Variation of Skin Surface pH, Sebum Content and Stratum Corneum Hydration with Age and Gender in a Large Chinese Population

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Key Words
Age differences • Stratum corneum hydration • Skin surface pH • Sebum

Abstract
Background and Objectives: Evidence suggests the importance of skin biophysical properties in predicting diseases and in developing appropriate skin care. The results to date of studies on skin surface pH, stratum corneum (SC) hydration and sebum content in both genders and at various ages have been inconclusive, which was in part due to small sample size. Additionally, little is known about the skin physical properties of Asian, especially Chinese, subjects. In the present study, we assess the difference in skin surface pH, sebum content and SC hydration at various ages and in both genders in a large Chinese population without skin diseases.

Methods: 713 subjects (328 males and 385 females) aged 0.5–94 years were enrolled in this study. The subjects were divided by age into 5 groups, i.e., 0–12, 13–35, 36–50, 51–70 and over 70 years old. A multifunctional skin physiology monitor was used to measure SC hydration, skin surface pH and sebum content on both the forehead and the forearms.

Results: In males, the highest sebum content was found on the forearm and the forehead in the age groups 13–35 (61.91 ± 6.12 μg/cm²) and 51–70 years (7.54 ± 2.55 μg/cm²). The forehead sebum content was higher in males aged 13–70 years than in age-matched females; the sebum content on the forehead in both males and females was higher than that on the forearm. Skin surface pH on the forehead of both males and females over the age of 70 years was higher than that in younger groups. SC hydration on the forehead in both males and females was lower above the age of 70, and the one in males aged 13–35 was higher than that in females (43.99 ± 1.88 vs. 36.38 ± 1.67 AU, p < 0.01). SC hydration on the forehead in both males and females did not significantly differ from that on the forearm. Conclusions: In a large Chinese cohort, the skin surface pH, sebum content and SC hydration vary with age, gender and body site.

Introduction
Much attention has been paid to skin biophysical properties, such as skin surface pH, stratum corneum (SC) hydration, sebum content and epidermal permeabil-

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Subjects and Methods

Subjects
A total of 713 volunteers, 328 males and 385 females aged 0.5–94 years, were enrolled in this study (Table 1). All subjects had no systemic or skin disorders which could influence skin surface pH, hydration and sebum content at the study sites. According to their developmental stage, the subjects were divided into 5 age groups, i.e., 0–12 years old (prepuberty group), 13–35 (young group), 36–50 (middle age), 51–70 (old group) and over 70 years (older). No skin care products were applied to the measured sites 24 h prior to the measurement being taken, and the measured sites were not washed with soaps or surfactants for at least 12 h prior to the study.

Measurements
All measurements were performed by dermatologists. Surface sebum content, SC hydration and skin surface pH were measured on the forehead and the forearm (flexor site) with respective probes (Sebum Cassette, Corneometer CM825 and pH 905) attached to a Courage & Khazaka MPA5 system [36, 37]. All subjects rested for at least 30 min at 22–24 °C, at a relative humidity of 45–55%, prior to measurement. This work was performed between February and May (spring time) at the Dalian Skin Disease Hospital, which is at a latitude of 38°43' to 40°10' north. The study protocol was approved by the Human Research Committee of Dalian Skin Disease Hospital, The People’s Republic of China.

Statistics
Graph Pad Prism 4 software was used for all statistical analyses. Notably, repeated-measures ANOVA could not be performed in this study, since the measurements in each group were not from the same individual, and the groups differed both in size and subject age [38]. Instead, a one-way ANOVA analysis, with Tukey correction, was used to determine significant differences, when 3 or more groups were compared, while an unpaired t test with Welch’s correction was used for comparisons between 2 groups. Data were expressed as means ± SEM.

Table 1. Characteristic of subjects

<table>
<thead>
<tr>
<th>Age group</th>
<th>0–12</th>
<th>13–35</th>
<th>36–50</th>
<th>51–70</th>
<th>over 70</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>128</td>
<td>85</td>
<td>60</td>
<td>31</td>
<td>24</td>
<td>328</td>
</tr>
<tr>
<td>Females</td>
<td>142</td>
<td>102</td>
<td>82</td>
<td>28</td>
<td>31</td>
<td>385</td>
</tr>
<tr>
<td>Total</td>
<td>270</td>
<td>187</td>
<td>142</td>
<td>59</td>
<td>55</td>
<td>713</td>
</tr>
</tbody>
</table>

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Results

Sebum Content Varies with Age, Gender and Body Sites

We first assessed the sebum content on a sebum-enriched site, the forehead, and a sebum-impoverished site, the forearm, in both males and females at various ages. In females aged 13–70 years, the sebum content on both the forehead and the forearm was significantly higher than that in females aged 0–12 years or over the age of 70 (fig. 1a, b). The sebum content on the forehead in males aged 0–12 years was significantly lower than that of males aged 13–70 years and over the age of 70 (fig. 1c); that on the forearm was significantly higher in males aged 13–70 than in those aged 0–12 (fig. 1d). There was no significant difference in sebum content on the forearm in males between the groups aged 0–12 and over 70 years. Overall, males tended to have a higher sebum content than females. The sebum content on the forehead of males aged over 13 years was significantly higher than that in females of comparable age (fig. 2a). Additionally, the sebum content on the forehead of males aged 13–35 years was also significantly higher than that in females of the same age (fig. 2a). Yet, changes in sebum content showed a comparable maximum with a peak at around the age of 40 years in females and 50 years in males (fig. 3a, b), and accordingly, the sebum content declined earlier in females than in males.

Skin Surface pH Varies with Age and Gender, but Not Body Site

Previous studies from our group have demonstrated that skin surface pH increases after the age of 50 [36]. In the present study, a higher skin surface pH also occurred in older age groups (fig. 4). In females, skin surface pH on the forehead was significantly lower at the age of 0–12 than that in older age groups (fig. 4a). Yet, skin surface pH on the forearms of females did not differ among the age groups (fig. 4b). In males, the highest skin surface pH on both the forehead and the forearm was found in the group aged over 70 (fig. 4c, d); there were no differences among males aged 0–12, 13–35, 36–50 and 51–70 years. Skin surface pH on the forehead of females aged 13–70 and the forearm of those aged 0–12, 36–50 and 51–70 was significantly higher than that in age-matched males (fig. 2b). The skin surface pH in females aged 13–35 was higher on the forehead than on the forearm (5.71 ± 0.066 vs. 5.40 ± 0.060, p < 0.001). In other age groups, there were no differences in skin surface pH between the forehead and forearm in either males or females. Overall, there was a positive linear correlation between skin surface pH and age (fig. 5a, b).
Fig. 2. Comparison of sebum content (a), pH (b) and SC hydration (c) between males and females. The number of subjects in each group is detailed in table 1.

Fig. 3. Changes in sebum content with age in females and males. a On the forearm. b On the forehead.
SC Hydration Significantly Varies with Age

As seen in figure 6a, SC hydration on the forehead in females aged over 70 years was significantly lower than that in females under the age of 70 except in the group aged 13–35. However, there was no significant difference in SC hydration on the forearm in females among all age groups (fig. 6b). In contrast to females, SC hydration on the forearm in males aged 13–70 was significantly higher than that in the age group over 70 (fig. 6d). And SC hydration on the forearm in males aged 0–12 was significantly lower than that of those aged 36–50 (fig. 6d). SC hydration on the forehead in males aged over 70 was also signifi-
Significantly lower than that in groups aged 13–35 and 36–50 years (fig. 6c). There were no differences in SC hydration between the forehead and the forearm in males. SC hydration on the forehead was higher in males aged 13–35 than that in females (fig. 2c). The changes in SC hydration over the lifetime also show typical curves, with the peak at around the age of 40–50 years in both females and males on both the forehead and the forearm (fig. 7a, b).

Previous studies have demonstrated that sebum is a major source for glycerol, which, in turn, regulates SC hydration [37, 39]. We therefore next assessed the correlation of SC hydration with sebum content. As seen in fig-

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There is a significantly positive correlation between sebum content and SC hydration on the forearms and the forehead of females (Fig. 8a, b). In contrast, there is no significant correlation between SC hydration and sebum content on the forehead of males (Fig. 8d).

Discussion

While previous studies were designed to compare skin physiology in young and old skin, here we compare multiple parameters over the whole spectrum of ages in both males and females. In agreement with previous findings [27, 36, 40], our results show that skin surface pH increases in the aged compared to the young group although no difference in skin surface pH on the forearms between old and young subjects was reported by others [28]. In contrast to the previous findings in 10 subjects studied in the USA [27], our results did not show any significant difference in skin surface pH in either males or females between the forehead and the forearm in all age groups. This result is in agreement with others [41]. Although the study on Caucasians aged 26–59 years showed that females have a lower skin surface pH on the forearm and axilla [33, 34], studies here demonstrated that skin surface pH on both the forehead of females aged 13–70 and the forearm of females aged 36–70 was higher than that of males. The difference may be due to sample size and/or the subjects’ ethnicities. The elevated skin surface pH in an aged group is attributable to the decrease in epidermal expression of Na/H+ exchange 1, which is one of the key factors regulating skin surface pH [36, 42].

It has been reported that the sebum content on the forehead in an older group is either not different from young subjects or higher than in a young group (study conducted in San Francisco, Calif., USA) [27, 28]. However, our results demonstrated that the sebum content on both the forehead and the forearm in females aged 13–70 years is significantly higher than in those under 13 and over the age of 70. And the sebum content on both the forehead and the forearm in males aged 0–12 is also significantly lower than that in other age groups. These differences may be due to sample size and/or ethnicity studied. Additionally, the sebum content on the forehead in males aged over 12 is higher than in females, which is consistent with the findings of others [29–31].

Fig. 8. Correlations of sebum content with SC hydration. Significances are shown in the figure. The number of subjects in each group is detailed in table 1. a For the forearms of females. b For the forehead of females. c For the forearms of males. d For the forehead of males.
In summary, the present study shows that sebum content, skin surface pH and SC hydration vary with age, gender and body sites in a Chinese population. These changes, especially sebum content, are correlated with age. Whether these results in the Chinese population are comparable to those in other ethnicities is not known yet. Nevertheless, these results suggest that special care should be given to the skin in older individuals, particularly the Chinese.

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