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On the Physiology and Biochemistry of the Scalp and Hair Lipids*

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Summary. Analyses were made of the scalp and hair lipids of 67 test persons. These were the most important results:
1. Seborrhoea is caused on one hand by a high secretion performance of the sebaceous glands. A further cause is that a longer period of time passes before a constant lipid amount is established.
2. There was an average of 19.32% of free fatty acids in the scalp and hair lipids on the 1st day after the hair was washed, and 38.68% on the 10th day. These results allow an assessment of the physiological significance of microbial lipolysis outside the secretory ducts of the sebaceous glands.
3. On the hairy head the percentage of free fatty acids in the scalp and hair lipids is independent of the amount of lipids. Such a difference in the concentration of fatty acids as is found between seborrhoea oleosa and seborrhoea sicca on hairless skin can not be found on the hairy head.

Zusammenfassung. Bei 67 Versuchspersonen wurden Analysen der Kopfhaut- und Haarlipide vorgenommen. Die wichtigsten Ergebnisse waren:
1. Die Seborrhoe wird einerseits durch eine hohe Sekretionsleistung der Talgdrüsen bedingt. Eine andere Ursache ist, daß es länger dauert, bis sich ein konstanter Lipidspiegel einstellt.
2. Am 1. Tag nach einer Kopfwäsche beträgt der Anteil der freien Fettsäuren an den Kopfhaut- und Haarlipiden durchschnittlich 19,32%, am 10. Tag durchschnittlich 38,68%. Diese Ergebnisse lassen die physiologische Bedeutung der mikrobiellen Lipolyse außerhalb der Talgdrüsenausführungsgänge beurteilen.
3. Am behaarten Kopf ist der Anteil der freien Fettsäuren an den Kopfhaut- und Haarlipiden unabhängig von der Lipidmenge. Ein ähnlich gravierender Unterschied bezüglich der Fettsäurenkonzentration zwischen Seborrhoea oleosa und Seborrhoea sicca wie an der unbehaarten Haut ist am behaarten Kopf nicht nachweisbar.

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Literature references to the physiology and biochemistry of the scalp and hair lipids are extremely sparse. In this publication various results are described which open up new aspects of this subject.

I. Material and Methods

1. Organisation of the Tests

a) The Tests on Group A: There were 55 male test persons, from 15–38 years of age, who were all free from skin diseases. Each test person had his hair washed twice in a standardized way, with exactly 1 week between washings. Just before the 2nd washing, immediately after the hair washing and on the 5th day after the 2nd washing the scalp and hair lipids were quantitatively determined. On the 5th day after washing the composition of the lipids was also analysed by thin layer chromatography. During the whole test period the test persons refrained from any other hair washing or cosmetic measures.

b) The Tests on Group B: 12 male test persons between 23 and 27 years of age who were all free of skin diseases had their hair washed two times with an interval of 1 week between washings, under the same standardized conditions as group A and with the same solution. The scalp and hair lipids were obtained by extraction on the 1st, 3rd and 10th days after the 2nd washing and analysed by thin layer chromatography. The test persons refrained from any other cosmetic or cleansing measures for the hair during the whole of the test period.

II. Methods

a) Washing of the Hair: The hair was first dampened with tap water at 25–30° C, and then washed with 10 ml of a 6% solution of polyethylene glycol laurate ether sulfate, sodium salt[1]. It was distributed evently with glowed hands over the whole scalp and left for 2 min to soak in. The solution was rinsed off the scalp with liberal amounts of tap water at 25–30° C. The hair was dried with a hair dryer held at a distance of 30 cm; the same hair dryer was used in every case.

b) Joint Analysis of Scalp and Hair Lipids: We made the quantitative analysis of the scalp and hair lipids according to our own previous specifications [5] on closely adjacent or symmetrical positions of the back of the head by direct extraction with petroleum ether, followed by gravimetric determination. For this a glass cylinder with a basal surface of 2.25 cm^2 was used. The amount of petroleum ether was 10 ml, the extraction time 2 min. The hair was shortened to a length of 4.5 cm before the extraction, so it was the scalp lipids and those lipids from the proximal 4.5 cm of hair which were included in the analysis.

c) Thin Layer Chromatographic Separation: For the thin layer chromatographic analysis we used the microslide method of van Gent [1], modified by us as stated [6]. The corrective factors specified by Graumann [7] were taken into account. The following lipid fractions can be separated: free cholesterol, free fatty acids, triglycerides, wax and cholesterol esters, squalene and paraffins. Other substances with corresponding Rf-values may be contained in small quantities in these fractions. In the tests now under consideration only the percentages of the free fatty acids and the triglycerides were evaluated. In the calculation of these the paraffins were neglected because of their mainly exogenous origin.

III. Evaluation

In *group A* the following parameters were correlated with each other:

1. the absolute value of the amount of lipids before the hair was washed with the absolute value of the amount of lipids which were replaced within 5 days after fat removal by hair washing

[1] Elfan NS 242®; manufacturer: Akzo-Chemie, Düren; the percentage given refers to the surface active agents

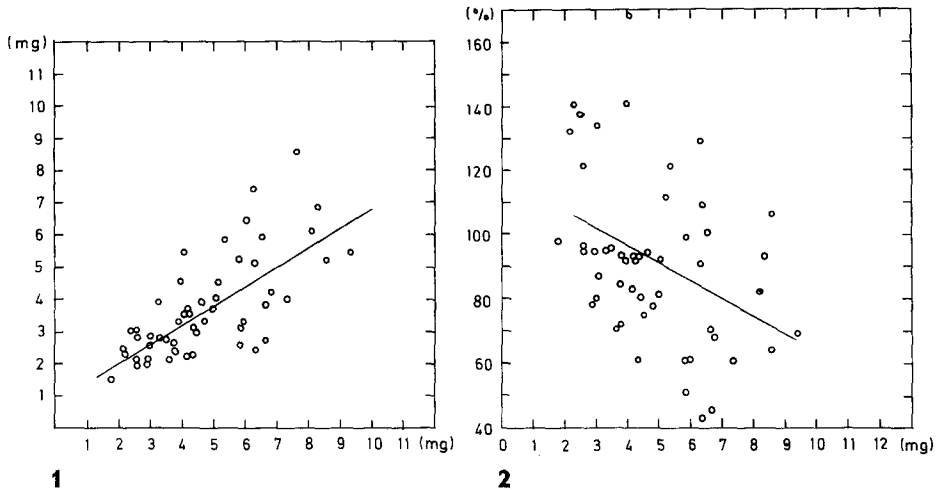

Fig. 1. Relationship between the absolute values of the scalp and hair lipids before the hair was washed and the absolute values of the scalp and hair lipids which were replaced within 5 days after fat removal by hair washing

Fig. 2. Relationship between the absolute values of the scalp and hair lipids before the hair was washed and the values of the scalp and hair lipids which were replaced within 5 days after fat removal by hair washing, expressed in percentages of the amount of lipids which were removed by hair washing

2. the absolute value of the amount of lipids before washing with the amount of lipids which were replaced within 5 days after fat removal by hair washing, given as a percentage of the amount of lipids which were removed by hair washing

3. the absolute value of the amount of lipids before washing with the percentage of free fatty acids in the scalp and hair lipids on the 5th day after washing.

In *group B* the average percentages of the free fatty acids and the triglycerides on the 1st, 3rd and 10th days after the 2nd hair washing were evaluated, taking into account the standard deviations; they were then compared statistically.

The statistical calculation was carried out by means of the correlation coefficients and the Wilcoxon test for paradifferences. The regressions lines shown in Figures 1 and 2 were calculated by means of the regressions coefficients. This calculation is based on the assumption that there are linear regressions. This assumption would seem to be justified because of the graphic representation of the single values.

Results and Discussion

Kuhn-Bussius [9] tested the re-lubrication process after previous removal of fat on hairless areas of skin. For this she compared test persons with dry skin with others having normal or oily skin. It can be seen from the graphs in that publication that the initial amount of lipids of those with oily skin was reached after 4 h, whilst this was the case after only 3 h in those with dry skin. This observation is however based only on very few cases and is not supported statistically.

Of more practical relevance is the re-lubrication process of the hairy scalp of people with dry skin and of people with oily skin. In this tests on group A under

consideration here we determined the absolute values of the lipids which were replaced within 5 days after previous removal of fat by hair washing. Then we compared these values with the absolute values of the lipid amount before washing. The resulting relationship can be seen in Figure 1. Taking a significance level of 1% it can be demonstrated that the larger the initial amounts, the bigger the amounts of lipids on the 5th day were. Therefore the large amounts of scalp and hair lipids in persons with seborrhoea results from a more intensive re-lubrication after previous removal of grease.

We further calculated the percentage of the amounts of lipids which were replaced within 5 days after previous removal of fat taking the amount of lipids removed by hair washing as 100%. We compared these percentage values with the absolute amounts of lipids before washing. The resulting relationship which can be found in Figure 2 is exactly opposite to the relationship in Figure 1. Taking a significance level of 1% it can be shown that the re-lubrication process on the 5th day after washing results in a lower percentage in those with oily skins than in those with dry skins. Therefore the large amounts of scalp and hair lipids of persons with oily skins results not only from a more intensive re-lubrication after previous removal of grease. A further reason is the fact that a constant lipid level takes longer to establish itself in people with oily skin than in those with dry skin.

These results are corresponding to those of Kuhn-Bussius. It seems that conditions are similar on areas of the skin with and without hair. As may be expected it is only the speed at which the re-lubrication takes place which is different. Whilst the initial amount is reached on hairless skin hours after fat-removal, it is reached only after days on the hairy scalp.

Nicolaides and Rothman [10] showed that free fatty acids in the hair lipids increase in number when the hair is stored for a longer time. It is true that these results are not supported statistically, but one can assume from them that lipases causing a splitting up of the triglycerides are present on the hairy head outside the secretory ducts of the sebaceous glands. The results of more recent bacteriological studies lead to the assumption that bacteria and fungi which set free the lipases are present on the hairy head outside the secretory ducts of the sebaceous glands.

But this publication does not allow any conclusions as to the quantitative relationships under physiological conditions. For this reasons we carried out a standardized hair washing on group B with a surfactant which has not antimicrobial effects. We made the lipid extractions on the 1st, 3rd and 10th days after the 2nd hair washing and determined the percentage of free fatty acids and triglycerides in the scalp and hair lipids by means of thin layer chromatography. The aim of the 1st hair washing was only to get standardized conditions. The resulting relationships can be seen in Figure 3. The graph shows that the percentage of free fatty acids in the scalp and hair lipids just about doubles itself from the 1st day to the 10th day. The reverse is the case with the triglycerides. So whilst there is a ratio on the 1st day of about 1 : 2 between fatty acids and triglycerides, this relationship is reversed by the 10th day. The increase in the fatty acids from the 1st to the 3rd, and from the 3rd to the 10th days is significant ($\alpha = 1\%$ in each case).

If one compares this with hairless skin one finds these conditions corresponding quantitatively with the conditions on the head on the 1st day after washing. But unlike on the scalp which is covered with hair, the free fatty acids on hairless skin

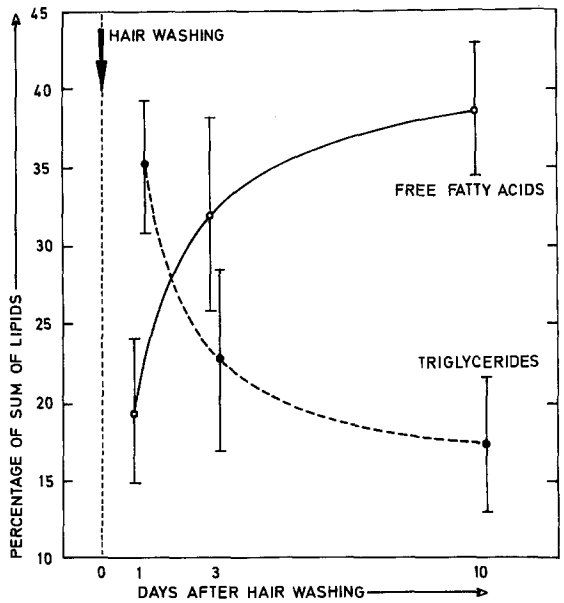

Fig. 3. Average percentages of the free fatty acids and triglycerides in the scalp and hair lipids after washing. The standard deviations are entered beside the mean values

do not increase appreciably in the course of time. This is because the bacteria which set free the lipases on hairless skin are essentially only effective inside the secretory ducts of the sebaceous glands. Above all these findings are also of pharmacological interest. Antimicrobial substances which are applied locally lead as a rule to considerable reduction of free fatty acids on the hairy head, to the advantage of the triglycerides. We were able to show this clearly in earlier tests using colloidal sulphur [4]. But such an effect on hairless skin can only be expected when it is possible to activate the antimicrobial agents in the secretory ducts of the sebaceous glands. The effect of locally applied antimicrobial substances on the free fatty acids is therefore as a rule not so impressive quantitatively on hairless as on hairy skin.

Gloor et al. [2] compared the amount and composition of the skin surface lipids on hairless skin of people with seborrhoea oleosa and seborrhoea sicca. They found no essential differences in the amount of lipids. Where composition was concerned they were able to demonstrate that the free fatty acids are more in cases of seborrhoea oleosa than in cases of seborrhoea sicca. The percentages found here were 23.40% for seborrhoea oleosa and 14.20% for seborrhoea sicca. As free fatty acids, unlike most other elements of the skin surface lipids, have a hydrophile group, these authors assumed that the clinical picture of seborrhoea oleosa or seborrhoea sicca is causally connected with these results. This is also supported by results of Gloor et al. [3] which show that physiological characteristics of the skin depend on the percentage of free fatty acids in the skin surface lipids.

People with seborrhoea oleosa therefore probably differ mainly from those with seborrhoea sicca, in that the bacterial lipolysis in the secretory ducts of the sebaceous glands is different. This is because only very few free fatty acids are present in the

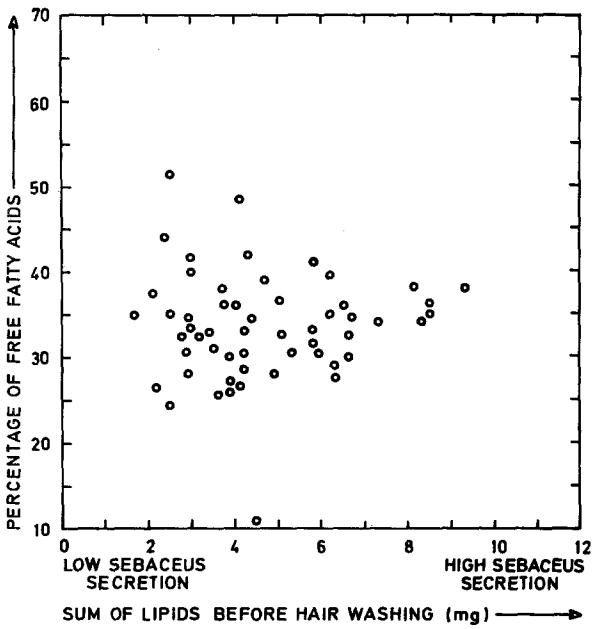

Fig. 4. Relationship between the amounts of scalp and hair lipids before the hair was washed (steady state) and the percentages of the free fatty acids on the 5th day after washing

pure contents of the sebaceous glands, and because, as has already been explained, a splitting up of triglycerides on the surface of the skin itself happens only to a small degree [8, 11, 12]. It is possible that conditions on the hairy scalp are different, for the considerable lipolysis which takes place outside the secretory ducts of the sebaceous glands on the hairy scalp possibly is not parallel with the bacterial lipolysis inside the secretory ducts. We compared the percentage of free fatty acids in the scalp and hair lipids on the 5th day after washing with the steady state of the amount of scalp and hair lipids. Figure 4 shows that the percentage of free fatty acids is not essentially different in those with oily skin and those with dry skin. Over-average and under-average proportions of free fatty acids occur with about the same frequency on the hairy scalp of people with oily skin and people with dry skin, whilst the range of distribution for the percentages of free fatty acids is smaller in the persons with oily skin than in the persons with dry skin.

Whilst the skin surface lipids of the hairless skin of people with seborrhoea oleosa contain considerably more free fatty acids than those of people with normal or dry skin, and in people with seborrhoea sicca there are about the same proportions of free fatty acids as in people with normal and dry skin, such a clear definition is not possible in connection with the hairy scalp. We think that a condition which is corresponding to the term seborrhoea sicca on the hairy scalp physiologically is very rare. As a rule if there is a seborrhoea, there is a seborrhoea oleosa. But this holds only good under physiological conditions. A seborrhoea sicca can be achieved by the therapeutical application of antimicrobial agents.

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