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Inter-and intra-individual differences in skin hydration and surface lipids measured with mid-infrared spectroscopy

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ABSTRACT

Skin health is characterized by heterogeneous system of water and lipids in upper layers providing protection from external environment and preventing loss of vital components of the body. Skin hydration (moisture) and sebum (skin surface lipids) are considered to be important factors in skin health; a right balance between these components is an indication of healthy skin and plays a central role in protecting and preserving skin integrity. In this manuscript we present inter- and intra-individual variation in skin hydration and surface lipids measured with a home-built experimental prototype based on infrared spectroscopy. Results show good agreement with measurements performed by commercially available instruments Corneometer and Sebumeter used for skin hydration and sebum measurements respectively.

Keywords: Sebum, Skin hydration, Skin oiliness, Spectroscopy, Optical diagnosis, Skin barrier function

1. INTRODUCTION

The Stratum Corneum is seen as water-lipid heterogeneous system, which protects the human body from micro and macromolecular substances in our hostile environment and also against uncontrolled loss of vital biological substances such as water [1]. Optimal balance between sebum and hydration levels provides the skin with a radiant, smooth texture and a natural pigmentation appearance, which is important from a cosmetic perspective. Oily skin look bright, flaxy and turgid, pale yellow. Dry skin is rough, stiff, fragile, opaque, pale gray [2]. Disrupted balance in sebum – hydration also results in a defective skin barrier function and is an indication of different types of skin disorders. The most common dermatological disorders [3] are reported to show disrupted balance of sebum and water in stratum corneum. Such indications are found for eczema (minor water loss combined with moderate oiliness drop (~25%) [4, 5], psoriasis (dramatic decrease of hydration (~70%) and oiliness (~40-70%) [6]), ichthyosis vulgaris (decreased hydration level (~63%) combined with minor variations in skin oiliness (~±15%) [7, 8]).

To facilitate quantitative and simultaneous measurement of skin hydration and surface lipids, we developed a short wave Infrared Optical Spectroscopic set-up using differential detection between three wavelengths 1720, 1750, 1770 nm corresponding to the lipid vibrational bands that lie "in between" the prominent water absorption bands. The goal of this study is to measure inter-and intra-individual differences in skin hydration and surface lipids and to compare these with conventional Corneometer and Sebumeter measurements.

2. MATERIALS AND METHODS

The experimental setup used for the skin hydration and oiliness level measurement comprises three quasi continuous laser sources, beam shaping optics and mirrors to guide the laser beam via the beam path. The laser sources are short wave infra-red lasers emitting a wavelength of 1720, 1750, 1770 nm. We selected the spectral window around 1700 nm corresponding to high absolute values of the absorption coefficient and a high ratio of the absorption coefficient of sebum to the one of water and, simultaneously, a minimal influence of other skin chromophores such as melanin and blood. All lasers were coupled along the same optical path to illuminate the skin. Light backscattered from the skin was detected with a Ge detector and processed using a simple algorithm for estimating the amount of water and skin surface lipids based on Beer–Lambert's law for light propagation in turbid media. The wavelengths 1720 nm & 1750 nm are used for estimating the sebum content and 1750 nm & 1770 nm for the water content.

For in vivo experiment five male and female volunteers were chosen. The participants were selected from volunteers having the largest available spread in terms of skin hydration and oiliness level. All participants were judged

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devoid of skin disorders by a thorough dermatologic health history. Subjects with a susceptibility for atopic dermatitis, asthma, contact dermatitis, allergy, or any other skin disorders at present or in childhood were not included in the study. None of the subjects had used skin care products or make up on the investigation area one day before experiment. The study was approved by local ethical committee and all volunteers gave written informed consent. The intra-individual variations were measured on three locations (forehead, cheek and forearm). The forearm was chosen because it is an area with very low content of sebaceous glands. The cheek represent area with medium density of sebaceous glands and medium sebum excretion rate respectively, while the forehead is an area of T-zone – a location with the largest sebum excretion rate and highest skin oiliness respectively [9]. Variation in the skin hydration and sebum levels are also dependent on seasonal changes, personal features and cosmetics use [10]. All measurements were performed in climate controlled room with temperature 21^{0}C, 45% humidity. Prior to the experiment all participants had acclimatization for 30 minutes. Measurements were performed on forehead, cheeks and forearm using our home-built experimental prototype, Corneometer and Sebumeter. Corneometer and Sebumeter was used for obtaining reference values for hydration and sebum respectively. Measurements were repeated five times for each investigating area.

3. RESULTS AND DISCUSSION

Intra- and inter-individual variation of hydration and oiliness level of human skin for different skin locations are presented on figures 1 and 2 respectively. The horizontal axis corresponds to the estimated hydration of the investigating area of skin, while vertical axis corresponds to the estimated oiliness level of the skin. Home-built experimental set-up provides simultaneous estimation of both parameters: hydration and oiliness; the comparison for the data were provided by Corneometer and Sebumeter measurements respectively. Our experimental results correlated with reference measurements obtained with Corneometer and Sebumeter. The large error bars observed both in experimental results and in reference values measured using Corneometer and Sebumeter are due to the incident and reflection angle of light from the skin surface as a result of muscle tremor and influence of facial beard hair. The results show that the intra-individual inter-site variability is higher than the inter-individual within site variability measured on comparable sites between different individuals.

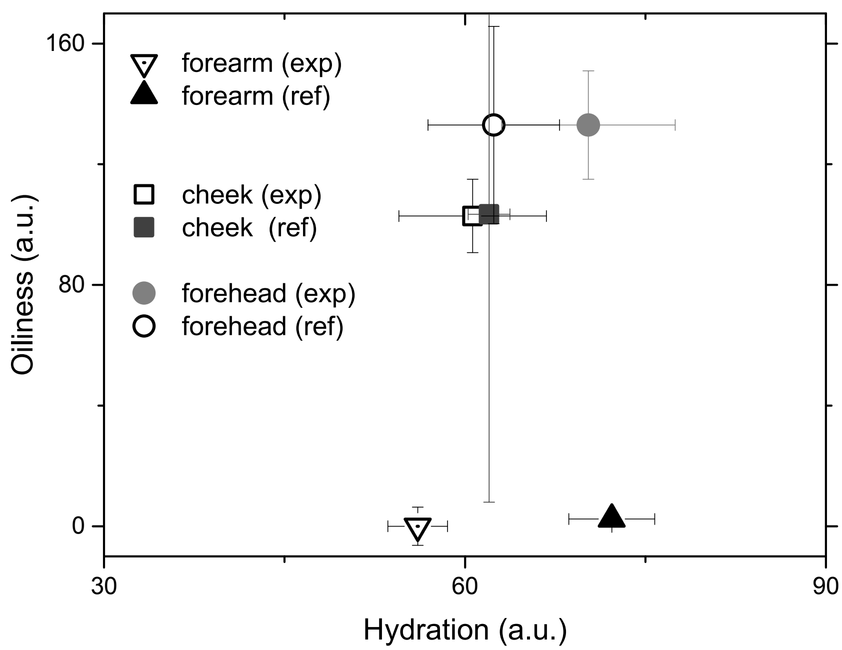

Figure. 1. Intra-individual variations of skin hydration and sebum levels measured on the dorsal side of forearm, cheek and forehead with Infrared spectroscopy and corresponding reference values obtained with Corneometer and Sebumeter.

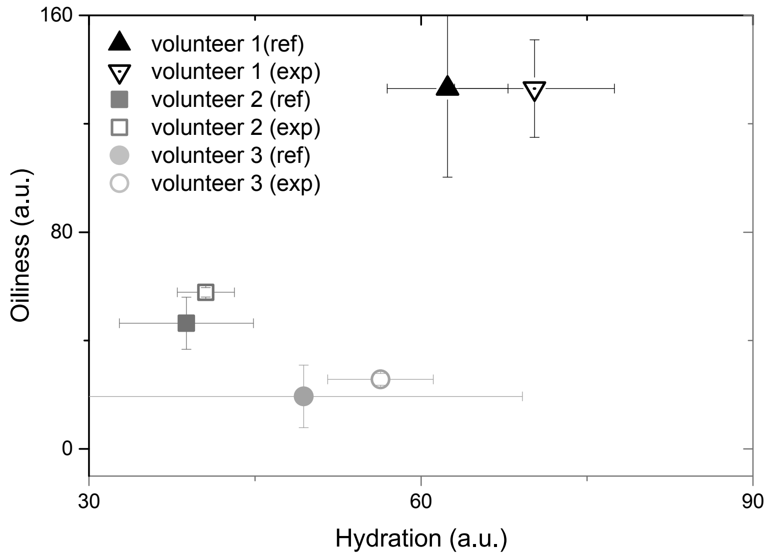

Figure. 2. Inter-individual variations of skin hydration and sebum levels measured on three persons on the forehead with Infrared spectroscopy and corresponding reference values obtained with Corneometer and Sebumeter.

This study presented inter- and intra-individual variations in human skin hydration and oiliness measured with home-built experimental set-up based on Infrared spectroscopy and its comparison to reference measurements obtained with commercially available devices for hydration and oiliness measurements: Corneometer and Sebumeter respectively. The direct comparison of our results with these commercial devices is difficult as both techniques sample different depths inside skin. The probing depth of conductance and capacitance method is defined [11]. The initial experiments performed with increasing layers of a sebum thickness applied placed on the surface of the skin indicates that the sampling depth of our experimental set-up is around 200 μm. Corneometer usually show high reliability, but suffer from disrupted contact due to high oiliness leading to change of dielectric properties of skin surface and thereby influencing the measurement values [12]. It is also reported that Corneometer is sensitive to the pressure applied by the probe onto the skin resulting in local occlusion and thereby changing the biophysical properties of the skin [13]. While capacitance method show lack of sensitivity at high hydration values and conductance method lacks some sensitivity for liquids of low dielectric constant. The readings of Sebumeter depends on contact quality which is influenced by skin roughness and application pressure [14]. Physical contact of probe with skin provides swelling reaction affecting measuring data, while optical method is not suffering from it. Non-invasive optical method presented here provides more accurate data all over whole physical range to compare with traditional moisture and oiliness measuring devises. Another potential advantages of this method is that the proposed method is less sensitive to the presence and variation of other skin chromophores such as blood, melanin indicating the potential of an optical method for all Fitzpatrick skin types. Moreover, the probe does not need to be in contact with the skin so that the repeated measurements can be performed on the same location without changing the skin conditions.

Further in vivo clinical studies were performed to measure the variation of oiliness and hydration of disordered human skin for various skin conditions. The result will be reported separately in the nearest future.

4. CONCLUSIONS

This study presented the feasibility of a home-built prototype based infrared spectroscopy for measuring intra- and inter-individual variations of skin hydration and lipids levels. The natural hydration and sebum level are measured on forearm, cheek and forehead and their variations to external stimuli measured with the set-up are in good agreement with the reference measurements obtained using Sebumeter and Corneometer. The novel method presented here enable the clinicians to classify the skin types into Normal skin (N), Dry skin (D), Oily Skin (O), Oily-Hydrated skin (OH) and oily-dry skin (OD) and can provide personalized skin treatment solutions.

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