

Article

Impact of Lifestyle on Differences in Skin Hydration of Selected Body Areas in Young Women

Piotr Załęcki ¹, Karolina Rogowska ¹, Paulina Waś ¹, Kamila Łuczak ¹, Marta Wysocka ¹ and Danuta Nowicka ^{1,2,*} 
¹ Faculty of Physiotherapy, Wrocław University of Health and Sport Sciences, 51-612 Wrocław, Poland; karolina.rogowska92@gmail.com (K.R.); pina7562@gmail.com (P.W.)

² Department of Dermatology, Venereology and Allergology, Wrocław Medical University, 50-368 Wrocław, Poland

* Correspondence: danuta.nowicka@umw.edu.pl

Abstract: Measuring skin hydration is important for dermatology research, cosmetic practice, and daily skincare; it provides valuable insight into skin assessment and predicts treatment outcomes. This study investigated the level of skin hydration on various parts of the body in female university students, utilizing corneometry for measurement. Demographic, water intake, skincare, and exercise habit data were collected. The highest hydration levels were on the face ($n = 40$), followed by cleavage skin ($n = 42$), neck skin ($n = 48$), and leg skin ($n = 42$). Differences were observed between the chin and forehead (106.06 ± 21.06 vs. 91.20 ± 26.68 ; $p = 0.001$) and the chin and cheek (106.06 ± 21.06 vs. 92.00 ± 27.63 ; $p > 0.001$). The differences in the hydration measurement results on cleavage were not significant (right clavicle 55.1 ± 12.93 ; left clavicle 51.84 ± 10.00 ; sternum 53.55 ± 16.3 ; $p = 0.379$). On the neck, the middle point exhibited the highest hydration (left 41.7 ± 11.3 ; middle 49.2 ± 12 ; right 47.2 ± 8.2 ; $p > 0.001$). The skin on the thigh was significantly drier than that on the shank (31.09 ± 6.89 vs. 33.54 ± 6.28 ; $p = 0.008$). Water consumption was positively associated with skin hydration and the amount of physical activity. We conclude that every skin area is characterized by different levels of hydration. Water intake and physical activity contribute to improved skin hydration.

Keywords: skin hydration; corneometry; skincare; stratum corneum; water intake



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1. Introduction

Healthy skin equates to well-hydrated skin. Water is found in every cell of the human body and is the substrate and product of many reactions and transformations taking place in the body. It is also an essential substance for the proper functioning of the skin, which is the largest organ of the human body. It plays a significant role in the stratum corneum of the skin, where it combines with proteins and lipids [1]. The proteins are highly cross-linked. They adhere tightly to each other within the corneocytes—the dead cells of the stratum corneum. The corneocytes are surrounded by a lipid matrix consisting of free fatty acids, cholesterol, and ceramides. This forms a specific barrier, a ‘protective wall’ of the skin that prevents excessive transepidermal water loss (TEWL) [2]. Osmolytes present in the stratum corneum are small-molecule, polar chemical compounds that lower the chemical potential of water and form a natural moisturizing factor (NMF). By binding to water molecules, the role of the NMF is to maintain optimal skin moisture. It primarily comprises free amino acids and their derivatives such as pyrrolidone carboxylic acid (PCA), trans urocanic acid (UCA), and free ions, sugars, urea, or lactic acid [3]. Adequate skin hydration is essential for skin homeostasis, and it also maintains barrier function, adequate tissue elasticity, and balance of inflammatory molecule release [4]. However, different parts may exhibit varying hydration levels [5].

Measuring skin hydration is important for dermatology research, cosmetic practice, and daily skincare. Corneometry is a commonly utilized method in dermatology. The method provides a means to assess skin hydration levels and is used to test the effectiveness

of ointments, lotions, or creams [6,7]. Hua et al. compared Courage + Khazaka corneometry with other devices and concluded that although the results for specific skin properties are correlated with measurements from other devices, Courage + Khazaka corneometry demonstrated low variability in outcomes for skin hydration and TEWL [8]. Holm et al. considered corneometry a valuable noninvasive instrument for the quantification of disease severity in patients with atopic eczema [9]. In a recent study, Ridd et al. used corneometry in a randomized controlled trial evaluating skin hydration and other disease-specific outcomes in children with eczema before and after the use of emollients. They observed that corneometry results exhibited less correlation with the clinical outcomes; however, measurements were conducted in uncontrolled home conditions, potentially introducing bias to the outcomes [7]. We conducted our measurements in controlled conditions as advised by the manufacturer. The aim of our study was to investigate the levels of skin hydration in various body areas in female university students using corneometry.

2. Materials and Methods

2.1. Population

For this study, young adult women (university students) were invited. In total, 84 young women were recruited and divided into four groups based on the examined skin area: 40 women participated in the examination of the facial skin, 48 had neck skin examination, 42 had the skin on the neckline examined, and 42 underwent examination of their skin on the thigh and calf. All participants were students of the Physiotherapy Department of Wrocław University of Health and Sports Sciences, Wrocław, Poland. All participants were instructed about study procedures and gave their informed consent for participation in the study. The study was approved by the Senate Committee of Ethics.

At the start of the study, participants were asked to fill out the questionnaires and answer questions about their demographics, their knowledge of skincare, and their lifestyle habits, which are related to skincare and may impact skin hydration. Hydration of neck skin was measured in 48 women, face skin in 40 women, neckline skin in 42 women, and the skin on the leg in 42 women.

2.2. Corneometry

Skin hydration was measured with a corneometer. The corneometer works on the principle of electrical conductivity, where increased water content in the stratum corneum corresponds to greater conductivity, indicating skin hydration levels. The test procedure uses a current with a frequency in the range of 0.9–1.2 MHz, and the measurement depth is very shallow—10–20 µm deep into the stratum corneum. The device works based on the capacitive method, in which the difference between the high dielectric constant and other substances (many times lower) is determined. Changes in the constant, which are caused by changes in the water content of the skin, lead to changes in the calculated capacitance. The corneometer has two electrodes with different electrical charges, which generate an electromagnetic field from which the electrical permeability is calculated. The test results are given in relative units from 0 to 130. The test can be carried out in three ways: (1) Continuous measurement by applying the measuring probe to the skin; (2) Continuous measurement without direct contact between the probe and the skin; (3) A single one-second measurement used to compare the lowest average and highest values for water in the stratum corneum [10,11]. The Courage + Khazaka System Multi Probe Adapter MPA (Courage + Khazaka electronic GmbH, Köln, Germany) was used. Measurements were made in several selected body parts while fulfilling the conditions recommended by the device manufacturer [10]:

- Constant temperature and humidity in the room—the recommended temperature is 20 degrees, and the optimum humidity is between 40% and 60%.
- Measurements were not taken in direct lamplight or sunlight, as heat radiation can cause inaccurate measurements.

- The test persons were not directly measured after intense physical activity and, as recommended by the manufacturer, had time to rest for a while so that their blood circulation could regain an appropriate level; the measurement was carried out on hairless skin.

2.3. Study Procedures

Participants were instructed to refrain from using any cosmetics, including moisturizers, on the day before the examination. All tests took place at the Wrocław University of Health and Sport Sciences in a measurement room with a constant temperature and humidity. Subjects acclimated themselves for 30 min before the measurement.

Skin corneometry was measured once in selected locations on the face (three spots: one on the cheek, one on the forehead, and one on the chin), neck (three spots: one on the left, one on the right, and one in the middle), neckline (three spots: one on the clavicle and right clavicle and one on the sternum) and on the lower limb (two spots: on the inside of the thigh and the shank). The locations of measurements are shown in Figure 1. The measurements were taken with a corneometer probe, which was placed on the skin for one second. The measurement area was approximately 10–20 μm^2 .

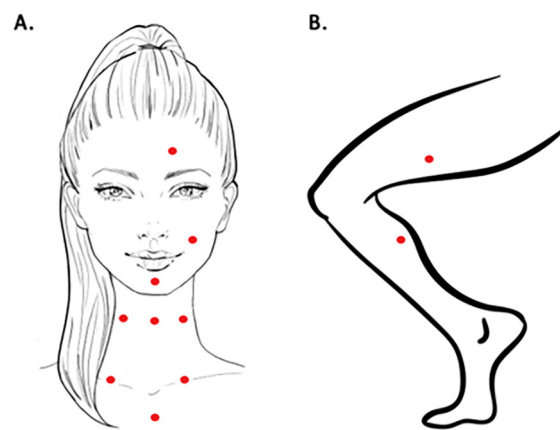


Figure 1. The locations of measurements (A) on the face and neck and (B) on the lower limb.

2.4. Statistical Analysis

Data from the measurements were recorded and saved in an MS Excel spreadsheet (Microsoft Excel 2013; Microsoft Corp., Redmond, WA, USA) for further statistical analysis. Continuous variables were presented as means and standard deviations, while categorical ones were presented as numbers and percentages. Statistical analysis was carried out using Statistica software v.13.1 (StatSoft, Tulsa, OK, USA). The distribution of data was checked before comparisons. Differences between groups were examined using the Student's *t*-test or the Wilcoxon Signed Rank test depending on the type of data distribution (for data that were not normally distributed). For the comparison of multiple groups, the Kruskal–Wallis test was used. The differences were considered statistically significant at a *p*-value < 0.05.

3. Results

3.1. Skin Hydration

The results of the corneometric measurement showed that every area of the skin was characterized by a different level of hydration. The face exhibited the highest hydration, followed by the neckline skin, neck skin, and the skin on the leg. Regarding the facial skin, the measurement results between the chin, forehead, and cheek areas showed that hydration levels in these areas were statistically significant differences ($p = 0.0002$) as compared with the Kruskal–Wallis test. The differences were observed between the chin and forehead ($p = 0.001$) and the chin and cheek ($p > 0.001$). The differences in the hydration measurement results among the three points on the cleavage did not show significant differences ($p = 0.379$). The mean hydration of the neck skin was 46.0 ± 8.6 , but there were

significant differences among the three measured points of the neck ($p > 0.001$), with the highest result in the middle of the neck. The driest skin was observed on the leg. The skin on the thigh was significantly drier than that on the shank ($p = 0.008$). Measurements of skin hydration are presented in Table 1.

Table 1. Skin hydration results in selected areas of the body.

	Number	Mean $\pm$ SD	Range (Min–Max)
Neck left	48	41.7 $\pm$ 11.3	14.8–69.0
Neck middle	48	49.2 $\pm$ 12	24.4–72.1
Neck right	48	47.2 $\pm$ 8.2	26.6–67.7
Cheek	40	92.00 $\pm$ 27.63	8.7–118.2
Forehead	40	91.20 $\pm$ 26.68	3.2–119.5
Chin	40	106.06 $\pm$ 21.06	32.6–119.6
Right clavicle	42	55.1 $\pm$ 12.93	5–73.1
Left clavicle	42	51.84 $\pm$ 10.00	29.6–70.4
Sternum	42	53.55 $\pm$ 16.3	0.9–86
Thigh	42	31.09 $\pm$ 6.89	14.6–55.9
Shank	42	33.54 $\pm$ 6.28	14–45

3.2. Condition of the Skin on the Face and Facial Skin Care Habits

This group included 40 students aged between 18 and 28 years. As skin condition is generally associated with the perception of overall health, participants had their skin type determined, and they reported the problems they experienced in relation to their skin. The majority of the women had a mixed skin type, characterized by a combination of different skin types on different parts of the face. Specifically, most of them had an oily T-zone (forehead, nose, and chin), while the cheeks were normal. In terms of dermatologic skin problems, acne vulgaris was the most frequently occurring issue. The skin types and skin conditions experienced by study participants are outlined in Figure 2.

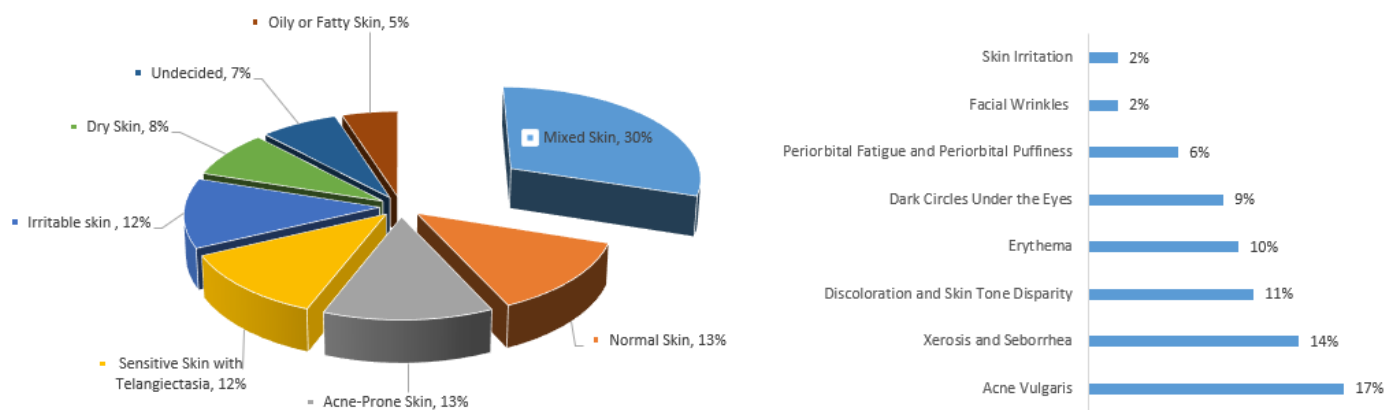


Figure 2. Summary of facial skin types and facial skin conditions in the study group.

More than half of the respondents assessed their state of health as 'good' (57%), almost one-third (35% of respondents) answered that they felt 'very good,' and another group—'I feel bad' (5%). The smallest number of respondents indicated that they felt 'average' (3%).

The majority of respondents (94%) stated that they use skincare products that match their skin type, while 6% did not specifically prioritize the right choice of cosmetics. It was positively surprising that 90% of the respondents declared never using a solarium, while on the other hand, only 5% said that they used preparations containing UV filters throughout the year.

3.3. Condition of the Skin on the Neck and Neck Skin

In the neck skin examinations, 48 women aged from 19 to 21 years were included (mean 19.2 ± 0.5 years). The most common skin type in this group was combination skin ($n = 25$; 47.17%). This type of skin had, on average, higher skin hydration than other types of skin (mean 47.2 vs. 44.53). Over half of the participants ($n = 25$; 52.8%) reported having no skin problems and demonstrated a considerable awareness of choosing cosmetics with suitable ingredients for their skin type. The face appeared to receive more attention in terms of care compared to the skin of the neck. The skin types of the neck are outlined in Figure 3. No pathological skin conditions were identified on the neck skin.

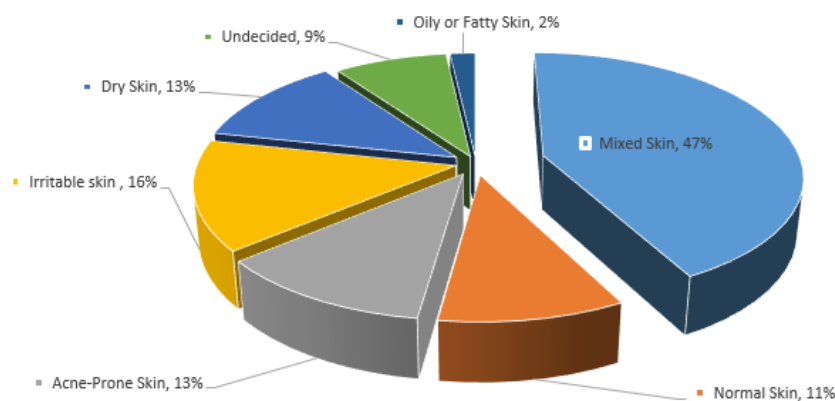


Figure 3. Summary of neck skin types in the study group.

3.4. Neckline Skin Habits

In the neckline examinations, 42 women aged 19 to 21 were included (mean 19.1 ± 0.4 years). Participants almost equally frequently admitted to having normal, dry, and mixed skin (Figure 4). Only four participants reported the occurrence of acne on the neckline, and one person reported atopic dermatitis; other participants denied experiencing any pathological skin conditions in this area. All those participants remain under the supervision of a dermatologist.

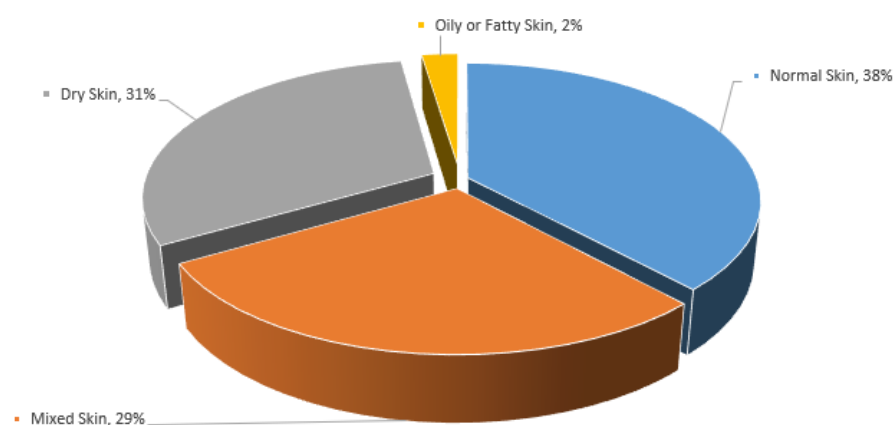


Figure 4. Summary of neckline skin types in the study group.

The vast majority of the study participants ($n = 32$; 76.19%) declared that they drink 1.5 L of water a day, while the remaining 10 (23.79%) women drank less than 1.5 L of water per day. There were no differences in hydration with regard to the amount of water consumed ($p = 0.172$). Skin diseases, reported by 17% of the subjects, were found not to have a statistically significant effect on the results of the study, as were dietary supplements and smoking. However, this does not imply the absence of certain trends affecting the hydration of the neckline skin. The lack of statistical significance is most likely due to the small size of the group studied.

3.5. Leg Skin Habits

The hydration of the skin on the lower limb was examined in 42 women aged 19 to 26 (mean: 20.1 ± 1.2). None reported any skin problems in this area. The amount of water consumed during the day was the following: 19 (45.2%) women drank from 0.5 to 1.0 L a day, 13 (30.9%) women consumed between 1.6 and 2 L of water per day; 7 (16.6%) women from 1.1 to 1.5 L per day, and 3 (7.1%) women more than 2 L of water per day. The results of the measurements showed that the amount of water consumed per day had a significant effect on the measured skin hydration parameters ($p < 0.001$). Increased water consumption was associated with higher hydration levels observed in both the thigh and shank.

The participants were asked about the frequency of physical activity. Fourteen (33.3%) of them declared that they practiced physical activity 2–3 times a week, 12 (28.5%) students exercised occasionally, 9 (21.42%) students practiced once a week, and 7 (16.6%) students trained more than three times a week. It was not shown that the intensity of physical activity significantly changed the level of skin hydration ($p = 0.295$). Nevertheless, we observed that people who engaged in physical activity two or more times a week had, on average, higher skin hydration than people who practiced less frequently.

Regarding the knowledge about skincare, 25 (59.52%) women declared that they knew how to properly moisturize their skin, while the remaining 17 (40.47%) women were uncertain about skincare methods. Those who declared that they had knowledge of effective skin care had significantly higher levels of hydration in the study area compared to those with little knowledge ($p < 0.001$).

4. Discussion

The results of the study indicate varying levels of hydration in the different areas of the body. The skin on the face was the most hydrated, followed by neckline skin, neck skin, and the skin on the leg. Young women prioritize caring for the skin on their face the most; however, the measured values show a fairly high level of hydration of the neck skin despite not taking adequate care of it. The consumption of adequate amounts of water and physical activity were linked with better skin hydration. Multiple factors contribute to adequate skin hydration, with the most crucial ones highlighted in Figure 5.

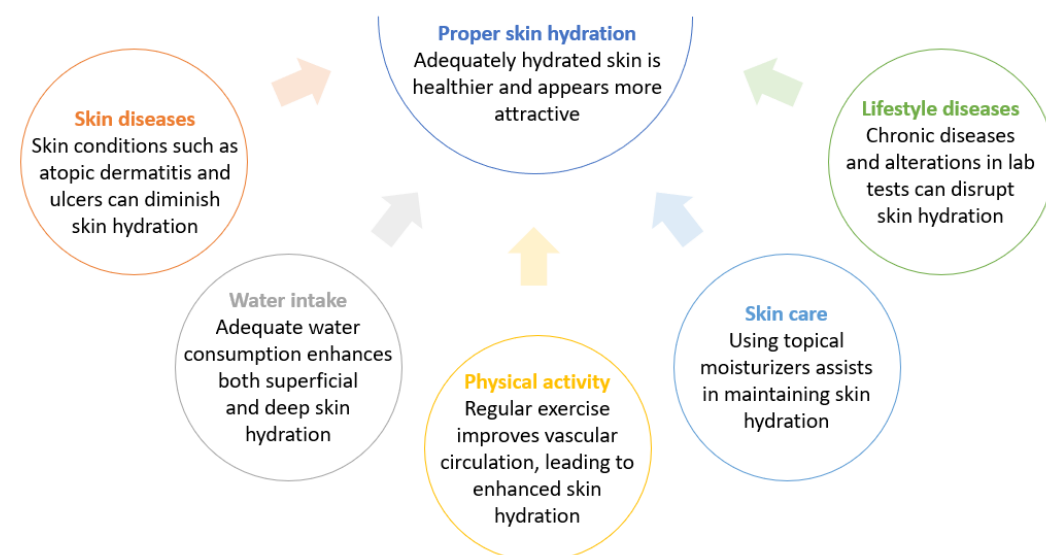


Figure 5. Enhancing skin hydration: key factors at a glance.

Skincare aims to ensure a beautiful appearance; however, proper skin care has other benefits as well. An interesting study was conducted among young women in Shanghai [12]. Of the 111 young women aged 18 to 25, 33 (29.7%) were classified as having ideal skin based on the absence of pores, wrinkles, spots, and signs of acne. The ideal skin, in comparison to undesirable skin, had lower sebum content, transepidermal water loss,

melanin, hemoglobin, and roughness; however, it was characterized by higher hydration and skin pH value. Furthermore, ideal skin had a healthier skin microbiome with higher bacterial species diversity. The authors concluded that skin hydration was an important factor contributing to microbiome diversity and skin homeostasis. It is worth noting that skin hydration can be increased through an increase in water intake, which was shown in our research and other reports [13,14]. The impact of adequate skin hydration on the microbiome adds another dimension to skincare and can serve as an encouragement to increase water intake. This improvement in skin condition applies to both healthy individuals and those with skin diseases, given that the microbiome is often disrupted in various skin pathologies [15,16]. Research indicates that the skin with higher levels of hydration not only appears healthier but is also healthier, while reduced hydration can serve as a marker of certain pathologies. A study conducted by Lai et al. [17] compared skin hydration in patients with diabetes ($n = 73$) and patients without diabetes ($n = 73$). Although a difference in average hydration level was not statistically significant between those groups (median [IQR]: 111.33 [40.50] in diabetics vs. 107.33 [51.67] in non-diabetics; $p = 0.874$), overall skin hydration was significantly lower in patients with diabetic neuropathy in comparison to those without diabetic neuropathy (median [IQR]: 107.18 [29.33] vs. 118.17 [32.3]; $p = 0.005$). Skin hydration was also significantly lower in patients with fasting blood sugar above 7 mmol/L in comparison to those with a fasting blood sugar of 7 mmol/L and below (128.67 [50.14] vs. 102.03 [35.06]; $p = 0.005$). In another study conducted among diabetic patients with diabetic foot, Namgoong et al. [18] determined that the level of skin hydration is significantly correlated with microvasculature measured using transcutaneous oximetry. Furthermore, Lee et al. [16] examined retrospectively patients with diabetic foot complicated with forefoot ulcers, which were treated with percutaneous transluminal angioplasty. They showed that skin hydration at baseline correlated significantly with wound healing ($p = 0.0018$). An increase in the values of skin hydration at baseline demonstrated statistically significant reductions in the incidence of major amputation in comparison to healing without amputation (odds ratio [OR] 1.149, 95% confidence interval [CI] 1.06–1.246) and also significant in comparison to minor amputation (OR 1.105, 95% CI 1.013–1.205). For patients with atopic diseases, Hon et al. [19] showed associations between skin hydration and the presence of eczema and Scoring Atopic Dermatitis (SCORAD). Skin hydration was significantly lower in children with eczema than in children without eczema, regardless of age and sex. Additionally, in children with eczema, skin hydration values were significantly negatively correlated with the SCORAD score ($p < 0.001$). Wang et al. [20] investigated the importance of skin hydration in children with atopic dermatitis. They found that after treatment with topical corticosteroids and an emollient, skin hydration increased significantly, from 19.96 ± 1.05 to 34.61 ± 1.10 ($p < 0.001$) on the cheek. Moreover, skin hydration negatively correlated with pruritus ($r = 0.174$; $p < 0.0001$), quality of life score ($r = 0.042$; $p = 0.002$) and eczema severity ($r = 0.294$; $p < 0.0001$).

Water consumption is one of the vital factors in maintaining proper skin hydration and skin biomechanics [14]. Palma et al. [13] employed a Food Frequency Questionnaire to assess water intake accurately in 49 young healthy females. Over a four-week period, participants were observed and subsequently divided into two groups based on their baseline water consumption (below and above 3200 mL/day). They were then instructed to supplement their regular daily water intake with an additional 2000 mL per day. Skin parameters were measured on various areas of the body, including the face (zygomatic and forehead), arm (ventral forearm and hand), and leg (external parts). The additional water intake led to a significant increase in both surface and deep hydration levels, highlighting its role in enhancing water availability for physiological processes occurring across all skin layers. Interestingly, the level of TEWL remained unchanged during the period of increased water intake [13]. Two other studies conducted by the same research group revealed that a greater improvement in superficial skin hydration was associated with lower initial water consumption. Regarding deep skin hydration, the authors suggested that the increase in

hydration might be regardless of the level of baseline water consumption [21,22]. The study by Boelsma et al. [23] investigated the relationship between dietary nutrient intake and certain skin parameters, including hydration, sebum content, and skin surface pH. Skin hydration was measured using the same device employed in our study. In this research, 302 healthy men and women were invited to participate. Two complementary Food Frequency Questionnaires were utilized, and regression analysis was applied to account for potential confounding factors. The study revealed that the mean fluid intake in the study group was 2853 mL per day, indicating a relatively modest intake. Furthermore, the research showed that increased total water intake positively affected superficial skin hydration. However, concurrently, it led to a slight decrease in skin pH, specifically in men. Interestingly, there was no discernible relationship between skin hydration and protein or carbohydrate intake. However, total fat intake and overall energy consumption were found to be negatively associated with skin hydration [23]. Mac-Mary et al. [24] conducted their study in France, involving 80 older participants with a mean age of 56 ± 5.6 years. All participants were instructed to modify their daily water consumption habits by adding an extra liter of water per day (500 mL in the morning and 500 mL in the afternoon) throughout the 42-day study period. Skin surface hydration was measured using the same device as in our study. At the study's conclusion, the hydration index significantly increased from 33.98 ± 5.45 to 39.53 ± 7.71 ($p < 0.001$) compared to baseline values. However, this effect was accompanied by an increase in TEWL, which rose significantly from 2.80 ± 0.91 to 3.16 ± 0.94 ($p < 0.001$). Interestingly, participants reported a decrease in skin dryness and roughness, while simultaneously perceiving their skin as more elastic. Given the beneficial effects observed in both clinical evaluations and self-assessments of the skin, the authors concluded that increasing the consumption of natural mineral water can be recommended as a management strategy for skin dryness in adjunct to cosmetic approaches [24]. Optimal water intake not only improves skin properties in otherwise healthy individuals but also serves as a subject of study in populations with skin diseases. Increased water intake could potentially alleviate skin symptoms such as dryness and enhance skin barrier properties, consequently reducing the frequency of skin flares and the severity of the disease. However, these aspects necessitate further research, as emphasized by Douladiris et al., who recently conducted a literature review to shed more light on the optimum water intake level for improving the course of atopic skin [25].

The impact of physical activity on skin hydration has not been widely studied, and reports on this topic are scarce in the literature. Hence, our study, emphasizing the importance of regular physical activity in maintaining adequate skin hydration, holds significant value. On the one hand, hypohydration (body water deficit) can occur in both professional and recreational athletes following the completion of a training session and is associated with a loss of body water due to exercise-induced heat stress. In such instances, rehydration is essential to rectify this temporary hypohydration because even a minor drop in body water can lead to dysfunctions, resulting in impaired performance and posing health consequences, especially in older populations [26]. On the other hand, regular physical exercise can have the opposite effect, as it improves nutrition and oxygenation of the skin via improved circulation. An interesting study conducted by Ryosuke et al. [27] involved 86 Japanese university students (median age of 30 years, ranging from 20 to 62 years) with the aim of investigating the impact of exercise habits on skin moisturizing function, including measurements of hydration levels and TEWL. The study revealed that the group characterized by the highest level of physical activity exhibited the highest hydration levels. The median hydration values were as follows: 38.5 (range 22.7–56.1) in the low-level activity group, 34.4 (range 24.3–48.8) in the medium-level activity group, and 46.5 (range 35.1–56.1) in the high level of activity group. This difference was statistically significant ($p < 0.001$). Interestingly, the level of physical activity was not associated with values of TEWL ($p = 0.22$). The authors concluded that regular training might prevent dry skin, and the study findings could be utilized to promote the benefits of exercise [27]. To our knowledge, these are the only studies on the impact of regular physical activity on skin

hydration. Therefore, additional studies in this area would contribute valuable evidence to the existing body of knowledge.

The above examples of studies show that the hydration of skin is important for maintaining the good and healthy condition of the skin. However, there is little evidence from studies that investigate skin hydration of the entire body in healthy people, which could serve as a starting point for skin assessment. The facial skin is the most commonly evaluated due to the interest of the cosmetic industry [28–30] or in dermatology [7,9,31]. In light of data scarcity, the study by Cortés et al. [32], which mapped human body skin hydration, is of value. They reported differences in hydration among 23 anatomical regions. The study, however, included only five men and showed a high degree of variability. In our study, selected areas were examined in about 40 women, which is an advantage. Our future research is focused on the development of the skin hydration map in relation to age, as this factor has been proven to affect skin hydration and is important from a practical viewpoint [33,34].

Several limitations should be considered when interpreting the results. The study sample is relatively small and consists solely of young women, introducing limitations related to generalizability. A larger population may exhibit differences in skin care habits, lifestyle, and awareness of the importance of skincare. Additionally, the sample lacks gender representativeness as it includes only female volunteers. Data on water intake, physical activity, and skin care were collected through a questionnaire, making them susceptible to recall bias.

5. Conclusions

Young women tend to prioritize facial skincare while neglecting other parts of the body. Adequate water consumption and regular physical activity have been associated with improved skin hydration. Skin hydration varies across different body locations; however, future research is required to develop a comprehensive skin hydration map that considers age, a factor that influences corneometry results. Finally, our study addresses a significant gap in current knowledge concerning the relationship between skin hydration and regular physical activity. It is important to note that our findings regarding the positive impact of physical activity on skin hydration should be regarded as preliminary results, warranting further investigation in larger populations.

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Data Availability Statement: Data are available on request from the authors.

Conflicts of Interest: The authors declare no conflicts of interest.

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