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Comparative Effect of Soft, Hard and Chlorinated Water on Atopic Skin and Clinical Benefits of a Dermocosmetic Routine

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Abstract

Background: Epidemiological data link hard and chlorinated water to atopic dermatitis (AD), but experimental evidence on their effect and on dermocosmetic benefit remains limited. Objectives: We aimed to compare the effects of soft, hard, and chlorinated water on atopic skin and assess whether a dermocosmetic routine mitigates these effects. Methods: In a 3-day, open-label, intra-individual study, 66 adults with atopic skin underwent repeated forearm immersions (five cycles/day) in soft, hard, or chlorinated water. One forearm received a cleansing-oil and moisturising-balm routine after each cycle; the contralateral forearm served as untreated control. TEWL, hydration, and global discomfort were assessed. In a 21-day real-life study, adults with AD regularly exposed to hard domestic or swimming-pool water used the routine daily. Discomfort and quality of life were recorded. Results: Water immersion induced modest, inconsistent TEWL changes, increased hydration and slightly reduced discomfort, without differences between water types. The routine reduced TEWL, increased hydration, and decreased discomfort for all water types. In real life, it produced immediate and sustained improvements in discomfort and quality of life. Conclusions: Under controlled exposure, soft, hard, and chlorinated water exert comparable, limited effects on atopic skin. The dermocosmetic routine consistently improves barrier-related parameters and comfort, independently of water type.

Keywords: atopic dermatitis; cosmetic routine; soft water; hard water; chlorinated water

1. Introduction

Atopic dermatitis (AD) is a chronic inflammatory skin disease characterised by recurrent eczematous flares, intense pruritus, and xerosis, which substantially contribute to its burden [1]. It may cause physical discomfort, emotional distress, stigma, and limitations in daily activities, including sleep and social functioning [2]. Although genetic predisposition plays a central role in AD pathogenesis, environmental factors are increasingly recognised as important modulators of disease onset and flares. Exposure to external stressors such as harsh cleansers, pollutants, weather changes, and variations in water quality can impair skin barrier integrity and heighten sensitivity to irritants and allergens [1]. Consequently, addressing modifiable environmental triggers is considered an essential component of AD management and may help improve the quality of life of those affected.

Epidemiological data suggest an association between domestic water hardness and the prevalence of AD, with some evidence that early-life exposure may increase the risk of eczema in childhood [3–5]. Supporting this notion, clinical studies have shown that

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both children with and without filaggrin (FLG) mutations exhibit higher TEWL when exposed to elevated calcium carbonate ($CaCO_3$) levels, suggesting that hard water may contribute to barrier dysfunction independently of FLG status [6]. Hard water, rich in $CaCO_3$ and magnesium, has been proposed to affect skin barrier function through several mechanisms. By raising skin pH, it may enhance protease activity in the stratum corneum, thereby accelerating the breakdown of corneodesmosomes and reducing the synthesis of lipid lamellae, which can ultimately increase transepidermal water loss (TEWL) and skin dryness [7]. Large-scale population-based investigations have further supported this association, reporting higher AD prevalence in regions with harder water supplies [8,9]. In addition, hard water may promote the use of larger quantities of soaps and detergents to achieve effective cleansing, which can further irritate already dry or compromised skin [10]. An instrumental study comparing skin responses in subjects with AD and healthy controls demonstrated that hard water increased the deposition of sodium lauryl sulphate and was associated with greater TEWL and irritation, particularly among FLG mutation carriers [10]. In this context, soap anions can interact with calcium cations to form insoluble chalk-like residues that remain on the skin surface and may exacerbate irritation in individuals with eczema-prone skin [11]. Taken together, these findings indicate that water hardness may act as a cofactor in skin barrier disruption, although the exact magnitude and clinical relevance of this effect remain to be fully elucidated.

Chlorinated water, commonly used for disinfection of domestic tap water and swimming pools, may pose additional challenges for individuals with atopic skin. Sodium hypochlorite (NaClO) can induce oxidative stress and contribute to epidermal barrier impairment. Its by-products, including nitrogen trichloride (trichloramine), are recognised irritants that have been associated with skin inflammation, ocular discomfort, and respiratory irritation [12]. Exposure to chlorine in swimming pools has been linked to irritant or allergic contact dermatitis in some sensitive individuals, sometimes referred to as “pool water dermatitis” [13]. However, epidemiological studies have not consistently demonstrated a clear, independent effect of chlorine on AD risk [14], and the interaction between chlorine exposure and skin barrier status remains poorly defined.

European guidelines for AD management emphasise daily dermocosmetic care with gentle cleansers and regular emollient application to restore hydration and support barrier integrity [15]. In line with these recommendations, we previously showed that a dermocosmetic routine based on a cleansing oil and a moisturising soothing balm (NAOS, Laboratoire Bioderma, France) improves barrier function and AD symptoms when used either adjunctively or alternately with conventional topical therapies [16]. In the present study, we aimed to experimentally assess the cumulative effects of repeated exposure to soft, hard, and chlorinated water on atopic skin, and to evaluate whether this dermocosmetic routine could mitigate these effects and improve subjective comfort and quality of life.

2. Materials and Methods

2.1. Investigated Products

The products investigated in this study were specifically formulated for atopic skin. They consist of a pH-balanced cleansing oil [Atoderm line, NAOS (Bioderma), 13290 Aix-en-Provence, France] and a balm enriched with moisturising and anti-inflammatory agents [Atoderm line, NAOS (Bioderma), 13290 Aix-en-Provence, France]. A breakdown of their composition is provided in Table 1.

Table 1. Breakdown of the composition of the cleansing oil and the moisturising/anti-inflammatory balm.

Properties	Ingredients (INCI Names)
Cleansing Oil	
Formulation water	Aqua/Water/Eau
Hydration	Glycerin—Glyceryl Oleate
Cleansing agents	PEG-7 Glyceryl Cocoate — Sodium Cocoamphoacetate — Lauryl Glucoside—Coco-Glucoside
Replenishing agents	Glyceryl Oleate—Niacinamide
Soothing agent	Mannitol—Xylitol—Rhamnose — Fructooligosaccharides
Formulation base	PEG-90 Glyceryl Isostearate—Citric Acid — Fragrance -Polysorbate 20 — Laureth-2—Tocopherol — Hydrogenated Palm Glycerides Citrate — Lecithin—Ascorbyl Palmitate
Moisturising/anti-inflammatory Balm	
Formulation water	Aqua/Water/Eau
Hydration	Glycerin—Pentylene Glycol—1,2-Hexanediol
Replenishing agents	Paraffinum Liquidum/Mineral Oil/Huile Minérale — *Helianthus annuus* (Sunflower) Seed Oil — Canola Oil/Huile de Colza—Ceramide NP — Phytosphingosine—Ceramide AP — Cholesterol—Ceramide EOP — Caprylic/Capric Triglyceride
Soothing agent	Palmitamide MEA—Beta-Sitosterol — Xylitol—Mannitol—Rhamnose — *Laminaria ochroleuca* Extract
Anti-dysbiosis agents	Zinc Gluconate—Sucrose Stearate
Formulation base	Behenyl Alcohol— Hydroxyethyl Acrylate/Sodium Acryloyldimethyl Taurate Copolymer — Acrylates/C10-30 Alkyl Acrylate Crosspolymer — Caprylyl Glycol—Sodium Citrate — Sodium Lauroyl Lactylate—Sodium Hydroxide — Polysorbate 60—Sorbitan Isostearate—Tocopherol — Ethylhexylglycerin—Carbomer—Xanthan Gum — Fructooligosaccharides—Citric Acid

2.2. Ethics

The effects induced by water (soft, hard, and chlorinated) and by the two products were assessed in two clinical evaluations: (i) the assessment of the effects of repeated forearm immersion of forearms of subjects with atopic skin in soft, hard, or chlorinated water; (ii) the evaluation of the effects induced by repeated exposure of subjects with atopic skin to hard or swimming pool water under real-life conditions.

Both studies consisted of the non-invasive evaluation of cosmetic products; neither required approval by an ethics committee, in accordance with current legislation (Regulation (EC) No 1223/2009, Commission Regulation (EU) No 655/2013, and the Polish Order of the Minister of Health of 2 May 2012, Dz.U. 2012, item 491), even though the investigations concerned subjects with AD. Both studies adhered to the principles of the Declaration

of Helsinki and complied with Good Clinical Practice. All participants received detailed information regarding the study and provided written informed consent before enrolment.

2.3. Repeated Immersion of Forearms of Subjects with Atopic Skin in Soft, Hard, or Chlorinated Water

This three-day, open-label, intra-individual controlled study aimed to assess the effects of repeated water exposure and of a dermocosmetic routine (cleansing oil application and balm application) on the forearm skin of subjects with AD, comparing the effect of soft, hard, and chlorinated water, as well as evaluating within-day and between-day changes in skin parameters and subjective discomfort between randomly assigned treated and untreated forearm areas.

2.3.1. Subjects

A total of 66 subjects (60 women and 6 men; age range: 18–66 years; mean age ± SD: 40.5 ± 12.9 years) diagnosed with AD by a physician were recruited. The presence of AD was confirmed upon inclusion; however, participants with active eczema flares were excluded, as were those presenting cutaneous lesions or excessive hair on the forearms. Individuals under topical or systemic treatments that could interfere with the study, or those who had received such treatments within the two weeks preceding enrolment, were also excluded.

2.3.2. Interventions

Throughout the three-day study period, participants maintained their usual hygiene routine but were asked to refrain from applying any hygiene or skincare products to the forearm test areas.

Participants were randomly divided into three subgroups of 22 subjects whose forearms were immersed in (i) soft water (SW) produced by ion-exchange softening (Claro 25 L USTM, USTM, Poland) of local hard tap water (350–550 mg $CaCO_3$/L, 19.6–30.8 °dH) to an expected <17 mg $CaCO_3$/L; (ii) hard water (HW), unmodified local tap water verified at >400 mg $CaCO_3$/L using Aquadur® 4–21 semi-quantitative test strips (Macherey-Nagel, Germany); and (iii) chlorinated water (CW) prepared by adding a sodium hypochlorite to soft water, yielding 28.6 mg Cl_2/L, a concentration substantially exceeding Polish swimming pool regulation (0.3–1.4 mg Cl_2/L).

All three water types were maintained at 30 ± 2 °C in a controlled environment (22 ± 2 °C, 35–55% relative humidity).

Each day, participants underwent successive forearm immersions in the allocated water type (soft, hard, or chlorinated). A randomly selected forearm served as control forearm and was immersed in water for 10 min and then gently dried. The contralateral treated forearm was immersed for 10 min and rubbed with the cleansing oil for 2 min. In the chlorinated water condition only, it was then briefly rinsed with soft water. After gentle drying, the balm was applied to the treated forearm. After a 10-min interval, this immersion/treatment protocol was repeated for both forearms, resulting in a total of five cycles per day to simulate two weeks of daily washing within a three-day period.

2.3.3. Instrumental and Subjective Assessments

Evaluations were conducted twice-daily for both control and treated forearms. An initial assessment was performed before the first immersion/treatment cycle, and a second assessment was performed one hour after the final immersion/treatment cycle.

Instrumental evaluations included TEWL quantification using the Tewameter® TM 300 (Courage+Khazaka Electronic GmbH, Germany) and calculation of the skin hydration index (HI) using the MoistureMap MM 100® (Courage+Khazaka Electronic GmbH, Germany).

Participants rated their skin dryness, irritation, itching, tightness, and burning on a 0 (none) to 15 (severe) scale. The sum of the five scores yielded a global discomfort score on a 0–75 scale.

Adverse events were monitored throughout the study.

2.4. Repeated Exposure of Subjects with Atopic Skin to Hard or Swimming Pool Water Under Real-Life Conditions

This open-label, observational study evaluated the effects of a dermocosmetic routine consisting of the application of the cleanser and the balm in subjects with atopic skin regularly exposed to hard domestic or swimming pool water.

2.4.1. Subjects

Sixty-six subjects (31 women and 35 men; age range: 19–78 years; mean age ± SD: 38.5 ± 14.9 years) were recruited. All participants fulfilled the UK Working Party's diagnostic criteria for atopic dermatitis, presenting pruritus and at least three associated criteria: xerotic skin, personal history of eczema, history of asthma, rhinitis or allergic conjunctivitis, latent eczema, or onset of symptoms before the age of two [17]. Individuals under topical or systemic treatments that could interfere with the study were excluded, as were those who had received such treatments within the two weeks preceding enrolment.

Participants were divided into two subgroups of 33 subjects: a hard water subgroup, comprising subjects residing in a city supplied with hard water (350–550 mg $CaCO_3$/L, 19.6–30.8 °dH according to Polish standard), and a swimming pool water subgroup (0.3–1.4 mg Cl_2/L according to Polish regulation).

2.4.2. Interventions

Participants in the hard water subgroup used their domestic water supply for daily showering or bathing. Those in the swimming pool water subgroup attended two or three one-hour swimming pool sessions per week. Throughout the 21-day study period, all participants only washed their entire body with the cleansing oil at least once daily and applied the balm to the entire body twice daily. While they were permitted to maintain their usual routine, they were asked to refrain from using any other hygiene or skincare products on the forearm test areas.

2.4.3. Subjective and Tolerance Assessments

Subjects self-assessed five skin discomfort parameters: itching, irritation, burning sensation, tightness, and dryness, using a 4-point scale (0 = none, 3 = severe). The sum of these scores yielded a global discomfort score on a 0 to 15 scale. Assessments were conducted at baseline, immediately after the first exposure to hard or swimming pool water and product application (no later than 10–30 min after), and at study completion (day 21).

At baseline and at study completion, subjects also completed the Dermatology Life Quality Index (DLQI), a 10-item questionnaire resulting in a 0 (no impact on quality of life) to 30 (very high impact on quality of life) scale [18,19].

Adverse events were monitored throughout the study.

2.5. Statistical Analysis

Results are presented as means ± standard deviation (SD).

For continuous data (TEWL and hydration index), distribution was first assessed using the Shapiro–Wilk test ($\alpha < 0.05$). Comparisons between two conditions were performed using paired t-tests for normally distributed data and Wilcoxon signed-rank tests otherwise. Multiple comparisons of normally distributed data were performed using repeated-measures ANOVA followed by Tukey's HSD *post hoc* tests. Non-normally distributed data

were analysed using the Friedman test followed by pairwise comparisons with Wilcoxon signed-rank tests. In both cases *p*-values were adjusted using the Bonferroni correction.

All other outcomes were ordered categorical data, compared using Wilcoxon signed-rank tests. In the case of multiple comparisons, Friedman tests were first performed, and the significances from subsequent pairwise comparisons with Wilcoxon signed-rank tests were adjusted using the Bonferroni correction.

For all analyses, results were considered statistically significant for *p*-values (or Bonferroni adjusted *p*-values) below 0.05.

3. Results

3.1. Effect of Soft, Hard, and Chlorinated Water Immersion on Atopic Skin

To experimentally assess differences in the effect of soft, hard, and chlorinated water on atopic skin, we evaluated skin reactions (TEWL and hydration index) to these different water types by mimicking two weeks of daily washing within a three-day period. Among the 66 enrolled subjects, 65 completed the study; one participant from the chlorinated water group discontinued at the end of day 1 due to an adverse reaction to the water.

Intraday comparisons—performed before the first immersion cycle (T0) and one hour after the last cycle (T1)—revealed only occasional effects on TEWL across all water types (Figure 1A). Significant increases were observed on day 0 for soft water (+5%, $p = 0.037$), day 2 for hard water (+5%, $p < 0.001$), and days 1 and 2 for chlorinated water (+5% for both, $p = 0.002$ and 0.012, respectively). Multiple comparisons of measurements within each water type did not reveal significant differences among the six time points. Likewise, multiple comparisons of intraday TEWL differences across all three water types were not statistically significant (Figure 1B).

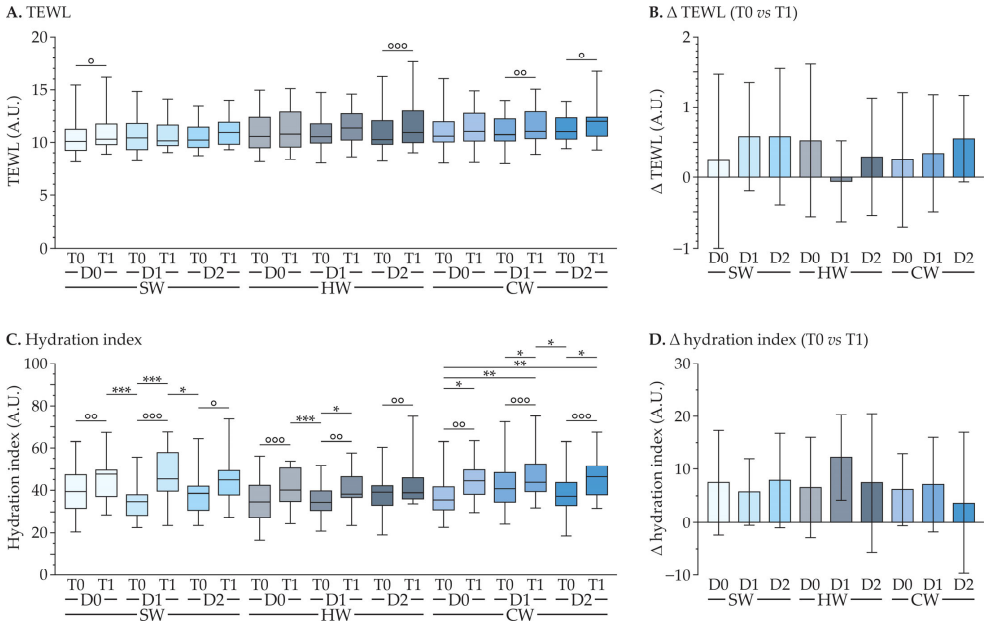


Figure 1. Variations in (**A**) TEWL and (**C**) hydration index, and intraday variations in (**B**) TEWL and (**D**) hydration index upon repeated immersion of control forearms in soft (SW), hard (HW), and chlorinated water (CW). Evaluations were conducted from day 0 (D0) until day 2 (D2), with measurements taken before the first immersion cycle (T0) and one hour after the last immersion cycle (T1). Intraday statistical comparisons between T0 and T1 are indicated with °: $p < 0.05$, °°: $p < 0.01$, and °°°: $p < 0.001$. Statistical significances from multiple comparisons of the effects of a given water type over the three days are reported as Bonferroni-adjusted *p*-values using *: $p < 0.05$; **: $p < 0.01$, and ***: $p < 0.001$.

A similar analysis of intraday hydration index variations (Figure 1C) revealed significant increases after each immersion cycle, ranging from a minimum of +11% (day 2 with chlorinated water, $p < 0.001$) to a maximum of +32% (day 2 with soft water, $p < 0.001$). Although multiple comparisons within each water type identified several differences, no consistent pattern of progressive increase or decrease was observed over the study period. In addition, multiple comparisons of intraday differences induced by all three water types did not show statistically significant differences (Figure 1D).

Assessment of intraday variations in global discomfort induced by immersion cycles (Figure 2A) revealed a reduction in discomfort on day 2 with soft water (−10%, $p = 0.011$) and on day 1 with hard water (−5%, $p = 0.038$). Upon multiple comparisons within each water type, hard water resulted in statistically significant decreases in discomfort on days 1 and 2 compared with day 0, both before and after immersion cycles; a phenomenon also observed between baseline and day 2 with soft water. Finally, comparisons of intraday variations across the three water types did not reveal significant differences (Figure 2B).

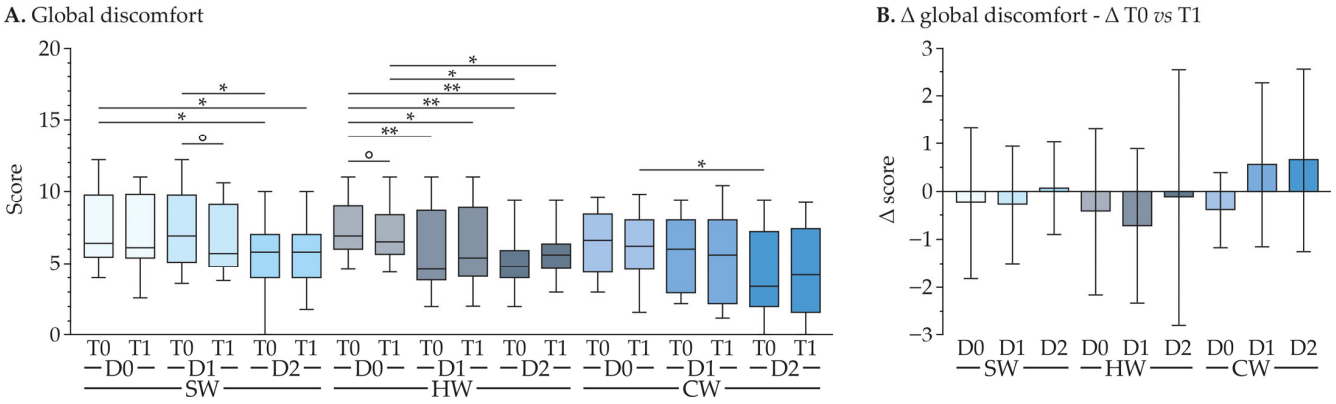


Figure 2. Variations in (**A**) global discomfort scores and intraday variations in (**B**) global discomfort scores upon repeated immersion of control forearms in soft (SW), hard (HW), and chlorinated water (CW). Evaluations were conducted from day 0 (D0) until day 2 (D2), with assessments performed before the first immersion cycle (T0) and one hour after the last immersion cycle (T1). Intraday statistical comparisons between T0 and T1 are indicated with °: $p < 0.05$. Statistical significances from multiple comparisons of the effects of a given water type over the three days are reported as Bonferroni-adjusted *p*-values with *: $p < 0.05$ and **: $p < 0.01$.

3.2. Benefits of the Dermocosmetic Routine on Atopic Skin Immersed in Soft, Hard, or Chlorinated Water

We then evaluated the effect of the dermocosmetic routine on forearms subjected to repeated immersions in soft, hard, and chlorinated water, comparing control forearms that were immersed in water with treated forearms that were rubbed with the cleansing oil during immersion and received the balm afterwards. The analysis is based on the 65 subjects who completed the study.

Upon multiple comparisons, TEWL measurements on control forearms confirmed limited time point-dependent variations across all water types (Figure 3A–C). Specifically, intraday TEWL variations—assessed by comparing values before (T0) and after the last immersion cycle (T1)—were restricted to day 2 with hard water, confirming the limited effect of water immersion *per se* on TEWL. By contrast, routine-treated forearms exhibited several statistically significant differences. With the exception of day 1 in the chlorinated water condition, the dermocosmetic treatment consistently induced a significant intraday decrease in TEWL (T0 *versus* T1; adjusted $p < 0.01$ to 0.001). Furthermore, TEWL values recorded after the immersion cycles on days 1 and 2 were significantly lower in routine-treated forearms than those measured on day 0 before the first immersion (adjusted

$p < 0.05$–0.001). When comparing routine-treated and untreated forearms at identical time points—excluding baseline, at which no treatment had yet been applied—lower TEWL was observed in treated forearms across all time points for both soft and hard water conditions (adjusted $p < 0.05$ to 0.001). A similar pattern of TEWL reduction was also observed in the chlorinated water condition, although it was restricted to time points following immersion cycles (adjusted $p < 0.05$ to 0.001 vs. untreated forearms). Finally, whilst the dermocosmetic routine appeared to exert a cumulative effect on TEWL over time, this was statistically significant only in the hard water condition, for which TEWL values measured before the immersion cycles on days 1 and 2 were significantly lower than the corresponding baseline measurement on day 0.

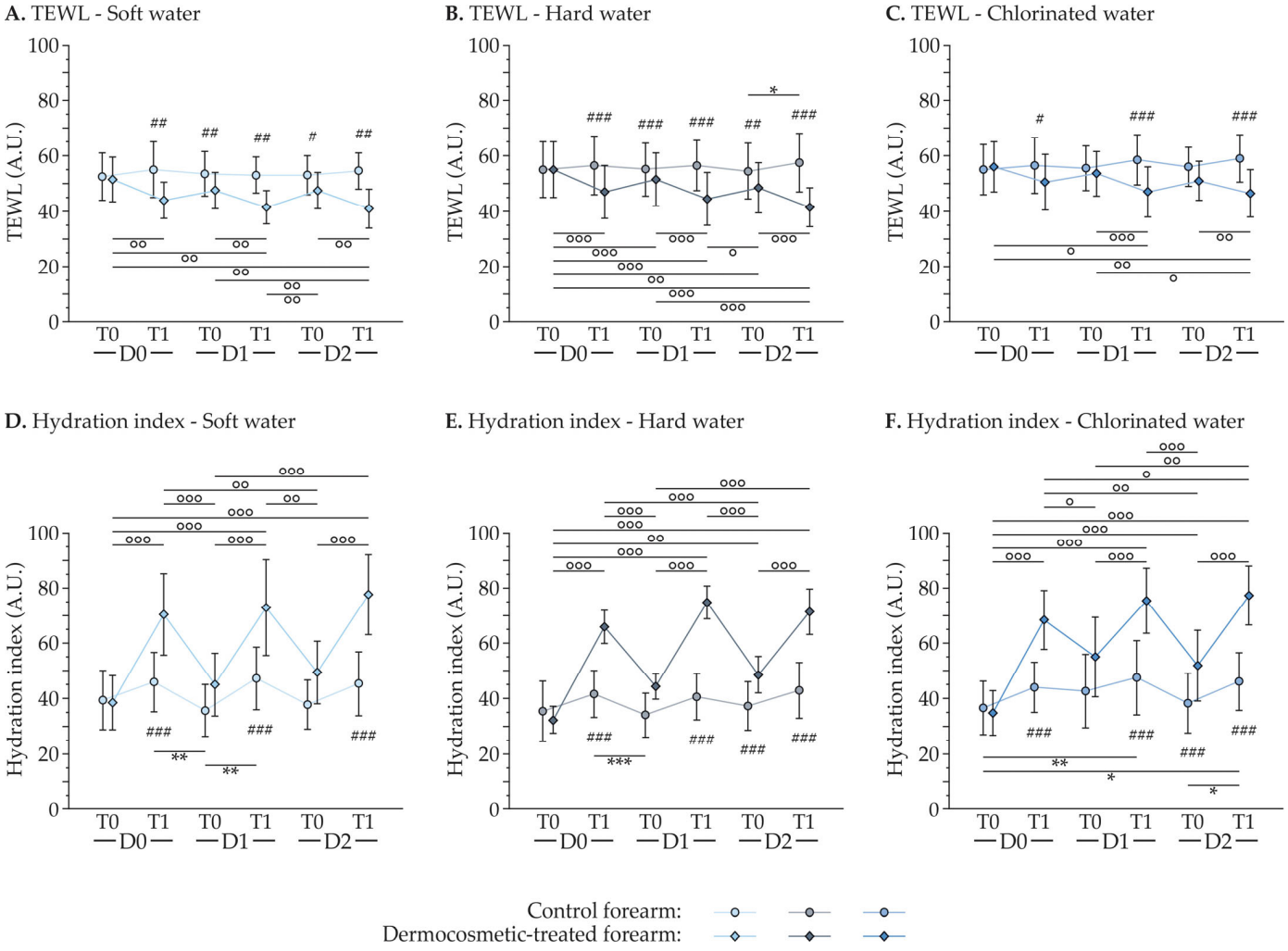


Figure 3. Variations in (**A**–**C**) TEWL and (**D**–**F**) hydration index upon repeated immersion in (**A**,**D**) soft, (**B**,**E**) hard, and (**C**,**F**) chlorinated water for control and dermocosmetic-treated forearms. Evaluations were conducted from day 0 (D0) until day 2 (D2), with measurements taken before the first immersion cycle (T0) and one hour after the last immersion cycle (T1). Statistical analysis relied on multiple comparisons of all 12 conditions evaluated for each water type. Inter-treatment differences are reported with #, differences within control forearms are presented with *, and differences within dermocosmetic-treated forearms are presented with °. Significances are reported as Bonferroni-adjusted *p*-values using $^{\#}$, *, °: $p < 0.05$; $^{\#\#}$, **, °°: $p < 0.01$, and $^{\#\#\#}$, ***, °°°: $p < 0.001$.

Similarly, multiple comparisons revealed that the three water types induced only a limited number of significant variations in the hydration index of control forearms, whereas the dermocosmetic routine produced significant changes across multiple time

points (Figure 3D–F). For all three water types, there was a highly significant intraday increase in the hydration index after each immersion cycle (adjusted $p < 0.001$), resulting in a highly significant difference (adjusted-$p < 0.001$) with the hydration index of control forearms. Although hydration index values before immersion cycles tended to increase from day 0 to day 1, these differences were not significant. The increases observed between days 0 and 2 were non-significant for soft water, but were significant for hard water (+37%, adjusted $p = 0.029$) and chlorinated water (+49%, adjusted $p < 0.001$).

The dermocosmetic routine also produced clear benefits in reducing global discomfort scores (Figure 4). Multiple comparisons across the 12 conditions evaluated for each water type confirmed limited effects in control forearms, except in the case of hard water. By contrast, the routine resulted in a marked reduction in discomfort across all water types, with lower scores at all time points—both before and after immersion cycles—compared with baseline values before the first immersion cycle on day 0.

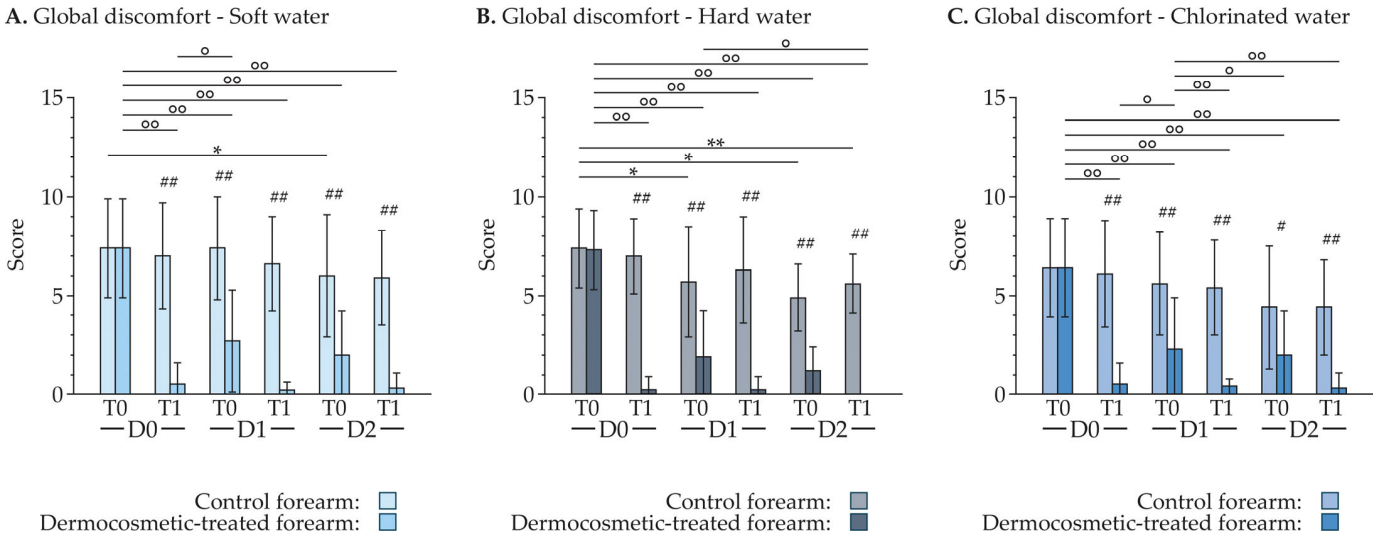


Figure 4. Variations in global discomfort score upon repeated immersion in (**A**) soft, (**B**) hard, and (**C**) chlorinated water for control and dermocosmetic-treated forearms. Evaluations were conducted from day 0 (D0) until day 2 (D2), with assessments performed before the first immersion cycle (T0) and one hour after the last immersion cycle (T1). Statistical analysis relied on multiple comparisons of all 12 conditions evaluated for each water type. Inter-treatment differences are reported with #, differences within control forearms are presented with *, and differences within dermocosmetic-treated forearms are presented with °. Significance levels are reported as Bonferroni-adjusted *p*-values using $^{\#}$, *, °: $p < 0.05$ and $^{\#\#}$, **, °°: $p < 0.01$.

None of the participants reported any adverse reactions to the dermocosmetic products.

3.3. Benefits of the Dermocosmetic Routine for Subjects with Atopic Skin Undergoing Repeated Exposure to Hard or Swimming Pool Water

To further evaluate the benefits of the dermocosmetic routine, we conducted a real-life observational study assessing its immediate and sustained effects in subjects with AD who either used their local hard water supply for their daily washing or attended swimming pool sessions two or three times per week (Table 2). All enrolled participants completed the investigation.

Table 2. Immediate and long-term efficacy of the dermocosmetic routine in subjects with atopic skin undergoing repeated exposure to hard water or swimming pool water.

	Immediate Efficacy				Long-Term Efficacy			
	After FW *	After FA **	Change (%)	*p*-value	Day 0	Day 21	Change (%)	*p*-value
Hard water study								
Itching	1.9 ± 0.5	1.2 ± 0.4	−35%	<0.001	1.8 ± 0.4	0.5 ± 0.6	−69%	<0.001
Irritation	1.7 ± 0.6	1.2 ± 0.4	−27%	<0.001	1.4 ± 0.5	0.3 ± 0.5	−77%	<0.001
Burning	1.6 ± 0.6	1.2 ± 0.4	−26%	<0.001	1.4 ± 0.5	0.4 ± 0.5	−72%	<0.001
Tightness	1.6 ± 0.5	1.2 ± 0.4	−28%	<0.001	1.4 ± 0.5	0.3 ± 0.5	−78%	<0.001
Dry skin	1.7 ± 0.6	1.3 ± 0.7	−21%	<0.001	2.1 ± 0.3	0.6 ± 0.6	−72%	<0.001
DLQI	-	-	-	-	6.6 ± 4.0	1.2 ± 2.3	−81%	<0.001
Swimming pool study								
Itching	1.5 ± 0.8	0.8 ± 0.7	−51%	<0.001	2.0 ± 0.2	0.3 ± 0.5	−86%	<0.001
Irritation	1.6 ± 0.8	0.7 ± 0.6	−56%	<0.001	1.9 ± 0.3	0.1 ± 0.2	−97%	<0.001
Burning	1.5 ± 0.9	0.7 ± 0.5	−55%	<0.001	1.7 ± 0.5	0.2 ± 0.4	−91%	<0.001
Tightness	1.6 ± 0.8	0.6 ± 0.5	−60%	<0.001	1.9 ± 0.3	0.1 ± 0.2	−97%	<0.001
Dry skin	1.7 ± 0.8	0.8 ± 0.6	−56%	<0.001	2.0 ± 0.2	0.2 ± 0.4	−91%	<0.001
DLQI	-	-	-	-	8.2 ± 4.7	1.5 ± 2.4	−82%	<0.001

* After FW: assessments conducted immediately after the first water contact (hard or swimming pool water).
** After FA: assessments conducted immediately after the first application of the dermocosmetic products.

In subjects using their local hard water supply daily, the dermocosmetic routine demonstrated efficacy immediately after the first application, reducing all subjective discomfort parameters by 21–35% ($p < 0.001$). Over 21 days, discomfort decreased markedly (69–78%; $p < 0.001$) and the Dermatology Life Quality Index (DLQI) improved by 81% ($p < 0.001$).

In subjects attending swimming pool sessions, the routine similarly produced immediate reductions in all discomfort parameters (51–60%; $p < 0.001$) and substantial improvements over 21 days (86–97%; $p < 0.001$), with the DLQI decreasing by 82% ($p < 0.001$).

None of the participants reported any adverse reactions to the dermocosmetic products.

4. Discussion

The present study investigated the comparative effect of immersion in soft, hard, and chlorinated water on TEWL, skin hydration, and subjective comfort in subjects with atopic skin, and evaluated the ability of a dermocosmetic routine combining a cleansing oil and a moisturising balm to mitigate these effects. Under controlled conditions, repeated forearm immersions in all three water types induced only limited effects on TEWL and consistently increased skin hydration after each immersion cycle, albeit to a modest yet statistically significant extent. Repeated immersions also reduced subjective discomfort as the number of immersion cycles increased, particularly in the hard water condition. These changes, observed in untreated forearms, remained perceptible when compared with those recorded in forearms subjected to the dermocosmetic routine. Nevertheless, the multiple comparison approach rendered them statistically non-significant, highlighting instead the consistent and marked benefits of the routine across all water types: a substantial reduction in TEWL, a pronounced increase in hydration after immersion cycles, and a near-complete alleviation of subjective discomfort. This reduction in discomfort was further corroborated under real-life conditions. The routine demonstrated both immediate and sustained efficacy in subjects with AD regularly exposed to hard domestic water or swimming pool water, with all five subjective discomfort parameters improving significantly after a single application, continuing to improve over 21 days, and accompanied by clinically meaningful reductions in the DLQI.

Epidemiological evidence has linked domestic water hardness to AD prevalence and severity [3–6,8,9], whilst the effect of chlorinated water remains poorly defined [14]. However, direct experimental evidence is limited, and the present study was designed to assess the effects of soft, hard, and chlorinated water on atopic skin under controlled conditions. Contrary to expectations, repeated immersion in the three water types led to almost no differences. Several factors may account for this apparent discrepancy. First, epidemiological associations between water hardness and AD prevalence reflect chronic, lifelong cumulative exposure, whereas the present protocol, although designed to simulate two weeks of daily washing within three days, necessarily remains a short-term approximation. Second, the concentrations of calcium carbonate and chlorine used in the present study, whilst representative of typical domestic and swimming pool water, may not have reached the threshold required to elicit measurable differential effects within the timeframe of the experiment. Although epidemiological studies are inherently subject to confounding, the limitations of our experimental approach suggest that the limited differences observed across water types do not necessarily contradict the epidemiological data but rather reflect the inherent constraints of short-term controlled experimental models in capturing the cumulative, long-term consequences of differential water exposure on atopic skin.

Although no significant differences were observed across water types, the patterns of TEWL and hydration changes induced by water immersion merit discussion. The consistent and significant intraday increases in the hydration index observed after each immersion cycle across all three water types are consistent with the known kinetics of water–skin interaction. Indeed, water penetrates the stratum corneum progressively, first accumulating within the primary furrows of the skin microrelief before reaching the secondary lines and the corneocyte plateaus, resulting in a measurable but transient increase in superficial hydration [20,21]. The stability of TEWL in the face of this hydration increase reflects a known disruption of the canonical inverse relationship between these two parameters in atopic skin [22,23]. Under normal physiological conditions, impaired barrier function simultaneously increases water egress and reduces the water-holding capacity of the stratum corneum. In AD, however, this relationship is altered. The structurally permeable barrier absorbs external water efficiently during immersion whilst TEWL does not increase accordingly, a dissociation that has been proposed to reflect the degree of barrier dysfunction and has led to the suggestion that the TEWL-to-hydration ratio may be a more informative marker of barrier homeostasis in AD than either parameter alone [24].

The trend towards reduced subjective discomfort over the course of repeated immersion cycles in control forearms, particularly in the hard water condition, also warrants comment. One plausible explanation is that progressive hydration of the stratum corneum, even in the absence of any dermocosmetic treatment, may have temporarily softened the corneocytes and reduced the mechanical stiffness associated with xerotic AD skin, thereby alleviating perceived tightness and pruritus [25,26]. This is consistent with the known transient anti-pruritic effect of brief, controlled water exposure, which may act through a combination of cooling, mechanical softening, and superficial rehydration of the epidermis [27,28]. Nonetheless, the absence of statistically significant differences in intraday discomfort variations across the three water types confirms that, under the conditions of the present study, soft, hard, and chlorinated water did not exert meaningfully distinct effects on subjective comfort in the absence of a dermocosmetic intervention.

Because these differences across the three water types were minimal, it is unsurprising that the dermocosmetic routine yielded improvements of similar magnitude across all three conditions. Accordingly, the consistent benefits observed, including in the soft water condition, imply that the routine's efficacy is independent of hard or chlorinated water-related specificities, but rather reflects the intrinsic moisturising and barrier-supporting

properties of the formulations on atopic skin. The observed effects are therefore best interpreted as product-related rather than as differential protection against water-type-specific damage.

The mechanisms by which the routine reduced TEWL and increased hydration are likely multifactorial. The cleansing oil contains mild surfactants that are less likely to deplete stratum corneum lipids and natural moisturising factor than conventional soap-based cleansers [29]. It also includes humectants and emollients, including glycerin, but their role, as well as that of the other ingredients, is unclear in a product that is rinsed off after use. The balm, as a leave-on product, is the likely contributor to the observed improvements in TEWL and hydration, acting through complementary mechanisms. The hydrating agents—glycerin, pentylene glycol, and 1,2-hexanediol—should contribute to stratum corneum hydration. Its occlusive lipid phase (mineral oil, sunflower seed oil, canola oil) is expected to limit transepidermal water loss by forming a semi-occlusive film on the skin surface [30]. The skin-mimetic lipids, comprising ceramides NP, AP and EOP, cholesterol, and phytosphingosine, are designed to replenish the depleted intercellular lipid lamellae of atopic stratum corneum. In particular, phytosphingosine is a ceramide precursor that stimulates enzymes involved in ceramide synthesis and epidermal differentiation protein expression [31]. The xylitol–mannitol–rhamnose complex is intended to support skin tolerance; sucrose stearate and fructooligosaccharides support microbiome homeostasis [32–35].

The individual ingredient activities described above provide a mechanistic rationale for the routine's overall benefits, particularly its capacity to reduce immersion-related discomfort. They also explain the particular pattern of effects observed in the controlled immersion study, namely the pronounced post-immersion reduction in TEWL and marked increase in the hydration index, which represent the most consistent differences compared with untreated forearms. This pattern deserves interpretation in light of the known relationship between TEWL and stratum corneum hydration [22,23]. In healthy skin, these two parameters are inversely related. An intact barrier retains water within the stratum corneum whilst limiting its passive evaporation. In atopic skin, however, this relationship is disrupted, with elevated TEWL coexisting with reduced water-holding capacity, reflecting the structural lipid deficiencies and tight junction dysfunction characteristic of the condition. The application of the dermocosmetic routine appears to partially restore this coupling. It reduces TEWL through the combined occlusive effect of the lipid phase, the barrier-reinforcing action of the ceramide complex, and the humectant activity of glycerin. Simultaneously, it provides a reservoir of exogenous water that is retained within the stratum corneum after immersion. Therefore, the routine should create conditions that could transiently approximate a more physiological barrier state. In this context, the water challenge imposed by repeated immersion cycles is likely to have amplified the visible benefit of the routine. On untreated forearms, the transiently absorbed water evaporates rapidly as TEWL remains elevated, while, on routine-treated forearms, the same water is partially retained by the improved barrier, resulting in a measurably higher hydration index and lower TEWL at the one-hour post-immersion time point. This interpretation is consistent with the cumulative nature of the TEWL reduction observed across days, suggesting that the barrier-reinforcing effect of the routine builds progressively over repeated application cycles.

Several limitations of the present study should be acknowledged. The controlled immersion protocol, whilst designed to simulate repeated daily washing, necessarily compresses several weeks of cumulative exposure into three days, potentially underestimating the differential effects of water quality on atopic skin over longer periods. The characterisation of the three water types was also limited. Although all originated from the

same local hard tap water supply, the effects of the ion-exchange softening process were not characterised, potentially introducing compositional differences between hard water and soft/chlorinated water conditions. Moreover, the chlorinated water concentration substantially exceeded real-life swimming pool exposure levels. Finally, Corneometer measurements, which rely on a capacitance-based approach, are not only sensitive to water content but also to polar compounds [36]. It may have been influenced by the differing mineral compositions of the waters. The open-label design and the observational nature of the real-life study do not permit the formal exclusion of placebo effects. Nevertheless, the convergence of objective barrier measurements with subjective endpoints strengthens the interpretation that the observed improvements reflect genuine biological effects of the interventions. The assessment of discomfort by visual analogue scale, although widely used, remains inherently subjective, and the absence of molecular or histological endpoints limits the mechanistic interpretation of the barrier-related findings. Finally, the relatively small sample sizes and the restriction of instrumental measurements to a single forearm site may reduce the generalisability of the findings. Future studies should consider longer exposure protocols, higher water hardness concentrations, blinded designs with vehicle-controlled arms, and the inclusion of molecular biomarkers—such as filaggrin expression, ceramide profiling, or skin microbiome composition—to substantiate the mechanistic hypotheses proposed here. The real-life study results, whilst encouraging, would benefit from confirmation in a larger, randomised controlled trial with objective barrier measurements as co-primary endpoints.

5. Conclusions

The controlled immersion study demonstrates that, over the short term and under the standardised conditions employed, soft, hard, and chlorinated water exert only modest and largely comparable effects on TEWL, stratum corneum hydration, and discomfort in atopic skin. The dermocosmetic routine combining a cleansing oil and a moisturising balm consistently improved barrier-related parameters and reduced discomfort across all three water types in the controlled setting. In the real-life study, the same routine provided immediate and sustained improvements in discomfort and quality of life in subjects with AD regularly exposed to hard domestic water or chlorinated swimming pool water. Therefore, these findings support the role of appropriately formulated dermocosmetic routines as effective adjuncts to the long-term management of atopic skin, independently of water quality.

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Institutional Review Board Statement: Both studies consisted of the non-invasive evaluation of dermocosmetic products and were conducted in Poland. Under the applicable legislative framework—Regulation (EC) No 1223/2009, Commission Regulation (EU) No 655/2013, and the Polish Order of the Minister of Health of 2 May 2012 (Dz.U. 2012, item 491)—such studies are explicitly exempted from mandatory ethics committee review. This exemption applied even though the participants had atopic dermatitis, given that the interventions involved no experimental drug, medical device, or invasive procedure. Both studies were conducted in full accordance with the principles of the Declaration of Helsinki and Good Clinical Practice.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the studies.

Data Availability Statement: Data is contained within the article.

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References

1. Guttman-Yassky, E.; Renert-Yuval, Y.; Brunner, P.M. Atopic dermatitis. *Lancet* **2025**, *405*, 583–596. [CrossRef] [PubMed]
2. Gochnauer, H.; Valdes-Rodriguez, R.; Cardwell, L.; Anolik, R.B. The Psychosocial Impact of Atopic Dermatitis. In *Management of Atopic Dermatitis*; Fortson, E.A., Feldman, S.R., Strowd, L.C., Eds.; Springer Nature: London, UK, 2024; pp. 69–81.
3. McNally, N.J.; Williams, H.C.; Phillips, D.R.; Smallman-Raynor, M.; Lewis, S.; Venn, A.; Britton, J. Atopic eczema and domestic water hardness. *Lancet* **1998**, *352*, 527–531. [CrossRef] [PubMed]
4. Miyake, Y.; Yokoyama, T.; Yura, A.; Iki, M.; Shimizu, T. Ecological association of water hardness with prevalence of childhood atopic dermatitis in a Japanese urban area. *Environ. Res.* **2004**, *94*, 33–37. [CrossRef] [PubMed]
5. Arnedo-Pena, A.; Bellido-Blasco, J.; Puig-Barbera, J.; Artero-Civera, A.; Campos-Cruañes, J.B.; Pac-Sa, M.R.; Villamarín-Vázquez, J.L.; Felis-Dauder, C. Dureza del agua de consumo doméstico y prevalencia de eczema atópico en escolares de Castellón, España [Domestic water hardness and prevalence of atopic eczema in Castellon (Spain) school children]. *Salud Publica Mex.* **2007**, *49*, 295–301. [CrossRef] [PubMed]
6. Perkin, M.R.; Craven, J.; Logan, K.; Strachan, D.; Marrs, T.; Radulovic, S.; Campbell, L.E.; MacCallum, S.F.; McLean, W.H.; Lack, G.; et al. Enquiring About Tolerance Study Team. Association between domestic water hardness, chlorine, and atopic dermatitis risk in early life: A population-based cross-sectional study. *J. Allergy Clin. Immunol.* **2016**, *138*, 509–516. [CrossRef] [PubMed]
7. Choi, E.H.; Kang, H. Importance of Stratum Corneum Acidification to Restore Skin Barrier Function in Eczematous Diseases. *Ann. Dermatol.* **2024**, *36*, 1–8. [CrossRef] [PubMed]
8. Engebretsen, K.A.; Bager, P.; Wohlfahrt, J.; Skov, L.; Zachariae, C.; Nybo Andersen, A.M.; Melbye, M.; Thyssen, J.P. Prevalence of atopic dermatitis in infants by domestic water hardness and season of birth: Cohort study. *J. Allergy Clin. Immunol.* **2017**, *139*, 1568–1574.e1. [CrossRef] [PubMed]
9. Jabbar-Lopez, Z.K.; Ung, C.Y.; Alexander, H.; Gurung, N.; Chalmers, J.; Danby, S.; Cork, M.J.; Peacock, J.L.; Flohr, C. The effect of water hardness on atopic eczema, skin barrier function: A systematic review, meta-analysis. *Clin. Exp. Allergy.* **2021**, *51*, 430–451. [PubMed]
10. Danby, S.G.; Brown, K.; Wigley, A.M.; Chittock, J.; Pyae, P.K.; Flohr, C.; Cork, M.J. The Effect of Water Hardness on Surfactant Deposition after Washing and Subsequent Skin Irritation in Atopic Dermatitis Patients and Healthy Control Subjects. *J. Investig. Dermatol.* **2018**, *138*, 68–77. [CrossRef] [PubMed]
11. Thomas, K.S.; Dean, T.; O'Leary, C.; Sach, T.H.; Koller, K.; Frost, A.; Williams, H.C.; SWET Trial Team. A randomised controlled trial of ion-exchange water softeners for the treatment of eczema in children. *PLoS Med.* **2011**, *8*, e1000395. [CrossRef] [PubMed]
12. Gomà, A.; de Lluis, R.; Roca-Ferrer, J.; Lafuente, J.; Picado, C. Respiratory, ocular and skin health in recreational and competitive swimmers: Beneficial effect of a new method to reduce chlorine oxidant derivatives. *Environ. Res.* **2017**, *152*, 315–321. [CrossRef] [PubMed]
13. Tlougan, B.E.; Podjasek, J.O.; Adams, B.B. Aquatic sports dermatoses: Part 1. In the water: Freshwater dermatoses. *Int. J. Dermatol.* **2010**, *49*, 874–885. [CrossRef] [PubMed]
14. O'Connor, C.; McCarthy, S.; Murphy, M. Pooling the evidence: A review of swimming and atopic dermatitis. *Pediatr. Dermatol.* **2023**, *40*, 407–412. [CrossRef] [PubMed]
15. Wollenberg, A.; Kinberger, M.; Arents, B.; Aszodi, N.; Avila Valle, G.; Barbarot, S.; Bieber, T.; Brough, H.A.; Calzavara Pinton, P.; Christen-Zäch, S.; et al. European guideline (EuroGuiDerm) on atopic eczema—Part II: Non-systemic treatments and treatment recommendations for special AE patient populations. *J. Eur. Acad. Dermatol. Venereol.* **2022**, *36*, 1904–1926. [CrossRef] [PubMed]

16. Gayraud, F.; Sayag, M.; Jourdan, E. Efficacy and tolerance assessment of a new type of dermocosmetic in infants and children with moderate atopic dermatitis. *J. Cosmet. Dermatol.* **2015**, *14*, 107–112. [CrossRef] [PubMed]
17. Williams, H.C.; Burney, P.G.; Pembroke, A.C.; Hay, R.J. The U.K. Working Party's diagnostic criteria for atopic dermatitis. III. In-dependent hospital validation. *Br. J. Dermatol.* **1994**, *131*, 406–416. [CrossRef] [PubMed]
18. Finlay, A.Y.; Khan, G.K. Dermatology life quality index (DLQI)—A simple practical measure for routine clinical use. *Clin. Exp. Dermatol.* **1994**, *19*, 210–216. [CrossRef] [PubMed]
19. Hongbo, Y.; Thomas, C.L.; Harrison, M.A.; Salek, M.S.; Finlay, A.Y. Translating the science of quality of life into practice: What do dermatology life quality index scores mean? *J. Investig. Dermatol.* **2005**, *125*, 659–664. [CrossRef] [PubMed]
20. Bouwstra, J.A.; de Graaff, A.; Gooris, G.S.; Nijsse, J.; Wiechers, J.W.; van Aelst, A.C. Water distribution and related morphology in human stratum corneum at different hydration levels. *J. Investig. Dermatol.* **2003**, *120*, 750–758. [CrossRef] [PubMed]
21. Morin, M.; Ruzgas, T.; Svedenhag, P.; Anderson, C.D.; Ollmar, S.; Engblom, J.; Björklund, S. Skin hydration dynamics investigated by electrical impedance techniques in vivo and in vitro. *Sci. Rep.* **2020**, *10*, 17218. [CrossRef] [PubMed]
22. Tagami, H.; Yoshikuni, K. Interrelationship between water-barrier and reservoir functions of pathologic stratum corneum. *Arch. Dermatol.* **1985**, *121*, 642–645. [CrossRef]
23. Mojumdar, E.H.; Pham, Q.D.; Topgaard, D.; Sparr, E. Skin hydration: Interplay between molecular dynamics, structure and water uptake in the stratum corneum. *Sci. Rep.* **2017**, *7*, 15712. [CrossRef] [PubMed]
24. Sreekantaswamy, S.; Meyer, J.; Grinich, E.; Leshem, Y.; Simpson, E.; Abuabara, K. Utility of transepidermal water loss-stratum corneum hydration ratio in atopic dermatitis. *Skin. Res. Technol.* **2024**, *30*, e13709. [CrossRef] [PubMed]
25. Rawlings, A.V.; Harding, C.R. Moisturization and skin barrier function. *Dermatol. Ther.* **2004**, *17*, 43–48. [CrossRef] [PubMed]
26. Fluhr, J.W.; Darlenski, R.; Angelova-Fischer, I.; Tsankov, N.; Basketter, D. Skin irritation and sensitization: Mechanisms and new approaches for risk assessment. 1. Skin irritation. *Skin. Pharmacol. Physiol.* **2008**, *21*, 124–135. [CrossRef] [PubMed]
27. Nicol, N.H.; Boguniewicz, M. Wet Wrap Therapy in Moderate to Severe Atopic Dermatitis. *Immunol. Allergy Clin. N. Am.* **2017**, *37*, 123–139. [CrossRef] [PubMed]
28. Herrero-Fernandez, M.; Montero-Vilchez, T.; Diaz-Calvillo, P.; Romera-Vilchez, M.; Buendia-Eisman, A.; Arias-Santiago, S. Impact of Water Exposure and Temperature Changes on Skin Barrier Function. *J. Clin. Med.* **2022**, *11*, 298. [CrossRef] [PubMed]
29. Mijaljica, D.; Spada, F.; Harrison, I.P. Skin Cleansing without or with Compromise: Soaps and Syndets. *Molecules* **2022**, *27*, 2010. [CrossRef] [PubMed]
30. Pinto, J.R.; Monteiro, E.; Silva, S.A.; Holsback, V.S.S.; Leonardi, G.R. Skin occlusive performance: Sustainable alternatives for petrolatum in skincare formulations. *J. Cosmet. Dermatol.* **2022**, *21*, 4775–4780. [CrossRef] [PubMed]
31. Choi, H.K.; Kim, H.J.; Liu, K.H.; Park, C.S. Phytosphingosine Increases Biosynthesis of Phytoceramide by Uniquely Stimulating the Expression of Dihydroceramide C4-desaturase (DES2) in Cultured Human Keratinocytes. *Lipids* **2018**, *53*, 909–918. [CrossRef] [PubMed]
32. Korponyai, C.; Kovács, R.K.; Erös, G.; Dikstein, S.; Kemény, L. Antiirritant properties of polyols and amino acids. *Dermatitis* **2011**, *22*, 141–146. [CrossRef]
33. Pelle, E.; Huang, X.; Mammone, T.; Marenus, K.; Maes, D.; Frenkel, K. Ultraviolet-B-induced oxidative DNA base damage in primary normal human epidermal keratinocytes and inhibition by a hydroxyl radical scavenger. *J. Investig. Dermatol.* **2003**, *121*, 177–183. [CrossRef] [PubMed]
34. Baba, T.; Yoshida, T.; Yoshida, T.; Cohen, S. Suppression of cell-mediated immune reactions by monosaccharides. *J. Immunol.* **1979**, *122*, 838–841. [CrossRef]
35. Le Bourgot, C.; Meunier, C.; Gaio, E.; Murat, V.; Micheletto, M.; Tedesco, E.; Benetti, F. Effects of short chain fructo-oligosaccharides on selected skin bacteria. *Sci. Rep.* **2022**, *12*, 9702. [CrossRef] [PubMed]
36. Crowther, J.M. Understanding effects of topical ingredients on electrical measurement of skin hydration. *Int. J. Cosmet. Sci.* **2016**, *38*, 589–598. [CrossRef] [PubMed]

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