)}	29.1±2.8 (23)	31.8±1.5 (23)	33.0±1.3 (23)
Skin pH ^{b)}	5.1±0.5 (21)	5.0±0.4 (23)	5.1±0.5 (23)	4.6±0.5 (24)
EWL ^{c)} (mg/cm ² /hr)	0.220±0.042 (23)	0.176±0.036 (23)	0.240±0.042 (20)	0.309±0.060 (24)

Statistical examination was performed for each combination of two values in a row. $p > 0.05$: regarded as not significant (N.S.).

a) July-January ($p < 0.001$), January-April ($p < 0.001$), January-October ($p < 0.01$), July-April ($p < 0.01$), July-October ($p < 0.02$).

b) July-April ($p < 0.01$), July-January ($p < 0.01$), July-October ($p < 0.01$).

c) July-January ($p < 0.001$), July-October ($p < 0.001$), July-April ($p < 0.001$), January-April ($p < 0.001$), January-October ($p < 0.001$).

d) Mean ± S.D.

e) Number of subjects.

The total lipid value in July was 2.2 times ($p < 0.001$) that in January. The values in the forearm skin were in the following order: July > October = April > January.

Similarly, the squalene value in July was 3 times ($p < 0.001$) that in January. The order of squalene value was as follows: July = April = October > January.

The free cholesterol value in July was approximately 1.3 times ($p < 0.01$) that in January. The values were in the following order: July = October > April = January.

The total cholesterol value in July was 1.7 times ($p < 0.01$) that in April. The order of total cholesterol value was as follows: July = October > January = April.

TABLE II. Seasonal Variations in Skin Surface Lipid Values

Skin parameter	1976		1977	
	October	January	April	July
Total lipid ^{a)} (μg/cm ²)	65.00±32.91 ^{e)} (22) ^{f)}	47.36±24.24 (23)	68.87±37.57 (23)	103.91±44.62 (23)
Squalene ^{b)} (μg/cm ²)	0.52±0.55 (22)	0.23±0.21 (23)	0.56±0.26 (19)	0.71±0.55 (22)
Free cholesterol ^{c)} (μg/cm ²)	1.43±0.51 (22)	1.27±0.37 (23)	1.29±0.48 (23)	1.61±0.27 (23)
Total cholesterol ^{d)} (μg/cm ²)	1.98±1.09 (19)	1.78±0.79 (20)	1.61±1.10 (22)	2.75±1.58 (24)

Statistical examination was performed for each combination of two values in a row. $p > 0.05$: regarded as not significant (N.S.).

a) July-January ($p < 0.001$), July-October ($p < 0.01$), July-April ($p < 0.01$), January-April ($p < 0.05$).

b) January-July ($p < 0.001$), January-April ($p < 0.001$), January-October ($p < 0.05$).

c) July-January ($p < 0.01$), July-April ($p < 0.01$).

d) July-April ($p < 0.01$), July-January ($p < 0.02$).

e) Mean ± S.D.

f) Number of subjects.

Relationships between Skin Parameters

The skin temperature has been reported to be a major factor controlling the amount of EWL^{3a),8)} or total lipids.⁹⁾ Therefore, the relationships between skin temperature (x) and the other two parameters (y) were examined statistically. The correlation coefficients and regression equations are given in Table III.

Significant positive correlations were found between skin temperature and EWL ($p < 0.01$), squalene ($p < 0.01$) and total lipids ($p < 0.05$). These regression lines are shown in

8) F.A.J. Thiele and K.G. van Senden, *J. Invest. Dermatol.*, **47**, 11 (1966).

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Fig. 1. However, there was no significant correlation between skin temperature and cholesterol values.

EWL, skin surface lipids and skin temperature are considered to be factors affecting the skin pH.⁶⁾ To investigate these relationships in more detail, statistical analyses were performed of the relationships between skin pH (y) and EWL (x), skin surface lipids (x) and skin

TABLE III. Correlation Coefficients between Skin Temperature (x) and The Other Skin Parameters (y)

x ————— y	r	n	p value	Regression equation
S.T. ^{a)} ————— EWL	0.4811	84	$p < 0.01$	$y = 0.0135x - 0.1883$
S.T. ————— Total lipids	0.2388	86	$p < 0.05$	$y = 4.1666x - 58.8749$
S.T. ————— Squalene	0.3148	80	$p < 0.01$	$y = 0.0564x - 1.2825$
S.T. ————— Free cholesterol	0.2033	86	$p > 0.05$	
S.T. ————— Total cholesterol	0.0960	79	$p > 0.10$	

r : correlation coefficient, n : number of subjects.

$p > 0.05$: regarded as not significant (N.S.).

a) Skin temperature.

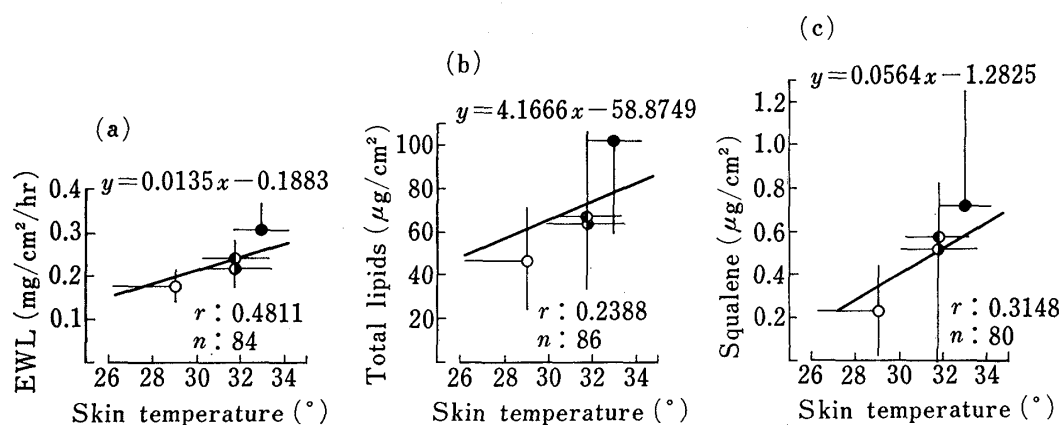


Fig. 1. Correlations between Skin Temperature and EWL (a), Total Lipid (b) and Squalene Values (c)

○ : mean ± S.D. in January.

● : mean ± S.D. in April.

● : mean ± S.D. in October.

● : mean ± S.D. in July.

TABLE IV. Correlation Coefficients between Skin pH (y) and the Other Skin Parameters (x)

x ————— y	r	n	p value	Regression equation
EWL ————— Skin pH	-0.2364	89	$p < 0.05$	$y = -1.6937x + 5.3252$
Total lipids ————— Skin pH	-0.1899	92	$p > 0.05$	
Squalene ————— Skin pH	-0.1901	84	$p > 0.05$	
Free cholesterol ————— Skin pH	-0.1728	90	$p > 0.05$	
Total cholesterol ————— Skin pH	-0.1123	83	$p > 0.10$	
Skin temperature ————— Skin pH	-0.2827	86	$p < 0.01$	$y = -0.0636x + 6.9080$

r : correlation coefficient.

n : number of subjects.

$p > 0.05$: regarded as not significant (N.S.).

temperature (x). The results are shown in Table IV. Inverse correlations were found between skin pH and skin temperature ($p < 0.01$) and EWL ($p < 0.05$). The regression lines are shown in Fig. 2. In contrast, there was no significant correlation between skin pH and skin surface lipid values.

Discussion

The Changing Patterns of The Skin Parameters

One of the most important aspects of skin care cosmetics is the retention or regulation of the water and fat contents of the skin surface in relation to seasonal changes,⁴⁾ for example, protection against dry ichthyotic skin during the winter.⁴⁾ Therefore, information on the degree and nature of changes in EWL and skin surface lipid values, *etc.*, may serve as a basis for the optimum use and formulation of cosmetics. In this regard, comparison of the values in the winter and summer is of interest.

It was found that the EWL value in the winter decreased to about 60 percent of that in the summer and 70–80 percent of that in the spring or autumn (Table I). EWL is generally defined as transepidermal water loss (TWL) below the threshold of eccrine sweating (below a skin temperature of 34°).¹⁰⁾ In July, the skin temperature was $33.0 \pm 1.3^\circ$ (Table I), which suggests that sweating contributed partially to the EWL value in July.

Concerning skin surface lipids, Gloor *et al.*¹¹⁾ reported seasonal variations in the amount of total lipids on the back skin of Caucasian subjects. However, less is known about seasonal changes in the chemical constituents of skin surface lipids. As shown in Table II, the amount of total lipids in the winter was approximately 50 percent of that in the summer. It was found that the amount of squalene in the winter decreased to about 30 percent of that in the summer. Furthermore, it is noteworthy that a greater seasonal change was found in the amount of sebaceous lipids (*i.e.* squalene value) than in that of epidermal lipids (*i.e.* cholesterol value) as shown in Table II.

On the other hand, the skin pH value decreased in the summer compared with that in the winter. However, the extents of changes of skin pH and cholesterol values were less than those of EWL, squalene and total lipid values, as shown in Tables I and II.

As mentioned above, the present results provide new information on the changing systemic patterns of four skin parameters in the forearm skin.

The Dependence of EWL and Skin Surface Lipids on Skin Temperature

Figure 1a) indicates that water loss *via* transepidermal or eccrine sweat glands is stimulated by rising skin temperature. It was also found that the amount of total lipids or squalene increases with rising skin temperature, as illustrated in Fig. 1b) and 1c). Furthermore, it is noteworthy that skin temperature affected sebaceous lipids (*i.e.* squalene value) more than epidermal lipids (*i.e.* cholesterol value), as shown in Table III.

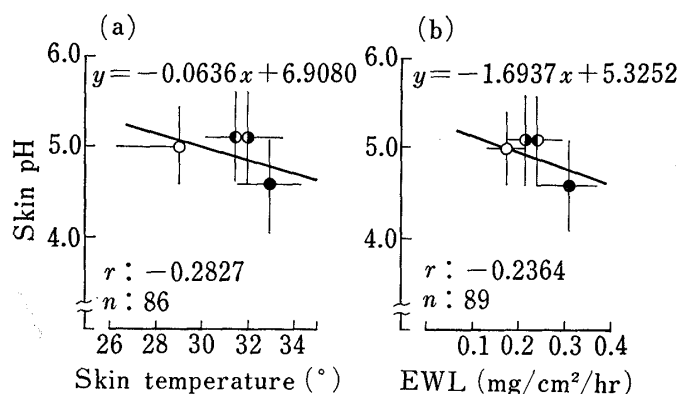


Fig. 2. Inverse Correlations between Skin pH and Skin Temperature (a) and EWL Values (b)

- : mean \pm S.D. in January.
- ◐ : mean \pm S.D. in April.
- : mean \pm S.D. in October.
- : mean \pm S.D. in July.

10) G. Rajka, *Arch. Derm. Forsch.*, **251**, 111 (1974).

11) M. Gloor, J. Handke, Ch. Baumann, and H.C. Friederich, *Derm. Mschr.*, **161**, 996 (1975).

The Acidity of The Skin Surface

It is known that there is a relation between the acidity of the skin surface and the bacteriological and chemical resistance of the skin. Although water-soluble components in the sweat, horny layer and sebum are considered to contribute to the surface acidity,⁶⁾ little is known about the statistical relationships among these factors. As shown in Fig. 2, inverse correlations were found between skin pH and EWL and skin temperature. Thus, it appears that the lowering of skin pH is mainly due to sweat secretion stimulated by increasing skin temperature. Further detailed studies on the relation between chemical components such as lactic acid and amino acids in the sweat or horny layer and the skin pH are desirable.

In conclusion, the present systematic study on the seasonal variations of four important skin parameters may provide a basis for the optimum use and formulation of cosmetics, such as emollient preparations against dry skin during the winter.

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