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Time Series Trend of the Water Content on the Different Human Anatomical Sites Using Single Frequency-Susceptance Measuring Method

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Abstract— **The water content of Stratum Corneum (SC) has been reported to vary depending on the anatomical sites [1-7]. Each anatomical site respectively have their own proper water content of SC which reflects the status of skin health. Also, this anatomical region can be divided into relatively wet and dry area according to the degree of the water content of SC [8]. In this study, we tried to investigate time series trend of the water content. Skin hydration was measured on the different anatomical sites for the first four seconds using single frequency-susceptance measuring method [10]. It is observed that the slope of the graph for the water content during the first four seconds is different depending on the anatomical sites and can be divided into two groups by the degree of the slope. These grouped areas are well aligned with traditional wet and dry area. It is presumed that the difference of the gradient could be caused by the thickness of SC. In this study, the different gradient of time series trend of water content of SC on different anatomical sites was found, and it could be conveniently used to distinguish the wet and dry area of the skin.**

I. INTRODUCTION

THE skin is consisted of epidermis, dermis and subcutis layer from the direction of outside and takes 20% of total body weight in case of adult. Specially, epidermis is divided into 7 layers and the outset layer is stratum corneum (SC) among them.

The function of skin is a barrier to the outside world, protecting the body's organs and tissues from damage and infection and to prevent loss of water and other body fluids, and helps keep body temperature in control. The most important factor to carry out this function is the water content of SC because skin dehydration can make the skin a less effective barrier to irritants and infection. Normally, the skin maintains its own water balance. The epidermis prevents water loss to the outside. However, if the epidermis, especially, SC is damaged or unhealthy, water loss increases and the water balance is lost. Therefore, the most important factor to determine the status of the skin health is the water content, that is, the water content of SC.

The water content of SC has been reported to be different with human anatomical sites. Measuring area should be exactly known to determine the status of the skin health because each anatomical site has their own proper water content of SC respectively. Some commercial products which measure water content of the skin use separate index to show the level of user's skin hydration, where skin areas are divided into two groups - wet area and dry area [9]. So we tried to investigate the level of the water content from different anatomical sites using susceptance measuring method and see the difference of time series trend of the water content between wet and dry area.

II. METHOD

A. Single Frequency Suceptance Measuring Methods

Among the various electrical ways to assess the degree of skin hydration [11], single frequency method was used which was designed by Oslo group in this study [10]. This method uses single-low frequency and measures susceptance, e.g. AC component of admittance. For this method to be carried out properly, the electrode area should be kept relatively small (e.g. below 0.5 cm^2) and the measuring frequency should be kept low (e.g. below 100 Hz). Moreover, a three-electrode system should be used, with the reference electrode close to the measuring electrode. In this case, susceptance should be measured to avoid influence from sweat duct. This method has been known as a very accurate one compared to other method [12]. In this case, time series trend of the water content reflected variation of susceptance by time.

B. The Experiment

Several experimental reports were used for our reference [13-15]. The most important thing in this experiment was to maintain constant humidity and temperature. In this experiment, Constant temperature (20±2°C) and humidity (50±5%) were maintained in a controlled chamber.

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Volunteers were forced not to wash and apply any treatment to their measuring area from at least 12 hours before the measurement on. A subject's measuring area was wiped with alcohol cotton and then exposed to the air in the controlled chamber for 30 minutes before experiment.

The water content was measured for 4 seconds and repeated 5 times on the same measuring spot. The measurement points were forehead, cheek, forearm extensor, hand dorsum, forearm flexor, and hand metacarpus. The electrode was cleaned after each measurement.

This study includes 10 healthy volunteers aged from 21 to 40(Mean: 27.3, S.D.:6.0); 2 men and 8 women.

III. Results & Discussion

The time series trends of the water content, that is, variance of susceptance by time on several anatomical sites were acquired from 10 volunteers as below in figure 1. Each graph was drawn by connecting averaged values of 10 intra-individual data at intervals of each 0.1 second.

In the figure 1, all of inflections were presented within 1 sec. and these graphs showed different increasing slope depending on regional difference from 1 sec. to 4 sec.. In the beginning, that is, from 0 sec. to 1 sec., gradients of all measuring area were not clearly distinctive, but the difference of these gradients became bigger at each measuring sites as time goes on. While the gradients of forehead, cheek and hand metacarpus were gradually increasing after 1 sec., the gradients of hand dorsum, forearm extensor, and forearm flexor showed the tendency of relatively slight increasing or flat. Table 1 shows several gradients at each time interval. The gradients of each time interval could be clearly distinctive after 2 sec. as shown in Table. 1. Therefore these graphs could be classified by difference of those gradients from 2 sec. to 4 sec. because the gradients of forehead, cheek, and hand metacarpus (H.M.) showed relatively more increasing trends compared to ones of hand dorsum (H.D.), forearm flexor (F.F.) and forearm extensor (F.E.) from 2 sec. to 4 sec. as shown in fig. 1 and table 1.

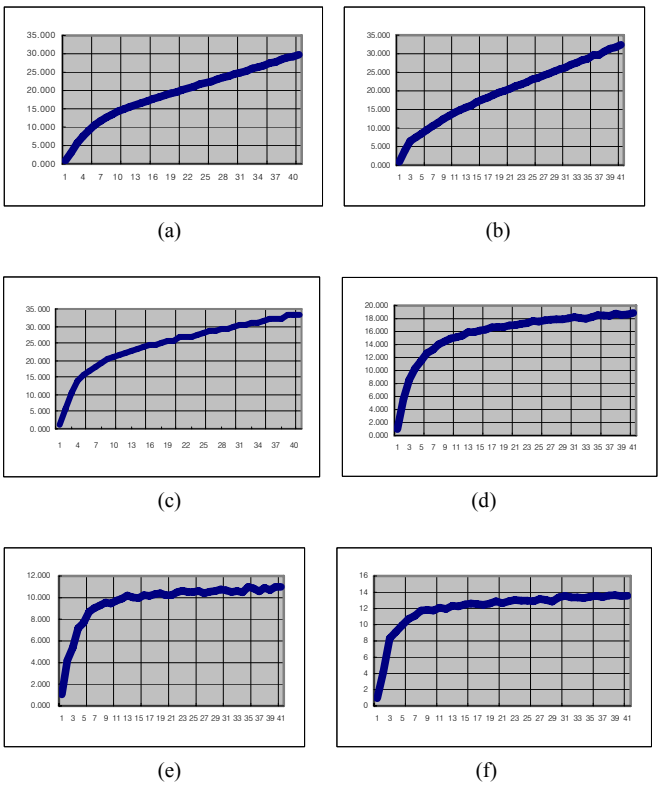

Fig. 1. Time series trend of the skin hydration on several anatomical sites; (a) forehead, (b) cheek, (c) forearm extensor, (d) hand dorsum, (e) forearm flexor, (f) hand metacarpus.

TABLE I
GRADIENTS ON SEPARATE ANATOMICAL SITES

Slope\site	forehead	cheek	H.M.	H.D.	F.E.	F.F.
t1-t0	1.253	1.092	1.221	0.949	0.785	0.890
t2-t1	0.482	0.832	0.364	0.114	0.020	0.018
t4-t2	0.539	0.770	0.214	0.058	-0.056	-0.003

t1-t0 : slope from 0 sec. to 1 sec., t2-t1 : slope from 1 sec. to 2 sec., t4-t2 : slope from 2 sec. to 4 sec..

Regional differences of water content in SC have been reported from many researches [1-7]. On the basis of these results, human anatomical sites can be grouped into relatively high hydration (wet) area and low hydration (dry) area. Forehead and hand metacarpus are classified as wet area and forearm extensor, forearm flexor and hand dorsum are dry [8].

Some commercial products measuring water content provide separate decision table to determine the level of user's water content by two groups [9]. In this product, forehead, cheek, T-zone, eyelid, temple, the corner of mouth, neck, back, and upper body part were classified as wet area group and arm, elbow, hand, leg were classified as dry area group on the contrary.

These results were very similar to ours so it was our observation that we could classify the wet and dry area based on the time series trends of the water content, that is, susceptance - different gradients from 1 sec. to 4 sec.

The thickness of stratum corneum in the skin has been known as the most critical factor in determining the level of water content. It was known that the thicker stratum corneum gives the higher (wetter) degree of water content in many cases [16]. It is also reported that there's a positive correlation between the thickness of stratum corneum and that of total skin which includes epidermis, dermis and subcutaneous layer.

According to a paper which measured the skin thickness of the various part of the body among Korean using ultra sound device, the thickness of the skin is in the order of cheek, hand metacarpus, forearm extensor, forearm flexor and dorsum [17]. This order is well aligned with the level of water content as observed in the time series trend above.

IV. CONCLUSION

In this study, the time series trends of the water content on the different anatomical sites were investigated. As a result, these trends could be grouped into gradually increasing gradient group and relatively slightly increasing or flat gradient group. These groups were similar to traditional classification of human body by water content grade and moreover the thickness of stratum corneum.

This is known that the degree of water content is proportional to the thickness of SC on measuring area. Therefore, the thicker stratum corneum gives the higher (wetter) degree of water content and the more increasing gradient of graph in time series trend on different anatomical sites. These results will help to distinguish relatively wet area from dry area automatically by system. Moreover the thickness of stratum corneum could be evaluated by measuring the gradient of time series trend of susceptance.

More study remains to be carried out, however, to clarify the mechanism.

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REFERENCES

[1] C.W.Blichmann and J.Serup, "Assessment of skin moisture, measurement of electrical conductance, capacitance and transepidermal water loss,"Acta. Derm. Venereol(Stockh), Vol.68, pp. 284-290, 1998

[2] D. C. Slater, "Instrumental methods for asscssing skin moisturization,," Cosmet. Toiletries, Vol. 102, pp.103-109, 1987

[3] D. Black, A. Del Pozo, J. M. Lagarde, Y. Gall, "Seasonal variability in the biophysical properties of stratum corneum from different anatomical sites," Skin Res. Technol. Vol. 6, pp.70-76, 2000

[4] T. Yamamoto, Y. Yamamoto, "Analysis for the change of skin a.O. impedance." Med. Biol. Eng. Comput. Vol. 15, pp.219, 1977

[5] A. O. Barel, P. Clarys, B. Wessels, A. de Romsee, "Non-invasive electrical measurements for evaluating the water content of the horny layer: comparison between capacitance and conductance measurements," in: Prediction of Percutaneous Penetration: Methods, Measurements, Modeling Scott, R.C., Guy, R.H., Hadgraft, J., and Boode, H.E., (eds), IBC Technical Services Ltd, London, Vol. 2, pp. 46, 1991

[6] J. W. Fluhr, H. Dickel, O. Kuss et al, "Impact of anatomical location on barrier recovery, surface pH and stratum cornuem hydration after acute barrier disruption." Br. J. Dermatol. Vol. 146, pp.770-776, 2002

[7] Z. Ya Xian, T. Suetake, H. Tagami, "Number of cell layers of the stratum corneum in normal skin relationship to the anatomical location on the body, age, sex and physical parameters." Arch. Dermatol. Res. Vol. 291, pp. 555-559, 1999

[8] Marie Loden, Dry Skin and Moisturizers: Chemistry and Function, Second Edition (Dermatology: Clinical & Basic Science), CRC press, pp.453, 2005

[9] Information and Operating Instructions for the Multi Probe Adapter MPA and its probes, CK electronics GmbH, Mathias-Bruggen-Str. 91

[10] O.,G., Martinsen, S., Grimnes, "On Using Single Frequency Electrical Measurements For Skin Hydration Assessment,"Innov. Techn. Biol. Med., Vol. 19, no. 5, pp. 395-399, 1998

[11] Severre Grimnes, Orjan Grottem Martinsen, *Bioimpedance and Bioelectricity Basics*, Academic Press, 2000, pp.294~296

[12] O.,G., Martinsen, S., Grimnes, "Measurement of the effect of topical liposome preparations by low frequency electrical susceptance,"Innov. Techn. Biol. Med. Vol. 17, no. 3

[13] T. Agner, J. Serup, "Comparison of Two Electrical Methods for Measurement of Skin Hydration. An Experimental Study on Irritant Patch Test Reactions,"Bioeng. Skin, Vol. 4, pp. 263,269, 1988

[14] D. Van Neste, "Comparative Study of Normal and Rough Human Skin Hydration in vivo: Evaluation with Four Different Instruments," J. of Dermatol. Sci., Vol. 2, pp. 119-124, 1991

[15] Boyce M. Morrison, Diana D. Scala, "Comparison of Instrumental Measurements of Skin Hydration,"J. Toxicol.-Cut.& Ocular Toxicol., Vol. 15, No. 4, pp. 305-314, 1996

[16] J. Serup, Gregor B.E. Jemec, Gary L. Grove, Handbook of Non-Invasive Methods and the Skin; Second Edition, CRC press, chap. 4, pp. 27-31, 2006

[17] Hyeon Ju Jung, Do Won Kim, Sang Lip Chung, Tae Hun Kim, "A Study on the skin Thickness of Koreans by Untrasound,"Kor. J. Dermatol. Vol. 28(2), pp. 121-129, 1990