Clinical, Cosmetic and Investigational Dermatology

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ORIGINAL RESEARCH

Dietary water affects human skin hydration and biomechanics

This article was published in the following Dove Press journal:
Clinical, Cosmetic and Investigational Dermatology
3 August 2015

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Abstract: It is generally assumed that dietary water might be beneficial for the health, especially in dermatological (age preventing) terms. The present study was designed to quantify the impact of dietary water on major indicators of skin physiology. A total of 49 healthy females (mean 24.5±4.3 years) were selected and characterized in terms of their dietary daily habits, especially focused in water consumption, by a Food Frequency Questionnaire. This allowed two groups to be set – Group 1 consuming less than 3,200 mL/day (n=38), and Group 2 consuming more than 3,200 mL/day (n=11). Approximately 2 L of water were added to the daily diet of Group 2 individuals for 1 month to quantify the impact of this surplus in their skin physiology. Measurements involving epidermal superficial and deep hydration, transepidermal water loss, and several biomechanical descriptors were taken at day 0 (T0), 15 (T1), and 30 (T2) in several anatomical sites (face, upper limb, and leg). This stress test (2 L/day for 30 days) significantly modified superficial and deep skin hydration, especially in Group 1. The same impact was registered with the most relevant biomechanical descriptors. Thus, in this study, it is clear that higher water inputs in regular diet might positively impact normal skin physiology, in particular in those individuals with lower daily water consumptions.

Keywords: dietary water, water consume, skin hydration, TEWL, skin biomechanics

Introduction

Water is a large component of the human body and plays a key role in normal physiological balance. This general concept has been widely explored by the food/beverage market to cultivate the idea that an increase of water intake in our diet might act as a health (and antiage) promotor. Regarding skin health, this association between water and better (skin) performance has been widely accepted, although not clearly demonstrated.[1–3]

Water is the main component of cells and tissues, a major element of body fluid compartments,[4] and represents 75% and 60% (from birth and in adults, respectively) of body's composition. It is an essential nutrient with unique properties as a solvent for ionic compounds and solutes[5] and acts as a carrier with a central role in cell homeostasis.[6,7] Water is the environment in which all transport systems work.[8] It helps in maintaining body volume (intracellular and extracellular),[9,10] which is essential to prevent dehydration, a potentially life-threatening condition.[11] The water in the body also plays an important role in thermoregulation[10] and acts as a lubricant and shock absorbent.[10]

Several studies have suggested that the amount of water supplied by regular food and beverages, including the water produced by the cellular metabolism, is not sufficient to meet the body's daily water requirements,[10,12–14] even considering the very effective neuroendocrine osmoreflexes regulating thirst and voluntary water ingestion.[13–15] Unlike other essential nutrients, daily recommendations for water consumption are often disregarded, and a clear definition of the daily water requirement needs does not exist. However, there are some indicative recommendations. The "Dietary Guidelines for Americans 2010" report[15] establishes as adequate water intake 3.7 and 2.7 L/day for men and women, respectively, between 19 and 30 years old, while the European Food Safety Authority (EFSA) indicates dietary reference values of 2.0 and 2.5 L of water per day for women and men, respectively.[16]

Regarding human skin's physiology, cutaneous water content is known to play an important role in different skin functions, such as the water "barrier" function or the "envelope" function, and water deficiency is associated with several dermatological dysfunctions.[17–19] Nevertheless, a direct relationship between these properties and regular dietary water consumption have not been clearly demonstrated, and only very few publications have addressed this theme.[20,21]

In this study, a validated Food Frequency Questionnaire (FFQ) was used to measure the total water intake in a population, ie, the water they drink, the water content of the dietary nutrients, and the water produced by regular metabolism.[22] In this way, a relationship between some cutaneous functions and water ingestion could be measured in order to look deeper into the impact of dietary water on normal skin physiology.

Material and methods

Subjects

A convenience sample of 49 healthy female volunteers, aged between 22 and 34 (24.5±4.3) years was selected. The effects of gender on normal physiology, including the skin are known.[22–26] So, this research compromise was intended to reduce the gender-related variability. The selection of volunteers took place after informed written consent was obtained, in accordance with previously established inclusion criteria. The methodologies used fully complied with all ethical standards set by the Declaration of Helsinki and its amendments,[27] and were previously approved by the institution's ethical commission.

Experimental design

The population's water consumption pattern involved all contributions accounting for the total amount of water consumed. The measurement instrument was an FFQ, which was previously validated to the Portuguese population.[22]

Volunteers were grouped according to their total water consumption, which corresponded to the sum of drinking water (DrW), water from the dietary nutrients (DiW), and water produced by metabolism (MeW).[22] Two groups with different total daily water consumptions were identified by cluster analysis (see the following section) as Group 1, corresponding to a total water consumption lower than 3,200 mL/day (n=38), and Group 2, corresponding to a water total consumption higher than 3,200 mL/day (n=11). The groups were stratified by the total water consumption over the preceding 4 weeks, with ratings on day 0 (T0), on day 15 (T1), and on day 30 (T2). Volunteers were then asked to supplement their normal diet with a fixed daily amount of water for 4 weeks in order to establish the impact of this surplus on their normal skin physiology. A mean value of 2,000 mL water/day was adopted as the reference surplus, based on the dietary reference values for women from EFSA.[16]

To quantify skin functions, measurements took place after full acclimation to room conditions by volunteers (temperature and humidity 21°C±1°C, 45%±5%, respectively) for a period of approximately 20 minutes. All evaluations were conducted in the absence of heat sources and forced convection, according to previously published recommendations.[23] Five anatomical sites were measured – face (zygomatic and forehead), arm (ventral forearm and hand), and leg (external face). BMI (body mass index) and blood pressure were controlled throughout the study in order to identify potential changes in weight and hemodynamics. The BMI was measured by the Quetelet's formula, while hemodynamics were monitored by blood pressure and heart rate measurements.

Biometrics

The epidermal "barrier" function was assessed by the transepidermal water loss (TEWL) measurement, obtained with

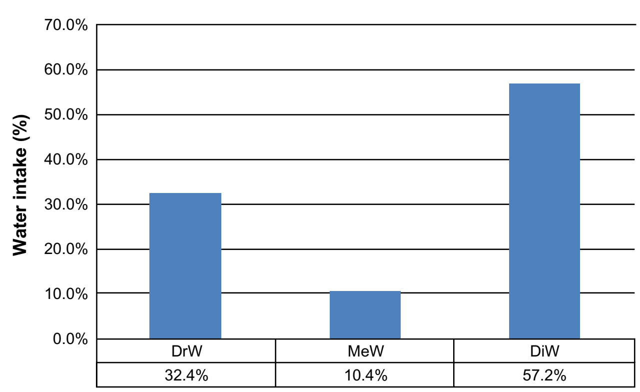

Figure 1 Contributions of DrW, MeW, and DiW to total water intake.
Abbreviations: DrW, drink water; MeW, metabolic water; DiW, diet water.

Table 1 Transepidermal water loss changes detected as an indicator of epidermal "barrier" in different anatomical areas in both groups of volunteers after the diet water surplus

	T0 (mean ± SD)	T1(mean ± SD)	T2 (mean ± SD)	*P*-value		
				(T1 vs T0)	(T2 vs T1)	(T2 vs T0)
Group 1						
Forehead	10.84±3.88	9.33±3.52	10.46±2.96	0.041*	0.176 (ns)	1.000 (ns)
Zygomatic	10.55±3.40	9.75±3.17	9.88±3.02	0.563 (ns)	0.801 (ns)	1.000 (ns)
Hand	8.88±3.25	8.31±3.01	8.40±2.77	0.641 (ns)	1.000 (ns)	0.957 (ns)
Forearm	6.14±2.34	5.55±1.83	5.79±1.64	0.346 (ns)	1.000 (ns)	1.000 (ns)
Leg	5.88±2.12	5.74±1.53	6.57±1.94	1.000 (ns)	0.080 (ns)	0.173 (ns)
Group 2						
Forehead	10.98±4.05	9.39±4.02	9.76±3.56	0.406 (ns)	1.000 (ns)	1.000 (ns)
Zygomatic	10.00±2.97	8.97±4.29	9.56±3.42	1.000 (ns)	1.000 (ns)	1.000 (ns)
Hand	8.87±2.98	7.62±2.43	8.84±4.21	0.612 (ns)	1.000 (ns)	1.000 (ns)
Forearm	5.83±1.33	4.98±1.95	4.90±1.39	0.702 (ns)	1.000 (ns)	0.136 (ns)
Leg	5.35±1.48	4.71±1.33	5.31±1.57	0.858 (ns)	1.000 (ns)	1.000 (ns)

Notes: Values are expressed in g/m^2/h. *$P<0.05$.
Abbreviations: ns, not significant; SD, standard deviation; T0, day 0; T1, day 15; T2, day 30; vs, versus.

the Tewameter TM 300 (CK Electronics, Cologne, Germany), expressed in g/m^2/h, and by the epidermal hydration measured by the MoistureMeter SC and Moisturemeter D (Delphin Technology D, Bergisch Gladbach, Germany) system, expressed in AU (arbitrary units). The "envelope" function was assessed by the Cutometer CM 575 system (in mm) from CK Technologies. The utility descriptors chosen were extensibility (U_f), the ability of the skin to return to its original state ($U_f - U_a$), total elasticity (U_a/U_f, including pulse stretching and recovery), elastic function (U_r/U_e), and viscoelasticity (U_v/U_e).[24,28,29]

Table 2 Skin hydration changes detected in different anatomical areas in both groups of volunteers after the dietary water surplus

	T0 (mean ± SD)	T1 (mean ± SD)	T2 (mean ± SD)	*P*-value (T1 vs T0)	*P*-value (T2 vs T1)	*P*-value (T2 vs T0)
Surface hydration						
Group 1						
Forehead	53.97±22.44	65.24±17.03	75.52±14.31	0.000**	0.000**	0.000**
Zygomatic	48.66±25.41	57.04±23.93	69.52±21.51	0.025*	0.000**	0.000**
Hand	33.59±18.29	30.31±16.91	47.48±15.60	0.125 (ns)	0.008*	0.000**
Forearm	29.09±11.77	35.14±13.71	37.83±13.01	0.040*	0.180 (ns)	0.000**
Leg	34.85±17.94	41.11±13.53	45.81±16.68	0.036*	0.172 (ns)	0.000**
Group 2						
Forehead	50.64±18.77	49.67±15.60	61.86±17.83	1.000 (ns)	0.023*	0.176 (ns)
Zygomatic	38.76±23.02	47.77±21.13	55.70±25.95	0.301 (ns)	0.601 (ns)	0.126 (ns)
Hand	27.01±10.06	36.08±13.52	37.26±13.50	0.312 (ns)	1.000 (ns)	0.238 (ns)
Forearm	26.89±22.16	28.16±12.30	27.94±7.85	1.000 (ns)	1.000 (ns)	1.000 (ns)
Leg	33.05±19.57	34.34±12.77	32.64±11.66	1.000 (ns)	1.000 (ns)	1.000 (ns)
Deep hydration						
Group 1						
Forehead	29.20±4.88	36.34±9.25	40.62±10.21	0.004*	0.008*	0.000**
Zygomatic	29.25±4.55	35.30±9.06	39.58±10.63	0.012*	0.007*	0.000**
Hand	33.51±5.45	41.29±10.47	46.02±11.95	0.004*	0.031*	0.000**
Forearm	23.32±3.96	28.37±7.50	30.64±8.65	0.030*	0.136 (ns)	0.000**
Leg	28.67±5.21	36.94±9.76	39.63±10.84	0.000**	0.457 (ns)	0.000**
Group 2						
Forehead	28.93±4.18	33.19±7.86	35.65±8.33	0.617 (ns)	0.720 (ns)	0.224 (ns)
Zygomatic	27.50±4.53	32.67±8.38	35.56±9.23	0.437 (ns)	0.345 (ns)	0.110 (ns)
Hand	34.15±8.59	36.72±11.10	36.70±11.25	0.315 (ns)	1.000 (ns)	0.344 (ns)
Forearm	23.94±6.34	23.58±4.06	23.90±4.53	1.000 (ns)	1.000 (ns)	1.000 (ns)
Leg	31.01±13.12	33.25±10.75	34.86±13.54	0.614 (ns)	1.000 (ns)	0.571 (ns)

Notes: Surface and deep hydration values were obtained with different Moisturemeter frequency probes and are expressed in arbitrary units. *$P<0.05$, **$P<0.001$.
Abbreviations: ns, not significant; SD, standard deviation; T0, day 0; T1, day 15; T2, day 30; vs, versus.

Table 3 Descriptive data (mean ± SD) from relevant skin biomechanical descriptors and the respective comparative statistics obtained at the beginning (T0), after two weeks (T1), and at the end (T2) of the study

	T0 (mean ± SD)	T1 (mean ± SD)	T2 (mean ± SD)	*P*-values (T1 vs T0)	(T2 vs T1)	(T2 vs T0)
U_f (mm)						
Group 1						
Leg	0.230±0.15	0.195±0.16	0.645±0.72	0.305 (ns)	0.003**	0.007**
Forearm	0.815±0.42	0.742±0.42	1.173±0.70	0.083 (ns)	0.004**	0.021*
Hand	0.941±0.43	0.816±0.40	1.173±0.71	0.509 (ns)	0.561 (ns)	0.004**
Zygomatic	1.798±0.67	2.009±0.75	1.889±0.75	0.500 (ns)	0.837 (ns)	1.000 (ns)
Forehead	0.614±0.36	0.706±0.86	1.006±0.86	0.451 (ns)	0.169 (ns)	0.031*
Group 2						
Leg	0.223±0.12	0.188±0.11	0.559±0.64	0.934 (ns)	0.352 (ns)	0.492 (ns)
Forearm	0.772±0.22	0.711±0.23	1.272±0.66	1.000 (ns)	0.171 (ns)	0.223 (ns)
Hand	0.867±0.16	0.826±0.54	1.196±0.72	1.000 (ns)	0.322 (ns)	0.395 (ns)
Zygomatic	1.594±0.77	1.735±0.91	1.711±0.89	1.000 (ns)	1.000 (ns)	1.000 (ns)
Forehead	1.005±0.68	0.872±0.70	1.067±0.83	1.000 (ns)	1.000 (ns)	1.000 (ns)
U_f–U_a (mm)						
Group 1						
Leg	0.032±0.02	0.036±0.03	0.774±0.59	1.000 (ns)	0.001***	0.001***
Forearm	0.105±0.06	0.093±0.06	0.805±0.68	0.364 (ns)	0.001***	0.001***
Hand	0.318±0.22	0.247±0.13	0.826±0.77	1.000 (ns)	0.014*	0.012*
Zygomatic	1.024±0.65	1.323±0.83	1.235±0.97	0.380 (ns)	1.000 (ns)	0.819 (ns)
Forehead	0.183±0.11	0.263±0.19	0.758±0.56	0.852 (ns)	0.018*	0.030*
Group 2						
Leg	0.032±0.02	0.022±0.01	0.469±0.46	0.403 (ns)	0.522 (ns)	0.549 (ns)
Forearm	0.121±0.06	0.087±0.03	0.814±0.80	0.255 (ns)	0.226 (ns)	0.267 (ns)
Hand	0.163±0.13	0.368±0.30	0.899±0.89	0.975 (ns)	0.546 (ns)	0.252 (ns)
Zygomatic	0.709±0.53	1.261±0.88	1.231±0.97	0.484 (ns)	1.000 (ns)	0.490 (ns)
Forehead	0.651±0.54	0.525±0.55	0.845±0.85	1.000 (ns)	0.690 (ns)	1.000 (ns)
U_a/U_f						
Group 1						
Leg	0.838±0.06	0.826±0.09	0.604±0.35	1.000 (ns)	0.002**	0.001**
Forearm	0.820±0.14	0.809±0.13	0.644±0.32	1.000 (ns)	0.020*	0.008**
Hand	0.782±0.21	0.776±0.18	0.647±0.29	1.000 (ns)	0.086 (ns)	0.017*
Zygomatic	0.577±0.27	0.505±0.27	0.595±0.32	0.624 (ns)	0.134 (ns)	1.000 (ns)
Forehead	0.746±0.14	0.727±0.19	0.590±0.29	1.000 (ns)	0.044*	0.015*
Group 2						
Leg	0.824±0.07	0.838±0.08	0.655±0.30	1.000 (ns)	0.406 (ns)	0.365 (ns)
Forearm	0.790±0.08	0.795±0.06	0.607±0.31	1.000 (ns)	0.316 (ns)	0.280 (ns)
Hand	0.765±0.15	0.723±0.20	0.617±0.33	0.756 (ns)	0.907 (ns)	0.666 (ns)
Zygomatic	0.626±0.26	0.543±0.23	0.591±0.30	1.000 (ns)	1.000 (ns)	1.000 (ns)
Forehead	0.612±0.22	0.680±0.26	0.610±0.32	1.000 (ns)	0.847 (ns)	1.000 (ns)
U_r/U_e						
Group 1						
Leg	1.201±0.29	1.300±0.31	0.925±0.63	0.539 (ns)	0.011*	0.051 (ns)
Forearm	0.860±0.28	0.823±0.22	0.622±0.38	1.000 (ns)	0.026*	0.006**
Hand	0.744±0.37	0.768±0.33	0.590±0.35	1.000 (ns)	0.068 (ns)	0.084 (ns)
Zygomatic	0.403±0.24	0.328±0.25	0.385±0.26	0.476 (ns)	0.402 (ns)	1.000 (ns)
Forehead	0.738±0.22	0.712±0.27	0.619±0.44	1.000 (ns)	0.715 (ns)	0.410 (ns)
Group 2						
Leg	1.166±0.24	1.230±0.43	0.926±0.53	1.000 (ns)	0.406 (ns)	0.365 (ns)
Forearm	0.765±0.17	0.792±0.10	0.529±0.34	1.000 (ns)	0.211 (ns)	0.288 (ns)
Hand	0.721±0.31	0.713±0.38	0.615±0.41	1.000 (ns)	1.000 (ns)	1.000 (ns)
Zygomatic	0.453±0.31	0.326±0.21	0.443±0.29	0.670 (ns)	0.446 (ns)	1.000 (ns)
Forehead	0.571±0.29	0.654±0.33	0.606±0.42	1.000 (ns)	1.000 (ns)	1.000 (ns)

(*Continued*)

Table 3 (*Continued*)

	T0 (mean ± SD)	T1 (mean ± SD)	T2 (mean ± SD)	*P*-values		
				(T1 vs T0)	(T2 vs T1)	(T2 vs T0)
U_v/U_e						
Group 1						
Leg	0.963±0.26	1.081±0.32	0.797±0.57	0.277 (ns)	0.040*	0.280 (ns)
Forearm	0.624±0.19	0.631±0.16	0.463±0.27	1.000 (ns)	0.012*	0.015*
Hand	0.576±0.33	0.615±0.26	0.461±0.26	1.000 (ns)	0.065 (ns)	0.307 (ns)
Zygomatic	0.260±0.18	0.215±0.21	0.231±0.16	0.995 (ns)	1.000 (ns)	1.000 (ns)
Forehead	0.689±0.24	0.661±0.26	0.589±0.56	1.000 (ns)	1.000 (ns)	0.966 (ns)
Group 2						
Leg	0.979±0.24	1.051±0.39	0.864±0.54	1.000 (ns)	1.000 (ns)	1.000 (ns)
Forearm	0.630±0.20	0.686±0.15	0.442±0.25	0.640 (ns)	0.080 (ns)	0.166 (ns)
Hand	0.544±0.12	0.588±0.23	0.490±0.28	1.000 (ns)	0.777 (ns)	1.000 (ns)
Zygomatic	0.368±0.24	0.309±0.23	0.334±0.29	1.000 (ns)	1.000 (ns)	1.000 (ns)
Forehead	0.561±0.24	0.606±0.32	0.535±0.42	1.000 (ns)	1.000 (ns)	1.000 (ns)

Notes: **P*<0.05, ***P*<0.001.
Abbreviations: ns, not significant; SD, standard deviation; T0, day 0; T1, day 15; T2, day 30; U_f, extensibility; U_f–U_a, the ability of the skin to return to its original state; U_a/U_f, total elasticity (including pulse stretching and recovery); U_r/U_e, elastic function; U_v/U_e, viscoelasticity; vs, versus.

Statistics

Statistical analysis (descriptive and comparative) was performed using the SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) software. The cluster's analysis, which is based on a hierarchic model that groups similar "objects", allowed to identify a group of individuals consuming less than 3,200 mL/day (n=38) as Group 1, and another group of individuals consuming more than 3,200 mL/day (n=11), as Group 2. The analysis of variance generalized linear model, the sphericity test of Mauchly, and the Levene test were applied to both groups. The goal was to test the homogeneity of these populations. So, we confirmed that variance of endpoint variables for these two groups were similar and that the data distribution was narrow, tending to normal. Post hoc multiple comparisons were performed using the Bonferroni test, a suitably robust method to control errors in handling.[30] Variables were also compared by the Spearman correlation coefficient. A confidence level of 95% was adopted. Due to the population homogeneity of age, age correction was not regarded as necessary.

Results and discussion

The water consumption pattern was crucial to assess the impact of dietary water on the cutaneous physiology within this population. Previous results have drawn attention to the importance of DiW in quantitative terms, representing more than 50% of the total water related to diet.[1,21,31] DiW includes water from food, juices and soup, and in accordance with those results, our FFQ detected that DiW contributed 57.2% of the total water accounted within these patients' diets, stressing the need to consider all sources of water input to calculate the total water consumption (Figure 1).

Results obtained from both groups having different daily water consumptions revealed no relevant changes regarding epidermal barrier and TEWL. As shown in Table 1, we found a progressive decreasing gradient from the face, the highest (forehead and zygomatic area), to the forearm and leg, where the lowest values were recorded in both groups. This is in accord with the known expected anatomical and functional variation.[32–35] Thus, our methodology did not significantly change the epidermal barrier in both groups. Regarding epidermal hydration, however, a dramatically different reality was registered, with a consistent improvement of superficial and deep hydration in both groups, although with different magnitudes (Table 2). In fact, changes observed in the group with lower initial water consumption (Group 1) were significantly greater and present in all anatomical areas, relative to the (reduced) impact observed in Group 2. Similar results were previously reported in individuals with dry skin, leading the authors to suggest that increasing the dietary water intake would affect the skin the same way as a topical moisturizer.[2] In our current study, impact on epidermal hydration was consistently noticed in both surface and deep hydration variables, which may signify that more water is available for the normal physiological processes (Table 2). These effects are especially detectable in Group 1, from T1 forward.

In order to look further into the impact of this dietary water overload on the skin's physiology, we also assessed the so-called "envelope" function. Skin hydration has been related to skin mechanics to justify preservation of a younger,

Table 4 Correlations (Spearman) found between epidermal hydration variables (superficial and deep) and the most relevant biomechanical descriptors obtained in the beginning (T0), after 2 weeks (T1) and in the end (T2) of the study

	T0		T1		T2	
	R	*P*-value	*R*	*P*-value	*R*	*P*-value
Face						
Group 1						
Surface hydration						
U_f	–0.113	0.489 (ns)	0.005	0.976 (ns)	0.405	0.010*
$U_f – U_a$	–0.004	0.980 (ns)	0.382	0.016*	0.567	0.000***
U_a/U_f	0.021	0.901 (ns)	0.011	0.945 (ns)	–0.132	0.425 (ns)
Deep hydration						
U_f	–0.036	0.835 (ns)	–0.053	0.761 (ns)	0.296	0.071 (ns)
$U_f – U_a$	–0.038	0.827 (ns)	0.342	0.044*	0.528	0.001***
U_a/U_f	–0.096	0.561 (ns)	–0.120	0.466 (ns)	–0.75	0.648 (ns)
Group 2						
Surface hydration						
U_f	0.722	0.018*	0.684	0.029*	0.636	0.048*
$U_f – U_a$	0.043	0.907 (ns)	0.394	0.260 (ns)	0.600	0.067 (ns)
U_a/U_f	–0.597	0.068 (ns)	–0.264	0.462 (ns)	–0.851	0.002**
Deep hydration						
U_f	–0.422	0.258 (ns)	0.540	0.133 (ns)	0.576	0.082 (ns)
$U_f – U_a$	–0.600	0.088 (ns)	0.583	0.099 (ns)	0.709	0.002*
U_a/U_f	0.273	0.084 (ns)	–0.487	0.153 (ns)	–0.505	0.137 (ns)
Upper limb						
Group 1						
Surface hydration						
U_f	–0.447	0.004**	–0.060	0.720 (ns)	0.005	0.977 (ns)
$U_f – U_a$	–0.138	0.394 (ns)	–0.271	0.095 (ns)	0.125	0.460 (ns)
U_a/U_f	0.205	0.200 (ns)	0.347	0.030*	0.097	0.556 (ns)
Deep hydration						
U_f	–0.294	0.086 (ns)	–0.276	0.114 (ns)	–0.014	0.936 (ns)
$U_f – U_a$	0.006	0.973 (ns)	–0.426	0.011*	0.381	0.020*
U_a/U_f	–0.072	0.664 (ns)	0.173	0.292 (ns)	–0.099	0.549 (ns)
Group 2						
Surface hydration						
U_f	–0.468	0.173 (ns)	–0.721	0.019*	0.072	0.865 (ns)
$U_f – U_a$	–0.390	0.265 (ns)	0.188	0.603 (ns)	0.758	0.011*
U_a/U_f	–0.238	0.508 (ns)	0.131	0.719 (ns)	–0.775	0.008**
Deep hydration						
U_f	–0.157	0.687 (ns)	–0.750	0.020*	–0.206	0.624 (ns)
$U_f – U_a$	–0.305	0.424 (ns)	–0.400	0.286 (ns)	0.923	0.000***
U_a/U_f	0.534	0.112 (ns)	0.467	0.173 (ns)	–0.742	0.014*
Leg						
Group 1						
Surface hydration						
U_f	–0.373	0.019*	–0.356	0.028*	–0.179	0.295 (ns)
$U_f – U_a$	–0.468	0.002**	–0.476	0.003**	0.111	0.511 (ns)
U_a/U_f	–0.165	0.309 (ns)	0.097	0.553 (ns)	–0.109	0.503 (ns)
Deep hydration						
U_f	–0.266	0.123 (ns)	0.099	0.578 (ns)	–0.148	0.389 (ns)
$U_f – U_a$	–0.050	0.765 (ns)	–0.121	0.496 (ns)	0.216	0.199 (ns)
U_a/U_f	–0.049	0.763 (ns)	0.209	0.196 (ns)	–0.173	0.285 (ns)
Group 2						
Surface hydration						
U_f	–0.292	0.414 (ns)	0.006	0.987 (ns)	0.095	0.824 (ns)
$U_f – U_a$	–0.455	0.187 (ns)	–0.103	0.777 (ns)	0.723	0.018*
U_a/U_f	0.315	0.375 (ns)	0.379	0.280 (ns)	0.316	0.374 (ns)
Deep hydration						
U_f	–0.496	0.174 (ns)	–0.117	0.765 (ns)	0.176	0.678 (ns)
$U_f – U_a$	–0.517	0.154 (ns)	–0.200	0.606 (ns)	0.496	0.145 (ns)
U_a/U_f	0.111	0.760 (ns)	0.102	0.779 (ns)	–0.212	0.556 (ns)

Notes: $*P<0.05$, $**P<0.01$, $***P<0.001$.
Abbreviations: ns, not significant; T0, day 0; T1, day 15; T2, day 30; U_f, extensibility; $U_f – U_a$, the ability of the skin to return to its original state; U_a/U_f, total elasticity (including pulse stretching and recovery); U_r/U_e, elastic function; U_v/U_e, viscoelasticity.

healthier looking skin. Dermal water was reported to decrease the friction between fibers, acting as a "lubricant", including in the upper layers, thus facilitating the dynamics of the overall structure.[26,36] However, a direct relationship between skin hydration and biomechanics has not been clearly demonstrated.[37–39]

Biomechanical descriptors such as maximum extensibility (U_f), the ability to return to the original state ($U_f - U_a$), total elasticity (U_a/U_f), elastic function (U_r/U_e), and the viscoelastic ratio (U_v/U_e) were chosen as the most relevant, in accordance to several authors[40,41] and because they have been referred as the most useful to detect improvements in the plasticity of skin[41–45] (Table 3). As mentioned previously, our experimental methodology did impact skin biomechanics in both groups with different magnitudes, and statistically significant evidence of biomechanical changes could be found in Group 1 (Table 3). Total extensibility (U_f) significantly improved in all body areas except the face after the 2 weeks of the test. By the end of the study, these improvements were still present in all the tested regions, with significant differences present in the leg, forearm, hand, and in the forehead (Table 3). Similar impact was registered for the ability of the skin to return to its original state ($U_f - U_a$), which significantly increased after the 2 weeks (T1) and 4 weeks (T2) of the water surplus in all the tested areas, except the zygomatic region in the face. This consistent increase of U_f and $U_f - U_a$ throughout the study seems to be related with the highest amount of water available in the epidermis of these volunteers, facilitating deformation and recovery after stress, as has been previously suggested.[25,46] The evolution of the other ratios are more difficult to follow. Total elasticity (U_a/U_f) was significantly reduced in all tested areas except the zygomatic, especially in T2, and this reflects a higher impact of the water surplus on skin extensibility (Table 3) rather than in the elastic recovery (U_a). The elastic function U_r/U_e and viscoelasticity (U_v/U_e) do not follow this pattern. However, these descriptors are closely age-related, thus they depend primarily on the dermal components whose contribution(s) cannot be specifically quantified with these methods.[28,40,47,48] A decrease in the viscoelasticity index has been reported after regular long-term use of topical moisturizers.[26,43]

We have finally analyzed a potential relationship between the most relevant descriptors representing epidermal hydration and biomechanics. In fact, many of the factors that modify skin mechanical properties have been identified, but relationships between epidermal structure and these characteristics are still insufficiently documented. Although suggested for many years,[49] experimental evidence is still recent (although rare), and are frequently obtained from other perspectives.[50–52] Moreover, the in vivo approach is particularly difficult, considering the close relationship between cutaneous tissues and the poor discriminative capacity of currently available technology. Recent results from a three-layer computational skin model[53] and from a new dynamic mechanical device,[54] both assessing mechanical properties of skin under different conditions, suggested that the epidermis, the statum corneum in particular, and different factors such as hydration, do influence skin mechanical properties in vivo as well.

After calculating a confidence range for each anatomical area, our data was tested by the Spearman correlation coefficient, a well-known determinant for these properties.[41,45] In this way, an estimated interval allowed a mean value calculation for each variable in the face, upper limb (forearm and hand), and leg in both groups. As shown in Table 4, clear, consistent relationships between epidermal hydration and biomechanical descriptors could not be found under the present experimental conditions. Nevertheless, significant relationships are nearly absent in both groups at T0. The water stress test seems to contribute to the significant relationships found, especially at T2 and in particular within Group 1. The progressive reduction of these relationships from the face to the leg areas should also be mentioned (Table 4). More sensitive, discriminative technology may be a key aspect behind this apparent absence of differential data.

Conclusion

The clinical relevance of this approach should be strongly emphasized in specific conditions where the correction of skin water balance by strategies other than pharmacological might dramatically improve the patient's quality of life. This particularly may be the case for the elderly or obese, for whom dry skin is a consistent compliant.

The present methodology allowed, for the first time, an objective clinical approach to study the effects of dietary water on normal skin physiology. These results seem to confirm that higher water inputs in one's regular diet might positively impact normal skin physiology, as expressed by its hydration and biomechanical behavior, and in particular in those individuals with lower daily water consumptions.

Acknowledgments

The authors thanks all patients enrolled in the study, and Carla Monteiro and Osvaldo Santos for statistical support.

Disclosure

The authors report no conflicts of interest in this work.

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