Effect of Post-Washing Time Interval on Skin Hydration Following Moisturizer Application on the Ventral Forearm in Healthy Volunteers

Supawit Klaewkla, MD[1], Bhakinai Temnithikul, MD[1]

[1] School of Anti-aging and Regenerative Medicine, Mae Fah Luang University, Bangkok, Thailand

Abstract

Background: Early post-washing moisturization is widely recommended, yet the optimal application interval remains unclear in healthy adults.

Objective: To evaluate whether different post-washing moisturizer application times influence stratum corneum hydration (SCH) and transepidermal water loss (TEWL).

Materials and Methods: This controlled experimental study employed a within-subject repeated-measures design in 36 healthy adults aged 21-65 years (18 females, 18 males), stratified into three age groups (21-35, 36-50, 51-65 years; 12 each). Five standardized circular sites on the ventral forearms were assigned to no moisturization (control) or moisturizer application at 2, 5, 10, or 15 minutes after water-only washing. SCH (Corneometer®) and TEWL (Tewameter®) were measured at baseline and at 30, 60, and 90 minutes after application under controlled temperature and relative humidity.

Results: Baseline SCH and TEWL were comparable across conditions. In overall analyses, moisturization significantly increased SCH and reduced TEWL versus the untreated control at 30, 60, and 90 minutes (all $p<0.001$). SCH did not differ among the four application-timing conditions after Bonferroni adjustment (all pairwise $p>0.05$). Earlier application conferred modest TEWL advantages: the 2-minute condition was lower than the 10- and 15-minute conditions at 30, 60, and 90 minutes (all $p<0.05$), and the 5-minute condition was lower than the 15-minute condition at the same time points (all $p<0.05$). Exploratory sex- and age group-stratified analyses showed similar SCH patterns, while TEWL timing effects were more apparent in females and in older age groups, particularly at 90 minutes.

Conclusion: Moisturization within 2-15 minutes after washing substantially improves SCH and reduces TEWL versus no moisturization, while earlier application (approximately 2-5 minutes) may confer a small additional TEWL-related barrier benefit.

Keywords: Moisturizer; Skin hydration; Stratum corneum hydration; Transepidermal water loss; Washing

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Skin hydration is essential for cutaneous barrier function[1]. Moisturizer use after bathing or washing is therefore commonly recommended to restore and stabilize moisture in the outer epidermis[2]. Dermatology organizations, including the American Academy of Dermatology and the Japanese Dermatological Association, advise applying moisturizers soon after bathing to reduce evaporative water loss[3,4]. However, quantitative human evidence defining the optimal post-bathing or post-washing application interval, particularly in healthy adults, remains limited.

What is already known about this topic?

- Moisturizer application after bathing or washing is widely recommended to improve skin hydration and reduce water loss from the skin.
- Previous studies suggest that moisturization improves stratum corneum hydration and barrier-related outcomes, but evidence regarding the optimal timing of application after washing remains limited and inconsistent.
- Existing studies have often compared only immediate versus delayed application or have focused on patients with atopic dermatitis rather than healthy adults.

What does this study add?

- This study provides a controlled within-subject evaluation of multiple early post-washing moisturizer application intervals, including 2, 5, 10, and 15 minutes, in healthy adults.
- Moisturizer application within 2-15 minutes after washing significantly increased stratum corneum hydration and reduced transepidermal water loss compared with no moisturization.
- The timing of application within this early interval did not significantly affect stratum corneum hydration, but earlier application, particularly within 2-5 minutes, showed a modest additional reduction in transepidermal water loss.

Correspondence to:

Temnithikul B.

School of Anti-aging and Regenerative Medicine, Mae Fah Luang University, Bangkok 10110, Thailand.

Phone: +66-81-7192567

Email: Bhakinai.tem@mfu.ac.th

ORCID: 0000-0002-4537-5434

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Previous timing studies have reported inconsistent findings and important design constraints. In healthy volunteers, Nguyen et al. (2022) found no significant difference between immediate moisturization and a 30-minute delay, although only two timing conditions were examined[5]. In contrast, Ueda et al. (2022) reported greater hydration when moisturizer was applied within 5 minutes rather than after 90 minutes, suggesting a possible time-dependent effect[6]. Studies in atopic dermatitis also show mixed results: Chiang & Eichenfield (2009) found no significant difference between immediate and 30-minute delayed application[7], whereas Wulandari et al. (2021) reported sustained benefits of immediate application in pediatric atopic dermatitis[8].

These discrepancies may reflect limited timing granularity, inclusion of diseased populations, inconsistent environmental control, and scarce data from Thai populations[5-8].

This study therefore evaluated whether moisturizer application at 2, 5, 10, or 15 minutes after washing affects stratum corneum hydration (SCH) and transepidermal water loss (TEWL) under controlled temperature and humidity, using the ventral forearm as a standardized test site.

Objective

The objective was to determine whether moisturizer application at 2, 5, 10, or 15 minutes after washing influenced SCH and TEWL compared with no moisturization in healthy adults.

Materials and Methods

Study Design and Setting

This nonrandomized controlled experimental study used a within-subject repeated-measures design, in which each participant received all predefined study conditions and served as their own control. The study was conducted at the skin testing laboratory, Bangkok Mae Fah Luang University Hospital, Thailand, under controlled ambient conditions.

The study protocol was approved by the Mae Fah Luang University Ethics Committee on Human Research (Protocol No. EC 25198-20; Certificate of Approval [COA] No. 212/2025; Approval date: November 4, 2025).

Participants and Recruitment

Healthy male and female volunteers aged 21-65 years were recruited through public study announcements using volunteer-based convenience sampling. Recruitment was planned to balance sex (18 females and 18 males) and age group (21-35, 36-50, and 51-65 years; 12 participants per group). Sex was recorded as a biological variable and used, together with age group, for prespecified exploratory subgroup analyses. Eligibility was assessed before enrollment using predefined inclusion and exclusion criteria.

Eligibility Criteria

Participants were eligible if they were aged 21-65 years, able to understand study procedures, and willing to provide written informed consent. Exclusion criteria were current or previous chronic inflammatory dermatoses involving the intended test areas, active inflammation at the test sites, use of topical or systemic agents that could affect skin hydration or barrier-related outcomes within 2 weeks before participation[1,9,10], pregnancy or breastfeeding, medical conditions that could impair skin barrier function[1,11,12], or known allergy or irritation to the study moisturizer or its ingredients.

Pre-study Safety Screening and Preparation

Before the study visit, participants performed a repeated open application test (ROAT) with the study moisturizer (Base Cream of Raj Pracha Samasai Institute, Department of Disease Control, Ministry of Public Health) by applying 1 fingertip unit to the ventral forearm twice daily for 7 days. Participants with suspected irritation or allergic reactions were discontinued and managed according to standard clinical practice. Before measurement, participants were instructed to avoid bathing or washing, soap or cleansers, and skincare products on both ventral forearms for at least 3 hours, and to abstain from caffeine, alcohol, and smoking for 24 hours[13].

Experimental Procedures and Intervention Assignment

Both ventral forearms were rinsed with room-temperature water (~25°C) for 30 seconds without soap or cleansers and gently patted dry[13]. Participants then rested for 30 minutes in a controlled room (20-22°C; relative humidity 40% to 60%) for skin equilibration[13-16]. Five circular test sites (A-E; 4-cm diameter) were marked on the ventral forearms, with sites A-C on the right forearm and sites D-E on the left forearm. The unit of assignment and intervention delivery was the anatomical test site within each participant. Conditions were assigned to fixed sites without randomization, blocking, stratification, minimization, or counterbalancing: site A, no moisturizer; site B, moisturizer at 2 minutes; site C,

Table 1. Overall changes in stratum corneum hydration (SCH)

Time	Mean (SD)					p-value*
	No moisturizing (n=36)	2 minutes (n=36)	5 minutes (n=36)	10 minutes (n=36)	15 minutes (n=36)	
0 minute	27.6 (3.5)	27.6 (3.3)	27.4 (3.4)	27.7 (3.6)	27.4 (3.7)	0.989
30 minutes	27.4 (3.7)	55.9 (5.3)	54.9 (5.2)	55.2 (5.5)	53.5 (5.7)	<0.001
60 minutes	26.2 (3.4)	54.3 (5.2)	53.5 (5.4)	53.2 (5.4)	51.9 (5.3)	<0.001
90 minutes	25.3 (3.4)	52.9 (5.0)	52.1 (5.1)	52.0 (4.9)	50.7 (4.9)	<0.001
p-value**	<0.001	<0.001	<0.001	<0.001	<0.001	

SD=standard deviation

* p-value for comparison across conditions at each time point, ** p-value for comparison over time within each condition

5 minutes; site D, 10 minutes; and site E, 15 minutes after the second wash.

Baseline SCH and TEWL were then measured. After baseline measurement, both forearms underwent a second water-only wash using the same procedure. The intervention consisted of standardized post-wash moisturizer application or no moisturization for the control site. The moisturizer was applied by the investigator at 0.1 g per site. SCH and TEWL were measured at 30, 60, and 90 minutes after moisturizer application for treated sites and at corresponding times after the second wash for the control site. Participants remained in the controlled environment and were allowed only low-intensity activities while avoiding physical exertion[13-15].

Outcomes and Adverse Events

The primary outcomes were SCH and TEWL at baseline and at 30, 60, and 90 minutes after moisturizer application or the corresponding post-wash time for the control site. SCH was measured using a Corneometer® CM 825 and recorded in arbitrary units, while TEWL was measured using a Tewameter® TM Hex and recorded in g/m²/hour. Readings were obtained at the center of each test site in triplicate and averaged. Local irritation or allergic reactions during ROAT or the study visit were assessed as potential adverse events.

Sample Size

The minimum sample size was calculated as 34 participants based on the difference in SCH at 30 minutes reported by Nguyen et al.[5]. To support balanced exploratory subgroup analyses by sex and age group, the final recruitment target was increased to 36 participants, comprising 18 females and 18 males and 12 participants in each age group.

Statistical Analysis

Categorical variables were summarized as frequencies and percentages[17]. Continuous variables were summarized as mean and standard deviation (SD). Because all five conditions were measured repeatedly within the same participant, the participant was treated as the repeated-measures unit. At each measurement time point, SCH and TEWL were compared across the five within-subject conditions using repeated-measures ANOVA to account for within-participant correlation[18,19]. When the overall test was significant ($p<0.05$), Bonferroni-adjusted pairwise comparisons were performed[20,21]. Sex- and age group-stratified analyses were prespecified and considered exploratory. Analyses were performed using IBM SPSS Statistics, version 28.0 (IBM Corp., Armonk, NY, USA).

Results

Participant Flow, Recruitment, and Baseline Comparability

Recruitment began on January 9, 2026, and experimental sessions were conducted between January 19 and February 26, 2026. Thirty-six participants were enrolled, assigned to the within-subject protocol, received all five study conditions, completed follow-up measurements, and were included in the overall analysis. No participants were lost, excluded, withdrawn because of adverse events, or involved in protocol deviations. The final sample included 18 females and 18 males, with 12 participants in each age group. Baseline SCH and TEWL were comparable across test sites.

Overall Changes in Stratum Corneum Hydration

Baseline SCH did not differ across conditions ($p=0.989$). At 30-90 minutes, SCH was substantially higher at all moisturized sites than at the non-moisturized control (Table 1), whereas differences among the 2-, 5-, 10-, and 15-minute application intervals were not detected after Bonferroni adjustment (Table 2).

Table 2. Post hoc pairwise comparisons with Bonferroni adjustment of overall changes in stratum corneum hydration (SCH)

Pairwise comparison	Post-moisturizer application time; mean (SD)					
	30 minutes		60 minutes		90 minutes	
	SCH (a.u.)	p-value	SCH (a.u.)	p-value	SCH (a.u.)	p-value
No moisturizing vs. 2 minutes	27.4 (3.7) vs. 55.9 (5.3)	<0.001	26.2 (3.4) vs. 54.3 (5.2)	<0.001	25.3 (3.4) vs. 52.9 (5.0)	<0.001
No moisturizing vs. 5 minutes	27.4 (3.7) vs. 54.9 (5.2)	<0.001	26.2 (3.4) vs. 53.5 (5.4)	<0.001	25.3 (3.4) vs. 52.1 (5.1)	<0.001
No moisturizing vs. 10 minutes	27.4 (3.7) vs. 55.2 (5.5)	<0.001	26.2 (3.4) vs. 53.2 (5.4)	<0.001	25.3 (3.4) vs. 52.0 (4.9)	<0.001
No moisturizing vs. 15 minutes	27.4 (3.7) vs. 53.5 (5.7)	<0.001	26.2 (3.4) vs. 51.9 (5.3)	<0.001	25.3 (3.4) vs. 50.7 (4.9)	<0.001
2 minutes vs. 5 minutes	55.9 (5.3) vs. 54.9 (5.2)	1.000	54.3 (5.2) vs. 53.5 (5.4)	1.000	52.9 (5.0) vs. 52.1 (5.1)	1.000
2 minutes vs. 10 minutes	55.9 (5.3) vs. 55.2 (5.5)	1.000	54.3 (5.2) vs. 53.2 (5.4)	1.000	52.9 (5.0) vs. 52.0 (4.9)	1.000
2 minutes vs. 15 minutes	55.9 (5.3) vs. 53.5 (5.7)	0.441	54.3 (5.2) vs. 51.9 (5.3)	0.446	52.9 (5.0) vs. 50.7 (4.9)	0.452
5 minutes vs. 10 minutes	54.9 (5.2) vs. 55.2 (5.5)	1.000	53.5 (5.4) vs. 53.2 (5.4)	1.000	52.1 (5.1) vs. 52.0 (4.9)	1.000
5 minutes vs. 15 minutes	54.9 (5.2) vs. 53.5 (5.7)	1.000	53.5 (5.4) vs. 51.9 (5.3)	1.000	52.1 (5.1) vs. 50.7 (4.9)	1.000
10 minutes vs. 15 minutes	55.2 (5.5) vs. 53.5 (5.7)	1.000	53.2 (5.4) vs. 51.9 (5.3)	1.000	52.0 (4.9) vs. 50.7 (4.9)	1.000

SD=standard deviation

Table 3. Overall changes in transepidermal water loss (TEWL)

TEWL (g/m^2/hour)	Mean (SD)					p-value*
	No moisturizing (n=36)	2 minutes (n=36)	5 minutes (n=36)	10 minutes (n=36)	15 minutes (n=36)	
0 minute	9.8 (1.3)	9.5 (1.2)	9.7 (1.2)	9.9 (1.4)	9.9 (1.4)	0.989
30 minutes	9.8 (1.4)	5.4 (0.9)	5.6 (1.0)	6.3 (1.4)	6.6 (1.5)	<0.001
60 minutes	10.1 (1.3)	5.8 (0.9)	6.0 (1.0)	6.7 (1.4)	6.9 (1.3)	<0.001
90 minutes	10.5 (1.3)	6.1 (0.9)	6.4 (1.0)	7.0 (1.3)	7.2 (1.3)	<0.001
p-value**	<0.001	<0.001	<0.001	<0.001	<0.001	

SD=standard deviation
* p-value for comparison across conditions at each time point, ** p-value for comparison over time within each condition

Table 4. Post hoc pairwise comparisons with Bonferroni adjustment of overall changes in transepidermal water loss (TEWL)

Pairwise comparison	Post-moisturizer application time; mean (SD)					
	30 minutes		60 minutes		90 minutes	
	TEWL (g/m^2/hour)	p-value	TEWL (g/m^2/hour)	p-value	TEWL (g/m^2/hour)	p-value
No moisturizing vs. 2 minutes	9.8 (1.4) vs. 5.4 (0.9)	<0.001	10.1 (1.3) vs. 5.8 (0.9)	<0.001	10.5 (1.3) vs. 6.1 (0.9)	<0.001
No moisturizing vs. 5 minutes	9.8 (1.4) vs. 5.6 (1.0)	<0.001	10.1 (1.3) vs. 6.0 (1.0)	<0.001	10.5 (1.3) vs. 6.4 (1.0)	<0.001
No moisturizing vs. 10 minutes	9.8 (1.4) vs. 6.3 (1.4)	<0.001	10.1 (1.3) vs. 6.7 (1.4)	<0.001	10.5 (1.3) vs. 7.0 (1.3)	<0.001
No moisturizing vs. 15 minutes	9.8 (1.4) vs. 6.6 (1.5)	<0.001	10.1 (1.3) vs. 6.9 (1.3)	<0.001	10.5 (1.3) vs. 7.2 (1.3)	<0.001
2 minutes vs. 5 minutes	5.4 (0.9) vs. 5.6 (1.0)	1.000	5.8 (0.9) vs. 6.0 (1.0)	1.000	6.1 (0.9) vs. 6.4 (1.0)	1.000
2 minutes vs. 10 minutes	5.4 (0.9) vs. 6.3 (1.4)	0.027	5.8 (0.9) vs. 6.7 (1.4)	0.007	6.1 (0.9) vs. 7.0 (1.3)	0.006
2 minutes vs. 15 minutes	5.4 (0.9) vs. 6.6 (1.5)	0.002	5.8 (0.9) vs. 6.9 (1.3)	<0.001	6.1 (0.9) vs. 7.2 (1.3)	<0.001
5 minutes vs. 10 minutes	5.6 (1.0) vs. 6.3 (1.4)	0.234	6.0 (1.0) vs. 6.7 (1.4)	0.133	6.4 (1.0) vs. 7.0 (1.3)	0.239
5 minutes vs. 15 minutes	5.6 (1.0) vs. 6.6 (1.5)	0.022	6.0 (1.0) vs. 6.9 (1.3)	0.012	6.4 (1.0) vs. 7.2 (1.3)	0.034
10 minutes vs. 15 minutes	6.3 (1.4) vs. 6.6 (1.5)	1.000	6.7 (1.4) vs. 6.9 (1.3)	1.000	7.0 (1.3) vs. 7.2 (1.3)	1.000

SD=standard deviation

Overall Changes in Transepidermal Water Loss

Baseline TEWL was comparable across conditions (p=0.989). At 30-90 minutes, TEWL was lower at all moisturized sites than at the control site (Table 3). Earlier application was associated with modest TEWL advantages: the 2-minute condition was lower than the 10- and 15-minute conditions, and the 5-minute condition was lower than the 15-minute condition at 30, 60, and 90 minutes (Table 4).

Sex-stratified Outcomes (Exploratory)

Sex-stratified analyses showed similar SCH

Table 5. Exploratory sex-stratified analyses of stratum corneum hydration (SCH) and transepidermal water loss (TEWL)

Outcome	Sex, n	Baseline comparison across conditions	Post-application moisturizer vs. control (30-90 minutes)	Significant between-timing comparisons after Bonferroni adjustment
SCH	Female, 18	No significant difference (p=0.981)	All moisturizer conditions higher than control at 30, 60, and 90 minutes (all overall p<0.001)	None
SCH	Male, 18	No significant difference (p=0.985)	All moisturizer conditions higher than control at 30, 60, and 90 minutes (all overall p<0.001)	None
TEWL	Female, 18	No significant difference (p=0.947)	All moisturizer conditions lower than control at 30, 60, and 90 minutes (all overall p<0.001)	2 vs. 10 minutes: - 30 minutes, p=0.015 - 60 minutes, p=0.015 - 90 minutes, p=0.024 2 vs. 15 minutes: - 30 minutes, p=0.005 - 60 minutes, p=0.006 - 90 minutes, p=0.008
TEWL	Male, 18	No significant difference (p=0.792)	All moisturizer conditions lower than control at 30, 60, and 90 minutes (all overall p<0.001)	None

Note: Sex-stratified analyses were prespecified and exploratory. Values shown for between-timing comparisons are Bonferroni-adjusted p-values. "Between-timing" comparisons refer to comparisons among the 2-, 5-, 10-, and 15-minute moisturizer application conditions. Statistical significance was defined as p<0.05.

Table 6. Exploratory age group-stratified analyses of stratum corneum hydration (SCH) and transepidermal water loss (TEWL)

Outcome	Age group (years), n	Baseline comparison across conditions	Post-application moisturizer vs. control (30-90 minutes)	Significant between-timing comparisons after Bonferroni adjustment
SCH	21-35, 12	No significant difference	All moisturizer conditions higher than control at 30, 60, and 90 minutes (all overall p<0.001)	None
SCH	36-50, 12	No significant difference	All moisturizer conditions higher than control at 30, 60, and 90 minutes (all overall p<0.001)	None
SCH	51-65, 12	No significant difference	All moisturizer conditions higher than control at 30, 60, and 90 minutes (all overall p<0.001)	None
TEWL	21-35, 12	No significant difference	All moisturizer conditions lower than control at 30, 60, and 90 minutes (all overall p<0.001)	2 vs. 15 minutes: 90 minutes, p=0.006 5 vs. 15 minutes: 90 minutes, p=0.026
TEWL	36-50, 12	No significant difference	All moisturizer conditions lower than control at 30, 60, and 90 minutes (all overall p<0.001)	2 vs. 10 minutes: 90 minutes, p=0.004 2 vs. 15 minutes: 90 minutes, p=0.001 5 vs. 15 minutes: 90 minutes, p=0.016
TEWL	51-65, 12	No significant difference	All moisturizer conditions lower than control at 30, 60, and 90 minutes (all overall p<0.001)	2 vs. 10 minutes: 90 minutes, p=0.005 2 vs. 15 minutes: 90 minutes, p<0.001 5 vs. 15 minutes: 90 minutes, p=0.021

Note: Age group-stratified analyses were prespecified and exploratory. Values shown for between-timing comparisons are Bonferroni-adjusted p-values. "Between-timing" comparisons refer to comparisons among the 2-, 5-, 10-, and 15-minute moisturizer application conditions. Statistical significance was defined as p<0.05.

responses in females and males, with all moisturized conditions exceeding the control and no significant differences among application timings after Bonferroni adjustment. TEWL was lower with moisturization in both sexes; however, significant between-timing differences were observed only in females (2 minutes lower than 10 and 15 minutes across time points), whereas no between-timing comparisons reached significance in males after Bonferroni adjustment (Table 5).

Age Group-stratified Outcomes (Exploratory)

Across all age groups, moisturization increased SCH and reduced TEWL compared with the control, while SCH did not differ significantly among application timings. Significant TEWL between-timing differences were confined to the 90-minute assessment and involved more pairwise comparisons in the 36- to 50- and 51- to 65-year groups than in the 21- to 35-year group (Table 6).

Adverse Events

No local irritation, allergic reactions, or other adverse events were reported during ROAT or the study visit.

Discussion

In this controlled-environment, within-subject repeated-measures study, moisturizer application after water-only washing consistently increased SCH and reduced TEWL compared with the non-moisturized control across all post-application time points. These

findings support the central role of moisturization in improving skin hydration and limiting water loss from the skin surface[1,2]. The coherent direction of both outcomes, higher SCH and lower TEWL, indicates that post-washing moisturization provides measurable short-term barrier-related benefits on the ventral forearm under standardized conditions aligned with established guidance for TEWL measurement[13,15,16]. No local irritation, allergic reactions, or other adverse events were observed, supporting the short-term tolerability of the study procedure and moisturizer in this healthy volunteer sample.

A key observation was the difference between SCH and TEWL in their sensitivity to application timing. SCH increased markedly after moisturization, but differences among the 2-, 5-, 10-, and 15-minute application intervals were not significant after multiplicity correction, suggesting that corneometry-derived hydration may reach a near-plateau within a practical early post-wash window. By contrast, TEWL showed modest timing-related differences in selected pairwise comparisons, with earlier application, most consistently at 2 minutes and less consistently at 5 minutes, associated with slightly lower TEWL than later application at 10-15 minutes.

This pattern is biologically plausible because capacitance-based SCH mainly reflects water content in the superficial stratum corneum, whereas TEWL is a dynamic marker of evaporative flux and barrier efficiency that may be more sensitive to surface film formation, occlusive effects, and rapid post-wash evaporation kinetics[1,2,13,15,16,22]. Thus, once the stratum corneum is rehydrated by an emollient/occlusive product, additional differences in measured hydration may be small, while earlier application may still provide a modest reduction in water loss before the skin fully equilibrates after washing[22].

In relation to prior studies, our findings are broadly consistent with existing human evidence but add greater timing granularity. Nguyen et al. (2022) reported no significant difference in hydration outcomes between immediate moisturization and application delayed by 30 minutes in healthy volunteers, although only two timing conditions were compared[5]. By evaluating multiple early intervals from 2 to 15 minutes, the present study suggests that SCH benefits are robust across this early window, whereas TEWL may retain some sensitivity to earlier application.

Ueda et al. (2022) observed superior hydration when moisturizer was applied within 5 minutes compared with a much longer 90-minute delay, supporting the concept that timing becomes more important when application is substantially postponed[6]. Taken together, these findings suggest a continuum: prolonged delays may reduce moisturizing benefit, whereas within a short practical interval after washing, SCH differences may be limited and TEWL differences may be modest[5,6].

Evidence from atopic dermatitis populations remains mixed, likely because baseline barrier impairment may modify response to moisturization[7-9]. Among patients with atopic dermatitis, Chiang & Eichenfield (2009) observed comparable hydration outcomes between immediate post-bathing moisturization and application delayed by 30 minutes[7]. In contrast, Wulandari et al. found that immediate moisturizer application was associated with higher skin hydration than 30-minute delayed application in pediatric atopic dermatitis[8]. Our study was conducted in healthy adults, and the consistency of SCH improvement across timing conditions may reflect intact barrier physiology and rapid responsiveness to occlusive/emollient application[1,2]. These results should therefore not be directly extrapolated to patients with established barrier dysfunction, such as atopic dermatitis, or systemic conditions associated with altered skin barrier function, including diabetes or chronic kidney disease[9,11,12].

Sex- and age-stratified analyses showed that the main finding, benefit of moisturization compared with no moisturization, was preserved across subgroups. The timing gradient for TEWL appeared modest and was not consistent across all subgroup comparisons, which is expected given smaller subgroup sample sizes and conservative Bonferroni adjustment[20]. Accordingly, subgroup results should be interpreted as exploratory and hypothesis-generating rather than confirmatory evidence of sex- or age-related effect modification[17-20]. From a practical perspective, the findings support a simple message: applying moisturizer soon after washing is consistently beneficial, while any additional advantage of application earlier within the first 15 minutes is likely modest and more apparent for TEWL than for SCH.

This study has several strengths. First, the within-subject design reduced between-person variability by allowing each participant to serve as their own control, improving efficiency for detecting condition effects[18,19]. Second, standardized temperature, humidity, test-site marking, moisturizer dose, application technique, and triplicate measurements supported protocol fidelity and reduced measurement variability, which is particularly important for TEWL[13,15,16]. Third, multiplicity-adjusted post

hoc testing reduced the risk of over-interpreting chance findings from multiple comparisons[20,21]. The intervention was also feasible to implement in a single controlled laboratory session, and no protocol deviations were observed.

Several limitations should be considered. The fixed, nonrandomized site allocation may have introduced residual anatomical-site or laterality-related confounding, despite baseline comparability and standardized procedures. The study evaluated a single anatomical region, a single base-cream formulation, and controlled laboratory conditions, which may limit generalizability to other body sites, climates, bathing practices, and moisturizer types[13,15,16,22]. Outcomes were short-term and measured only up to 90 minutes after application; therefore, longer-term barrier adaptation, patient-perceived dryness, and clinical outcomes cannot be inferred. In addition, subgroup analyses were exploratory and not powered to detect between-sex or between-age differences, so apparent subgroup patterns should be interpreted cautiously.

Future studies should evaluate broader post-washing delays, including 30-90 minutes or longer, compare different moisturizer formulations such as occlusive-dominant and humectant-dominant products, and assess anatomical sites with different barrier properties. Longer follow-up periods and patient-centered outcomes, such as perceived dryness or comfort, would improve clinical relevance. Studies in patients with barrier-compromised dermatoses may also clarify whether impaired baseline barrier function modifies the optimal timing of post-wash moisturization[9,22,23].

Conclusion

In healthy adults, moisturizer application after washing significantly improved both SCH and TEWL compared with no moisturizer application. However, while the timing of application within 2-15 minutes did not significantly affect SCH, earlier application was associated with modest but consistent reductions in TEWL. In exploratory subgroup analyses, this TEWL-related pattern appeared more evident in females and participants aged 36 years or older.

Author Contributions

SK and BT contributed to the study conception and design. Material preparation, data collection, and data analysis were performed by the authors. The first draft of the manuscript was written by SK, and both authors critically revised subsequent versions. All authors read and approved the final manuscript.

Clinical Trial Registration

This study was retrospectively registered with the Thai Clinical Trials Registry (TCTR; registration number TCTR20260523010) after completion of participant recruitment and data collection.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

De-identified individual participant data, the data dictionary, statistical code, and related study materials are not publicly available because of participant confidentiality and the scope of ethics approval. They may be made available from the corresponding author upon reasonable request and subject to approval by the relevant ethics committee or institutional data-sharing requirements.

Ethics Approval and Consent to Participate

The study protocol was approved by the Mae Fah Luang University Ethics Committee on Human Research (Protocol No. EC 25198-20; Certificate of Approval [COA] No. 212/2025; Approval date: November 4, 2025). The study was conducted in accordance with the Declaration of Helsinki and its later amendments. Written informed consent was obtained from all participants prior to enrollment.

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Use of Artificial Intelligence

During manuscript preparation and revision, the authors used ChatGPT (OpenAI; GPT-5.6 Sol) to assist with English-language editing, wording refinement, formatting suggestions, and preparation of submission-related administrative text. The AI tool was not used to generate study data, perform statistical analyses, create or modify research results, determine study conclusions, or replace the authors' scientific judgment. The authors critically reviewed, verified, edited, and approved all AI-assisted content and take full responsibility for the accuracy, integrity, and final content of the manuscript.

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