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"Relationship Between Scalp Barrier Function and Transepidermal Water Loss"

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Abstract

The purpose of this study was to investigate the relationship between scalp barrier function and Transepidermal Water Loss (TEWL). Thirty Asian participants with itchy, dandruff, greasy scalp and two or more problems (referred to as compound problems) were screened by questionnaires. The healthy and problematic scalp areas were photographed using a non-invasive scalp image analyzer, and the TEWL value of the test areas was measured using a VaPoMeter. Measurements showed that itchy, dandruff and compound problematic scalp areas are the core factors affecting scalp health, this brings possible directions in formulation development. Meanwhile, when evaluating scalp barrier function and scalp health through TEWL, itchy, dandruff and compound problematic scalp areas were found preferred as test areas.

Key words: scalp problems, scalp transdermal water loss (TEWL), scalp barrier function, scalp care

1. Introduction

The scalp, as a part of the skin, is mainly composed of keratinocytes, intercellular lipids and sebaceous membranes [1]. It is characterized by significant anatomical and physiological differences from other parts of the skin, and these differences directly affect its barrier function, microbial environment, and disease susceptibility. Damage to the scalp barrier will result in penetration of various substances from the outside into the internal environment and the loss of substances from the internal environment to the outside, resulting in the skin being susceptible to various external stimuli such as itching, dryness, infections, and various types of dermatitis, which can in turn cause hair loss [2,3]. Chinese residents commonly suffer from scalp health issues, with 83% of the interviewees facing scalp problems, of which 51.25% of the interviewees had hair loss problems, 46.26% of the respondents had scalp itching problems, and 41.74% of the respondents had greasy hair problems [4].

Skin Barrier Function is mainly maintained by Stratum Corneum (SC). Studies confirmed that TEWL measurements can be used to assess skin barrier function [5,6]. Differences in scalp TEWL with respect to before and after cosmetic application, as well as with respect to gender, age, and anatomical site in healthy individuals, have been studied [7-11]. However, the

relationship between scalp barrier function and the TEWL has not been substantively explored. Current mainstream TEWL measurements include the open probe method, closed probe method, contactless techniques (e.g., infrared thermography), and impedance-based indirect assessment. Closed probe method is usually applied to minimize the influence towards the scalp [7-11].

The aim of this study was to investigate the relationship between healthy and problematic scalp areas through TEWL, and to reveal the possible correlation between the two and their mechanisms through experimental data. A clear understanding of how scalp barrier function affects TEWL can help develop more effective scalp care products and treatment programs to improve scalp health.

2. Materials and Methods

I. Test equipment

Skin transdermal water loss meter (VaPoMeter), scalp image analyzer

II. Basic principles of human testing

The human efficacy evaluation test in this paper adhered to the ethical principles of the international Declaration of Helsinki, which required participants to sign an informed consent form, which explained the nature of the study, its purpose and the potential risks of participating in the study, and emphasized the voluntary nature of participation in the test, and that participants could withdraw from the study at any time for any reason. All participants were allowed to ask questions about the test and were given full consideration before signing. All informed consent signatures were made prior to the start of the study. The investigator took necessary medical precautions to maximize the protection of the participants during the trial. Necessary product safety evaluations were completed and passed prior to the conduct of the cosmetic human efficacy evaluation trial.

III. Situation of the participants

A total of 30 Asian participants (non-pregnant and lactating women) with itchy, dandruff, greasy scalp and compound problems were screened in this test through questionnaires and investigators assessments. There were 6 males and 24 females with a mean age of 34.7±7.2 years. Participants were able to read and understand all parts of the informed consent form and signed it voluntarily; they did not have severe systemic, immunodeficiency, or autoimmune diseases; they did not have skin treatments, cosmetic treatments, or other tests that could affect the results at the test areas; they did not have active allergic diseases; they did not use hormonal medications or immunosuppressive drugs in the last month; they did not have a high sensitivity level; and they were not currently or in the last three months undergoing the test. No other clinical test on the subject areas at present or in the last three months.

IV. Test Procedure

The investigators explained the test to the participants and signed an informed consent form. Participants were asked to disperse their hair in a relaxed state and to sit still for at least 30 minutes in a test room with a temperature of 21±1°C and a relative humidity of 50%±10%. Then test equipment was used to measure the TEWL values of the problematic and healthy areas on the scalp of the same participant and to capture the images corresponding to these areas.

V. Data processing

The data in each group were first analyzed descriptively to calculate the mean, standard deviation, median, maximum, and minimum of the TEWL values of the problematic and healthy areas. Then the normality Shapiro-Wilk test was examined for each group of data.

Analysis of variance: if the data conformed to normal distribution, Levene's test or Welch's t-test was used, otherwise Mann-Whitney U test was used.

Correlation analysis: the Shapiro-Wilk test (α=0.05) was performed on the two columns of data. Pearson's correlation coefficient could be used if the data were normally distributed; otherwise, Spearman's correlation coefficient was used.

3. Results

1.1. Descriptive statistics

Table 1. Descriptive statistics of raw data

Scalp symptoms	N	Minimum	Maximum	Mean	Standard deviation	Normal-ity test*
Healthy Areas	30	4.6	7.0	6.243	0.5600	0.068
Itchy head	23	7.1	11.5	8.930	1.0372	0.838
Dandruff	28	7.8	12.8	9.454	1.0919	0.061
Oily scalp	30	4.9	7.3	6.080	0.5081	0.400
Compound problematic scalp areas**	30	8.1	14.6	9.563	1.5788	< 0.001

Note1: *. Normality test Sig. value > 0.050 indicates that the data obeys normal distribution, Levene's test or Welch's t-test is used, otherwise Mann-Whitney U test is used. **. Compound problematic scalp areas are scalp areas with two or more problems.

1.2. Analysis of variance and correlation

Table 2. Analysis of variance and correlation

Healthy scalp area			
Problem Scalp Areas	**Coefficient of Cor-relation（r）**	**Sig.（two-tailed）**	**Significance (*p*) ***
Itchy head	0.668**	< 0.001	< 0.001
Dandruff	0.633**	< 0.001	< 0.001
Oily scalp	0.414	0.069	0.982
Compound problem-atic scalp areas	0.896**	< 0.001	< 0.001

Note 2: * When $p < 0.050$ indicates that there is a significant difference between healthy and problematic scalp areas on this indicator. **. At the 0.01 level (two-tailed), the correlation is significant.

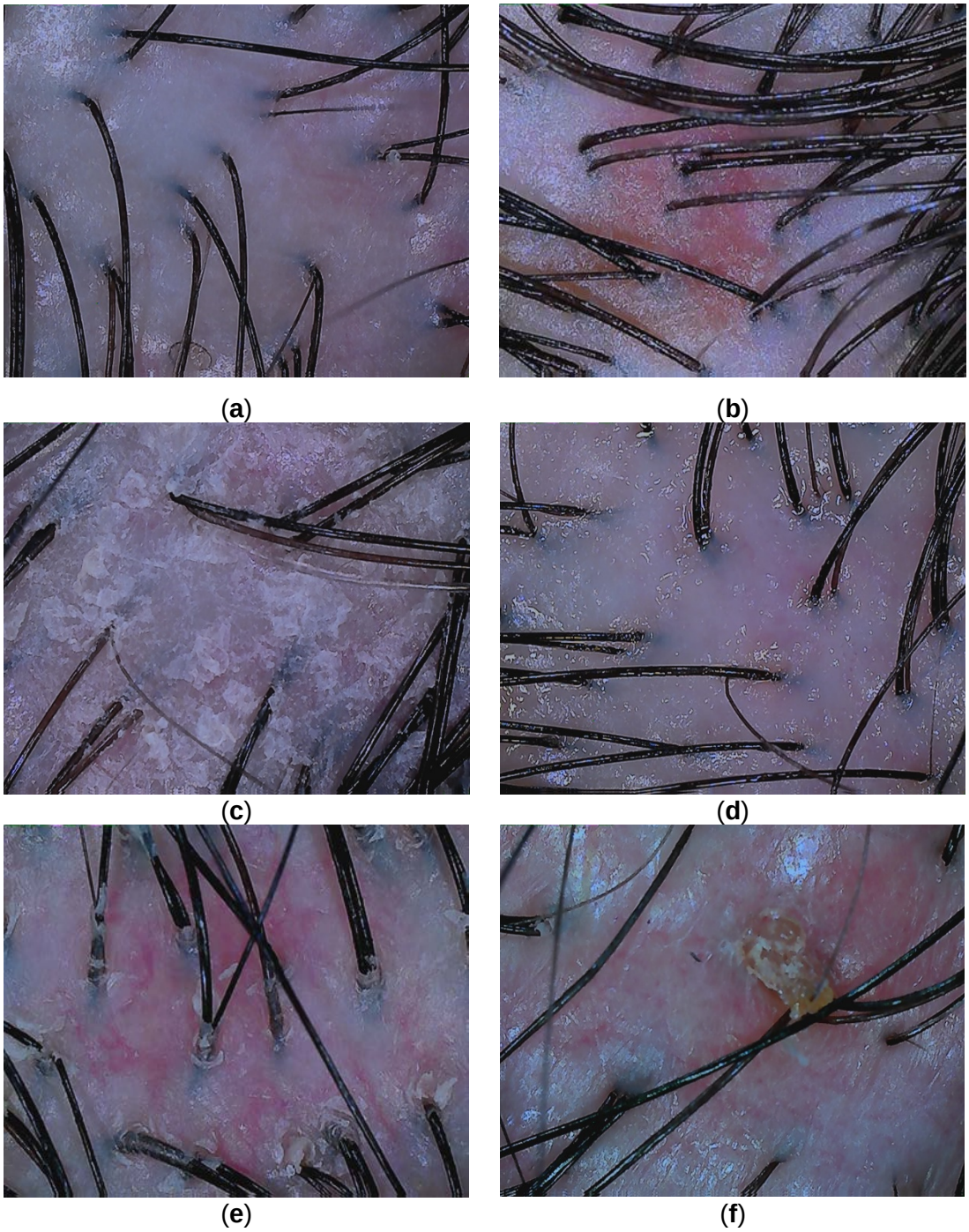

Figure 1. Images of healthy *versus* problematic scalp areas for selected participants : (a) Healthy scalp area; (b) Itchy head; (c) Dandruff; (d) Greasy scalp; (e, f) Compound problems

4. Discussion

The descriptive statistical characteristics showed that the mean value of the scores for the healthy areas (N=30) was 6.24 (SD=0.56), with a low degree of dispersion, indicating that the indicators of the healthy areas were relatively stable and significantly better than the other problematic areas. Higher scores for itchy head (N=23, mean 8.93, SD=1.04), dandruff (N=28, mean 9.45, SD=1.09), and compound problematic scalp areas (N=30, mean 9.56, SD=1.58) indicated that these symptoms were generally more severe and have greater

individual differences. According to the results of the test of variance, there were high significant differences in itchy head (p<0.001), dandruff (p<0.001) and compound problematic scalp areas (p<0.001), indicating that these symptoms significantly affected the scalp health scores. Scalp greasiness (p = 0.982) was not statistically different from the healthy areas, indicating that the scalp greasiness symptom itself has a weak effect on the scalp barrier. According to the results of the correlation analysis, healthy areas were strongly and positively correlated with itchy head (r=0.668, p<0.001), dandruff (r=0.633, p<0.001), and compound problematic areas (r=0.896, p<0.001), suggesting that these symptoms are strongly associated with deterioration of overall scalp health. In contrast, scalp greasiness (r = 0.414, p = 0.069) did not pass the test of significance, which probably due to the fact that the greasy film covers the surface of the scalp and blocks some of the water loss to the outside, resulting in a non-significant change in the value.

Participants with full healthy scalp have not been included in the study, and the TEWL values for those with a full healthy scalp may differ from those having scalp problems on certain areas. Our current study was limited and had an uneven sample size. Subsequent plans are to expand the sample size to improve the results reliability. The correlation analysis only reflects the association and needs to be combined with experimental design to further validate the causal mechanism.

Overall, this study reveals different types of scalp problems and their statistical relationships with healthy areas, providing data support for potential clinical treatments. Follow-up studies are needed to optimize the sample structure and to explore the mechanisms of the significant problems (e.g., “dandruff” and “compound problematic scalp areas”). There is still a large gap in data on scalp barrier function. We are planning to extend the scalp barrier function study through multi-omics approach, including genomics, epigenomics, transcriptomics, proteomics, metabolomics, and single-cell genomics.

5. Conclusion

This test measured, compared and analyzed TEWL values of normal and problematic scalp areas of 30 Asian participants with itchy, dandruff, greasy scalp and compound problems. It was found that itchy, dandruff and compound problematic areas were significantly negatively correlated and differentiated from the healthy scalp, this gives directions in future formula development. In particular, the compound problematic area (r=0.896) was highly linked to the healthy scalp, which may reflect systemic scalp problems. Scalp greasiness was not significantly associated with healthy areas and may need to be further analyzed in combination with other indicators (e.g., sebum secretion). In other words, itchy scalp, dandruff and complex problems are the core factors affecting scalp health, which suggested to prioritize in future formulation development. If need to evaluate the scalp barrier function or scalp health, itchy scalp, dandruff and compound problematic scalp areas are suggested to as evaluation test areas.

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