学　位　論　文

Effectiveness of weak wiping pressure during bed baths and prediction model for skin barrier dysfunction in hospitalized older adults

（高齢患者における弱圧清拭の有効性と皮膚バリア機能障害予測モデルの開発）

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Abstract

Background

There is a rapidly increasing global number of older patients, and the clinical demand for high-quality skin care is expected to increase further owing to skin vulnerability with aging. Bed baths are the most fundamental form of skin care aimed at enhancing skin integrity, cleanliness, and comfort in patients who have difficulty bathing. To provide safe and effective bed bath care that meets these three goals, nurses should select and practice high-quality bed bath methods based on appropriate skin assessments.

Excessive friction irritation (wiping pressure and number of wipes) during bed baths poses a risk of skin barrier dysfunction and skin tears. Skin barrier dysfunction and decreased potential of recovery in older patients are risk factors for various skin disorders. Therefore, we examined the optimal wiping pressure that satisfies these three requirements. Our previous studies using cotton towels suggested that bed bathing under weak pressure is more effective than under ordinary pressure, as routinely practiced by nurses, for maintaining the skin barrier function, removing dirt, and providing comfort for older patients. However, the following gaps need to be addressed to implement the evidence in clinical practice: 1) the actual conditions in the clinical settings and the cleaning effect of wiping pressure when using disposable towels remain unknown; 2) effects of consecutive interventions on skin barrier recovery are unknown; 3) there is no instrument to assess dry skin, the main clinical feature of skin barrier dysfunction; and 4) no clinical tool can easily predict the risk of skin barrier dysfunction caused by bed baths. These issues make it challenging to select bed bath methods based on skin assessment and provide high-quality bed bath care. Therefore, this dissertation aimed to verify the

effectiveness of weak wiping pressure during bed baths and develop a prediction model for skin barrier dysfunction in hospitalized older adults.

1. Minimum wiping pressure and number of wipes that can remove dirt during bed baths using disposable towels

This study analyzed the wiping pressure and number of wipes currently applied by nurses when using disposable towels during bed baths and proposed the minimum values for removing dirt from the skin. In Study 1 (a cross-sectional study), 101 nurses were observed by recording the wiping pressure and number of wipes when using disposable towels. In Study 2 (a quasi-experimental study), 50 healthy adults received oily and aqueous dirt on their forearms, which were wiped six times with disposable towels by applying one of four randomly assigned pressure categories. Color image analysis and a linear mixed model were used to estimate the dirt removal rate for each combination of wiping pressure and number of wipes. The results of Study 1 suggest that some nurses wiped excessively with disposable towels, which might cause skin problems. Study 2 indicated that excessive wiping is not required to adequately remove dirt, and wiping three times at a pressure of 10–20 mmHg was recommended regardless of the towel material used.

2. Effects of consecutive bed bathing with weak versus ordinary pressure on skin barrier recovery of hospitalized older adults

This study evaluated and compared the effects of consecutive bed bathing between weak and ordinary pressures on skin barrier recovery in older patients. This within-person randomized controlled trial involved 254 forearms (127 patients) and was conducted in a general hospital. The forearms were blinded and randomly assigned a site and sequence of two bed bathing sessions: wiping three times at weak (10–20 mmHg) and ordinary (20–30 mmHg) pressure once daily for two consecutive days. The skin barrier was assessed daily based on transepidermal water loss (TEWL) and stratum corneum hydration (SCH) before and 15 min after intervention. A linear mixed model showed that the time courses of TEWL and SCH differed significantly between groups. The impaired skin barrier function caused by ordinary pressure on the first day did not recover to the baseline values on the next day, whereas weak pressure did not cause significant changes. These findings suggest the safety of consecutive interventions under weak pressure and highlight the importance of wiping pressure during bed baths.

3. Reliability and validity of the Japanese version of the overall dry skin score in older patients

This study evaluated the reliability and validity of the Japanese version of the overall dry skin score (ODS-J), the gold standard for dry skin assessment. A cross-sectional study was conducted in 47 patients aged >65 years. Images of the skin on the limbs were captured using a digital camera and both the upper and lower limbs were assessed (n = 4/patient). The ODS-J was developed using a back-translation method. One dermatologist; two wound, ostomy, and continence nurses; and three nursing researchers independently evaluated the images using the ODS-J to assess the intraclass correlation coefficient for inter-rater reliability. SCH and TEWL were the external criteria used to verify concurrent and known-group validity. The ODS-J showed good inter-rater reliability, concurrent validity, and known-group validity, suggesting its usability in skin assessment during skin care in Japan.

4. A dynamic nomogram to predict skin barrier dysfunction during bed baths in hospitalized older adults

In this study, we developed a nomogram to predict skin barrier dysfunction during bed baths in older patients. The volar forearms of 149 older patients underwent a wiping friction test (wiping three times at 20–30 mmHg) with reliability and validity. TEWL was assessed before and 15 min after the test. Skin barrier dysfunction was defined based on the cut-off values. Candidate variables were obtained from the medical records and skin assessments. Predictor selection was based on findings from our latest systematic review, clinical practicality, and rigorous discussions with a statistician, dermatologist, and nursing researchers. A nomogram was constructed using multivariate logistic regression analysis. The performance of the model was internally validated using 1000-bootstrap resampling and evaluated for discrimination, calibration, and clinical usefulness. The results indicated that 26.2% of the older patients developed skin barrier dysfunction during bed baths. The predictors included chronic kidney disease, purpura, dry skin, activities of daily living (ADL: Barthel Index), and body mass index (BMI). Based on these routinely available predictors, the nomogram demonstrated good discrimination, calibration, and clinical utility. Finally, we developed a dynamic nomogram that anyone can access online (https://konya2023.shinyapps.io/launch/).

Conclusion and clinical implications

Bed bathing with weak pressure is recommended for older patients based on accumulated evidence. The novel nomogram can facilitate nurses' selection of tailored skin care methods to prevent skin disorders and incorporate patient preferences. For high-risk patients, users can plan care that pays particular attention to skin vulnerability, not only in terms of wiping pressure but also the type and frequency of skin care and the products used. Low-risk patients can receive standard care that prioritizes the maximum patient preferences and requests. Therefore, these findings enable the selection of tailored bed bath methods based on appropriate skin assessments using a predictive model, contributing to the realization of safe and effective bed bath care for a growing number of older patients. Further research is required to program these findings and implement them in clinical settings and through fundamental nursing education.

Chapter 1

Introduction

1.1. Background

By 2050, the global number of older adults is expected to more than double to over 1.5 billion, from the current level [1]. Aging is inevitably associated with functional disabilities, chronic diseases, and care dependency; thus, the number of older adults receiving long-term or home care is rapidly increasing [1]. Additionally, the skin barrier function of the stratum corneum becomes more vulnerable with aging [2]. This function plays a pivotal role in preventing the loss of internal water and invasion by external substances (pathogens, allergens, and chemicals) [2]. Impaired skin barrier function is associated with dry skin and inflammation and is a risk factor for severe skin disorders such as pressure ulcers and skin tears [3,4]. Therefore, preventing skin disorders and maintaining skin integrity through appropriate daily skin care in older patients are major goals in the clinical setting [5]. This is a critical issue in nursing settings, and the demand for daily skin care research is increasing in today's super-aged society, as it is more cost-effective than wound treatment [6,7].

Bed baths are the most fundamental form of skin care for maintaining hygiene in patients who have difficulty bathing and involve the use of warm towels to wipe their skin. The goals of bed baths are skin integrity, skin cleanliness, and comfort enhancement [8]; thus, appropriate bed baths remove skin dirt while maintaining skin barrier function and provide psychological effects such as comfort [9,10]. Furthermore, it has been practiced as meaningful nursing care that strengthens the nurse–patient relationship and improves patients' quality of life and well-being [11]. To provide safe and effective bed bath care that meets these three goals, nurses and caregivers must select and practice high-quality bed bath methods based on appropriate skin assessments.

Therefore, we conducted a systematic review to synthesize evidence for bed bath methods that meet these three goals [9]. Evidence for bed bath methods was categorized into towel materials, thermal stimulation, wiping methods, and chemical products. Among bed bath methods, the "wiping pressure during bed baths" is strongly related to all three goals [9]. Wiping pressure is particularly important for the safety of care because excessive frictional irritation can lead to skin barrier dysfunction and skin tears [12,13]. Our previous study reported that bed bathing under ordinary pressure (23–25 mmHg, as routinely practiced by clinical nurses) significantly decreased the skin barrier function in older patients compared to that under weak pressure (12–14 mmHg, assuming vulnerable skin) [14]. Moreover, wiping three times under weak pressure was sufficient to remove skin dirt [15] and did not cause discomfort to older patients [14]. Thus, a weak pressure may be the "optimal wiping pressure" that satisfies these three goals.

Previous studies on wiping pressure have been conducted using cotton towels. The influence of "towel material," another factor related to frictional irritation of the skin, must be considered. Disposable towels, which are widely used in the United States and Europe, have different surface structures than cotton towels [16]. Thus, directly transferring evidence on frictional irritation from cotton wipes to disposable wipes is inaccurate. Although nurses must remove dirt with minimal frictional irritation to maintain skin cleanliness and integrity, the wiping pressure and number of wipes that meet these two requirements when using disposable towels are unknown.

Furthermore, a previous study comparing the effects of weak and ordinary pressure on skin barrier function in older patients assessed for only 15 min after one daily bed bath [14]. The skin barrier function has a "recovery potential" and can maintain homeostasis through turnover even after damage [17]. However, the recovery function of older skin is markedly decreased, contributing to the high prevalence of skin disorders in older patients

[18]. Therefore, the safety of weak pressure can only be confirmed by evaluating the effects of consecutive interventions on skin barrier recovery.

In addition to evidence-based bed bath methods, skin assessment is essential for nurses and caregivers to prevent skin disorders [19]. Dry skin, the main clinical finding of skin barrier dysfunction, is most prevalent in older adults [20]. The overall dry skin score is the gold standard for assessing the presence and severity of dry skin [21], and it is widely used as an indicator of the effectiveness of skin care in clinical practice and research. However, a Japanese version is yet to be developed; thus, no standard instrument is available for medical workers to assess dry skin across various facilities in Japan, which has the highest proportion of older adults worldwide.

In addition to dry skin, various factors, including functional disabilities, chronic diseases, and nutritional status, can adversely affect the skin [22]. However, no risk factors have been identified to aid the risk assessment of skin barrier dysfunction during bed baths. Although skin-friendly care is a priority in preventing skin barrier dysfunction, practices that disregard patient preferences and requests are detrimental to patient comfort [11]. In other words, proper skin assessment is required to prioritize skin safety and comfort during bed baths. We hypothesized that screening patients at high risk of skin barrier dysfunction before bed baths could assist nurses in prioritizing the maintenance of skin integrity and meeting patient preferences, further guiding the selection of patient-specific care. However, no user-friendly clinical tools exist to predict the risk of skin barrier dysfunction caused by bed baths. This prevents the selection of high-quality bed bath methods that consider the patients' skin and comfort.

Therefore, this dissertation aimed to verify the effectiveness of weak wiping pressure during bed baths and develop a prediction model for skin barrier dysfunction in hospitalized older adults. This dissertation includes four studies that address the following evidence gaps: The specific objectives of each chapter are presented in the subsequent sections.

1） A multi-study approach to investigate minimal wiping pressure and number of wipes, to maintain skin cleanliness and integrity when using disposable towels

2） A randomized controlled trial comparing the effects of consecutive bed bathing under weak versus ordinary pressure on skin barrier recovery in older patients

3） A cross-sectional study to evaluate the reliability and validity of the Japanese version of the overall dry skin score in older patients

4） A predictive modeling study to develop a dynamic nomogram for predicting skin barrier dysfunction during bed baths in older patients

1.2. The objective of each chapter

Chapter 1. To synthesize evidence on gaps and aim of this dissertation, considering previous research on safe and effective bed bath care in older patients.

Chapter 2. To clarify the risk factors associated with skin barrier dysfunction in older adults through a systematic review.

Chapter 3. To evaluate the reliability and validity of the Japanese version of the overall dry skin score (ODS-J), the gold standard for dry skin assessment.

Chapter 4. To analyze the wiping pressure and number of wipes currently applied by nurses when using disposable towels during bed baths and propose minimum values for removing dirt from the skin.

Chapter 5. To evaluate and compare the effects of consecutive bed bathing under weak and ordinary pressure on skin barrier recovery in hospitalized older adults.

Chapter 6. To develop a nomogram for predicting skin barrier dysfunction during bed baths in hospitalized older adults.

Chapter 7. To conclude with the implications for clinical practice and future research based on the results of this dissertation.

1.3. The contribution of the dissertation

This study would contribute significantly to one of the 17 Sustainable Development Goals (SDGs), the SDG 3, regarding "Good Health and Well-being" (Figure 1). The development of safe and effective bed bath care for a growing number of older patients worldwide will lead to the provision of high-quality skin care in all clinical settings, including hospitals, long-term care, and home care. This would contribute to the prevention of skin disorders, leading to the improvement of activities of daily living (ADL) and quality of life (QOL), and the maintenance and improvement of the health of older patients. Furthermore, preventing skin disorders through appropriate skin care and assessment is more cost-effective than wound care, which requires special medical tape and dressings. Therefore, this study is expected to contribute to shorter hospital stays and reduced medical costs and waste, with spillover effects on the economic (Goal 12) and environmental (Goal 13) SDGs.

Figure 1. The three sustainable development goals to which this study will contribute

1.4. The operational terms

1) **Wiping pressure**: the force applied vertically to the skin surface during bed baths [23] (Figure 2). Wiping pressure is affected by the wiping speed, direction, towel material, towel contact area, and wiped skin area. Standardization of these conditions would allow for measurements using a pressure sensor, as shown in Figure 2.

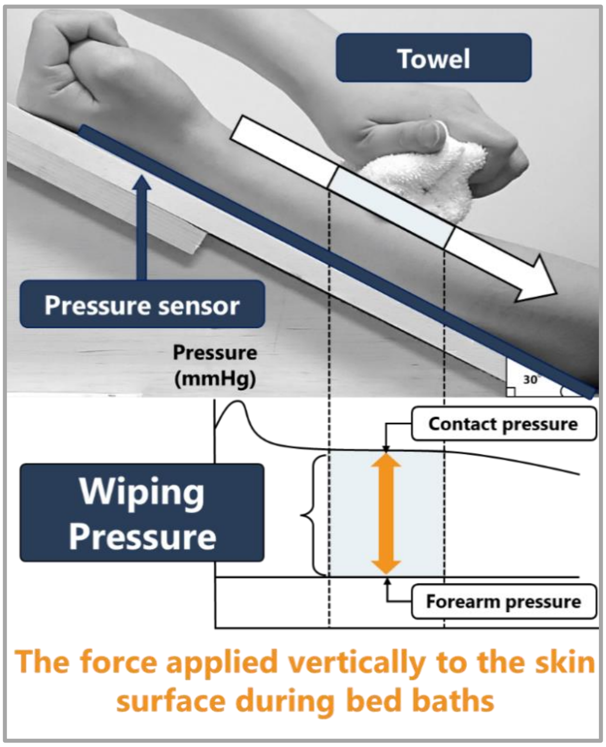

Figure 2. Defining the wiping pressure during bed baths

2) **Optimal wiping pressure**: an ideal wiping pressure that satisfies three requirements: skin integrity, skin cleanliness, and comfort enhancement. In the present study, it was defined as the wiping pressure required to remove dirt and achieve subjective satisfaction without impairing skin barrier function.

3) **Safe and effective bed bath care**: a series of care actions to select and practice optimal bed bath methods that satisfy patients' skin integrity, cleanliness, and comfort enhancement requirements based on an appropriate skin assessment.

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Chapter 2

Risk factors of skin barrier dysfunction in older adults:

A systematic review

2.1. Abstract

Background

Skin barrier dysfunction can trigger various skin disorders in older adults. Skin barrier assessment is essential for nurses and caregivers to prevent skin disorders; however, the evidence available for clinical assessment is limited. This systematic review aimed to clarify the risk factors of skin barrier dysfunction in older adults.

Methods

This review adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. The four databases were searched using multiple terms related to "aged" and "skin barrier." The search was initially run on April 19, 2023, and rerun on October 12, 2023. Peer-reviewed quantitative studies in English were included, with no publication time limit being set. Two reviewers assessed the risk of bias in a blinded and independent manner using JBI tools. Owing to the heterogeneity of the results, a narrative synthesis was performed.

Results

Among the database-identified 4833 studies, 20 studies were included. The extracted factors were categorized as demographic characteristics, functional characteristics, chronic diseases, nutritional status, skin condition, and environmental factors. However, owing to high-risk of bias and inconsistent results across studies, only chronic kidney disease and dry skin were considered risk factors for skin barrier dysfunction in older adults.

Conclusions

Assessment of chronic kidney disease and dry skin in daily skin care may guide the development of personalized skincare programs to maintain skin integrity in older adults.

Furthermore, cohort studies that consider confounding factors and the reliability of measurements are needed for an in-depth investigation into skin barrier dysfunction and more risk factors.

2.2. Background

The skin health of older adults is key issue in nursing settings in today's super-aged society [1]. The number of older adults receiving long-term or home care is rapidly increasing, and the older adult population is expected to more than double by 2050 [2]. Skin aging is associated with various skin disorders; an extensive survey of nursing homes in Germany spotlighted the high prevalence of skin disorders among older residents [3], notably dry skin (95.9%), incontinence-associated dermatitis (21.0%), skin tears (10.5%), and pressure ulcers (8.0%) [3]. Therefore, high-quality skin assessment and care are critical to maintain skin integrity in older adults; however, reliable evidence is limited [4].

In humans, regardless of age, the skin barrier function is vital for maintaining skin integrity. The stratum corneum (SC), the uppermost layer of the skin, comprises multiple layers of keratinocytes suspended in an extracellular lipid matrix, similar to layers of mortar (lipids)-bound bricks (keratinocytes) [5]. The SC barrier function prevents excessive transepidermal water loss (TEWL) and foreign substance penetration [6]. This function has a turnover time of approximately 40 days and is self-reparative [5].

However, skin barrier function in older adults is vulnerable because of intrinsic and extrinsic age-related changes, thus resulting in elevated TEWL and poor SC hydration (SCH) [6]. Intrinsic skin aging, a programmed biological change, causes slower turnover (≥60 days), epidermal thinning, and reduced levels of natural moisturizing factors, lipids, and sebum [6, 7]. In older adults, this change markedly decreases skin barrier function and limits its post-damage self-reparative ability, thereby triggering various skin disorders [7, 8]. Age-related health (including functional disabilities, chronic diseases, and medications) and environmental (sun exposure and individual habits) factors adversely affect the skin [9]; older adults are exposed to these factors daily. Moreover, inappropriate skin care methods can be a risk factor for skin barrier dysfunction [4]. Therefore, nurses and caregivers need to assess the risk of skin barrier dysfunction, before it visibly causes symptoms of severe skin disorders, and select preventive skin care strategies.

The practice of appropriate skin care can prevent the transition to skin disorders and would be efficient in terms of patient burden and cost [10], if the risk factors for skin barrier dysfunction are correctly assessed. Moreover, establishing a clinical assessment method is important, because the skin barrier function is indiscernible and its measurement requires expensive instruments [11]. Some reviews have described factors associated with skin barrier dysfunction, such as ethnicity, sex, skin type, anatomical sites, lifestyle, and body mass index [12, 13]; however, these reviews did not examine the risk of bias or focus on the evidence in older adults, for whom skin care is critical. Therefore, risk factors for skin barrier dysfunction in older adults, other than inappropriate skin care interventions, remain unclear.

This systematic review aimed to clarify the risk factors associated with skin barrier dysfunction in older adults. Our review could contribute to establishing effective skin assessment and supporting decision-making in selecting appropriate skin care for older adults.

2.3. Methods

2.3.1. Study protocol

This systematic review adhered to the guidelines of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines [14] and the JBI Reviewers' Manual [15]. The review protocol was registered in PROSPERO (CRD42023433299).

2.3.2. Eligibility criteria

The review question was, "what are the risk factors associated with skin barrier dysfunction in older adults?". This review particularly focused on the demographic and health characteristics associated with skin barrier dysfunction in older adults, i.e., the factors useful for skin assessment other than skin care interventions. Studies that did not address risk factors associated with skin barrier dysfunction were excluded. TEWL and SCH were focused on as the review outcomes in accordance with international guidelines [16]. These outcomes are the gold standard of skin barrier measurements, and elevated TEWL or decreased SCH indicates skin barrier dysfunction [16]. The inclusion and exclusion criteria used in the literature search was based on the population, exposure, outcome format and are listed in Table 1.

Table 1. Inclusion and exclusion criteria using the population, exposure, outcome format

Criteria	Inclusion	Exclusion
Population	Older adults/patients (lower limit of range age 50 years)	Neonates, infants, children, younger adults, animals, skin models, and cadavers
Exposures of interest	Risk factors associated with skin barrier dysfunction, including demographic and functional characteristics, disease, nutritional status, skin condition, medications. environment, and habits	Dermatological diseases, skin infections, occupational exposure, chemical substances, therapeutic interventions, cosmetic or preferential interventions, interventions focused only on the effects of skin care, and simple comparisons between older and younger adults
Outcomes	Skin barrier function assessed as transepidermal water loss and stratum corneum hydration	Skin barrier measurements on only mucous membranes, scalp, face, burns, scars, and wounds
Types of studies	Observational, randomized, and non-randomized studies, systematic reviews, and original studies peer-reviewed and published	Qualitative studies, case reports and series, reviews without risk-of-bias assessment, diagnostic test accuracy and scale development studies, protocol registration, and in-vitro studies
Language	English	Not in English

2.3.3. Search strategy

The lead reviewer devised a search strategy based on the review questions, keywords, and index terms. The search strategy was peer-reviewed by an experienced librarian and implemented after a consensus among all authors (Supplementary Table 1). No publication time limit was set for this study. The following electronic databases were initially searched on April 19, 2023 (the search was rerun on October 12, 2023): MEDLINE (via PubMed), CINAHL (via EBSCOhost), Cochrane Database of Systematic Reviews (CDSR) (via Wiley), and Cochrane Central Register of Controlled Trials (CENTRAL) (via Wiley). Duplicates were manually removed by a librarian using Microsoft Excel.

2.3.4. Selection process

The reviewer team confirmed the validity of the selection process using detailed procedure manuals in advance. Two reviewers screened the titles and abstracts of the potential literature according to the eligibility criteria. Subsequently, a full-text screening of the remaining studies was performed. Both processes were investigator-blinded and performed independently using the Rayyan software (https://rayyan.ai/reviews). Discrepancies and questions at each screening stage were discussed and resolved by a third reviewer. The final remaining literature was managed by Paperpile, a reference management software (https://paperpile.com/app). To search for relevant gray literature and additional articles, the reviewers examined the titles listed in the citations of the remaining studies after the full-text screening. Literature deemed relevant was manually searched and checked for abstracts or full text. As a result, no gray literature sources or additional articles meeting the inclusion criteria were identified.

2.3.5. Risk of bias assessment

The risk of bias was assessed using the JBI critical appraisal tools (checklist for cross-sectional studies and revised checklist for randomized controlled trials [RCT]: Supplementary Table 2) [15]. During the protocol planning phase, the Risk Of Bias In Non-randomized Studies of Exposures (ROBINS-E) tool, designed for cohort studies, was intended to be applied [17]. However, because most included studies used cross-sectional designs, they could not be effectively assessed using the ROBINS-E; therefore, other suitable assessment tools were substituted.

Two reviewers independently assessed these studies using the JBI critical appraisal tool and any discrepancies were resolved in consultation with a third reviewer. Each question within the tool received one of four ratings: “yes,” “no,” “unclear,” or “not applicable.” A “yes” rating corresponded to 1 point, and the cumulative score was calculated. Regarding questions 5 and 6, which pertained to confounding factors in the context of cross-sectional studies, the key confounding factors were predefined. The study design, data collection, and data analysis were assessed according to guidelines [16] for whether potential confounding variables (age, measurement site, sweat, skin diseases, skin care, and habitual indulgences) were effectively controlled. “Yes” and “no” responses for each item were interpreted as “low risk of bias (+)” and “high-risk of bias (×),” respectively, and the robvis tool was used to visualize the results [18]. The overall risk of bias for individual studies was determined based on the percentage of “yes” ratings as follows: high (<49%: ×), moderate (50–69%: –), and low (>70%: +) [19, 20].

2.3.6. Data extraction and synthesis

Using standardized data extraction tables, the following were recorded: authors, publication years, countries, design, participant information, setting/environment, risk factors, outcomes, instruments, analysis methods, main findings, and funding. Two reviewers independently performed this process, which was crosschecked by all review members. The assessment of meta-analysis, reporting bias, and certainty of evidence proved challenging owing to the heterogeneity in the results. Consequently, narrative synthesis was performed.

During the planning stage, the search and data extraction were conducted comprehensively, without including terms related to “factors” in the search strategy, given the possibility of finding both risk and protective factors. Finally, protective factors, i.e., appropriate skin care, were excluded based on the study objectives; only risk factors were extracted. Factors extracted from the results were classified into six categories: demographic characteristics, functional characteristics, chronic diseases, nutritional status, skin conditions, and environmental factors. The factors were ranked according to three criteria: 1) statistical significance observed, 2) multiple studies agreeing on the results, and 3) at least one study having low-risk bias. Subsequently, factors that met criteria 1) and 2) for “consistent results across multiple studies” and criteria 3) for “risk of bias” were defined as risk factors (Level A). Factors that met criteria 1) but did not meet either criteria 2) or 3) or both were defined as potential risk factors (Level B). There were two possible reasons for the occurrence of criterion 2): a) no multiple studies and b) inconsistent results across multiple studies. Factors that did not meet criterion 1) were defined as non-associated factors (Level C).

2.4. Results

2.4.1. Study selection

Among the database-identified 4833 studies, 947 duplicates were excluded. Of 3886 studies underwent title and abstract screening, 3841 studies were excluded owing to the eligibility criteria. Of the remaining 45 studies that underwent full-text screening, 25 were excluded; details of the reasons for exclusion are provided in Supplementary Table 3. Finally, 20 studies were included in the review (Figure 1).

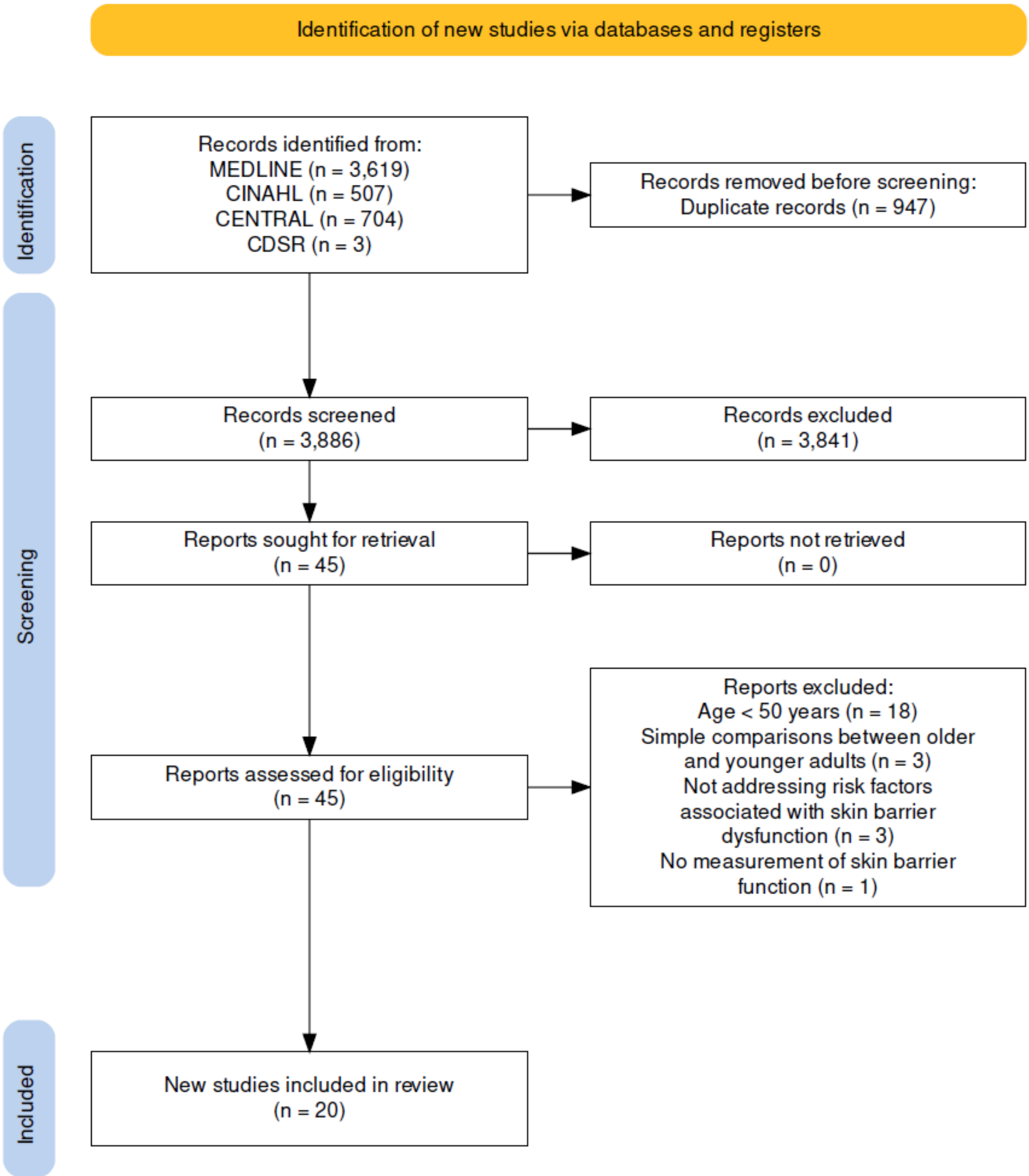

Figure 1. PRISMA flow diagram

2.4.2. Study characteristics

Table 2 summarizes the characteristics and main findings of the 20 included studies. Additional information is provided in Supplementary Table 4. Nineteen were cross-sectional studies, while one was a randomized crossover trial. These studies were conducted in various regions, namely, Japan (eight), China (four), Germany (three), Israel (two), the United States (one), Netherlands (one), and India (one), and in diverse settings: controlled environments (six), hospitals (five), long-term care facilities (three), community settings (three), and unknown (four). One among these was conducted in both a controlled environment and a hospital. The sample sizes in these studies ranged from 40 to 713 participants.

Nineteen of the 20 studies assessed SCH using six different instruments: Corneometer CM825 and CM820 (Courage+Khazaka Electronics, Cologne, Germany), Mobile Moisture HP10-N (Courage+Khazaka), Derma Unit SSC3 (Courage+Khazaka), Nova Dermal Phase Meter DPM 9003 (Nova Technology Corporation, Portsmouth, NH, USA), Dermalab Moisture Unit (Cortex Technology, Hadsund, Denmark), and Capacitance meter (IMS Ltd., Haifa, Israel). Twelve of the 20 studies assessed TEWL using three different instruments: Tewameter TM300 (Courage+Khazaka), VapoMeter (Delfin Technologies, Ltd., Kuopio, Finland), and Dermalab (Cortex Technology).

Table 2. Summary of the included studies (n = 20)

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Yosipovitch et al. (1995) [21] Israel	Cross-sectional	Controlled environment Temperature: 22.0 ℃ Humidity: 35.0%	P = 40 patients with end-stage renal failure (males: mean age [SD]: 61.3 [2.7] years; females: mean age: 57.3 [1.7] years) C = 45 age-matched healthy participants	Chronic kidney disease	SCH (Corneometer CM820) Sites: forearm, palm, sole, shin, forehead, and neck	At all sites, SCH was significantly lower in patients with chronic kidney disease than in healthy controls (all, *P*<.01).
Aisen et al. (1997) [22] Israel	Cross-sectional	Unknown	P = 38 bedridden patients (mean age: 75 [15.3] years) C = 7 ambulatory healthy older participants and 7 younger participants	ADL (immobility)	SCH (Capacitance meter) Sites: arm, chest, forehead, and face	At all sites, SCH was significantly lower in bedridden patient group than in the control group (*P*<.001).
Boelsma et al. (2003) [23] Netherlands	Cross-sectional	Controlled environment; Temperature: 22.0 [2.0] ℃ Humidity: 40.0–60.0%	P = 101 healthy older participants (mean age: 58.1 [6.1] years) O = 102 middle-aged participants (mean age [SD]: 41.4 [4.4] years) and 99 younger participants (mean age [SD]: 26.3 [5.0] years)	Dietary intake	SCH (Corneometer CM825) Sites: volar forearm	SCH negatively associated with dietary intake of total, saturated, and monounsaturated fats, even after adjusting for confounders (sex, age, and smoking).

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Man et al. (2009) [24] China	Cross-sectional	Single hospital Temperature: 22.0–24.0 °C Humidity: 45.0–55.0%	P = 114 healthy older participants (51–70 years: n = 59 and >70 years: n = 55) O = 270 prepubertal (0–12 years), 187 young (13–35 years), and 142 middle-aged (36–50 years) healthy participants	Sex	SCH (Corneometer CM825) Sites: forearm and forehead	No sex differences observed in SCH of the forearms in the 51–70 and >70 years age groups.
Angelova-Fischer et al. (2010) [25] Germany	Cross-sectional	Controlled environment Temperature: 21.0 [2.0] °C Humidity: 35.0–45.0%	P = 30 patients with chronic venous insufficiency (stage C2: mean age: 58 years; stage C4: mean age: 68 years) C = 15 age-matched healthy participants	Chronic venous insufficiency	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: calf, malleoli, dorsum of foot, and volar forearm	Patients with chronic venous insufficiency had higher TEWL at all sites on the lower legs (all, $P<.01$) than the controls. However, no significant differences were observed in SCH.
Chu and Kollias (2011) [26] United States of America	Cross-sectional	Unknown	P = 34 White healthy females (55–60 years: n = 20 and 65–75: n = 24) and 30 African American healthy females (55–60 years: n = 15 and 65–75: n = 15) O = 40 White healthy females (14–20 years: n = 20 and 25–40: n = 20) and 37 African American healthy females (14–20 years: n = 17 and 25–40 years: n = 20)	Ethnicity	TEWL (Vapometer) SCH (DPM 9003) Sites: dorsal forearm, upper inner arm	Regardless of age and site, White females had higher TEWL than African American females ($P<0.05$). For the dorsal forearm only, older White females had lower SCH than older African American females ($P<0.05$).

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Liu et al. (2012) [27] China	Cross-sectional	Single hospital Temperature: 22.0–24.0 ℃ Humidity: 45.0–55.0%	P = 42 sun-exposed older participants (males: mean age: 59.6 [1.3] years; females: mean age: 64.8 [0.7] years) C = 42 non-sun-exposed older participants (males: mean age: 67.5 [1.2] years; females: mean age: 69.3 [1.3] years) O = 84 sun-exposed and non-sun-exposed younger participants	Sun-exposed	SCH (Corneometer CM825) Sites: dorsal hand, canthus, and forehead	Only in older adult females: SCH was significantly lower in the sun-exposed group than in the non-sun exposed group (dorsal hand: $P<.02$).
Iizaka et al. (2012) [28] Japan	Cross-sectional	Single long-term care hospital Temperature: 24.3 [1.7] ℃ Humidity: 37.6 [8.2] %	P = 90 older residents (mean age: 82.5 [8.0] years)	Nutritional status indices (BMI, involuntary weight loss, arm muscle area and serum albumin and prealbumin levels)	TEWL (Vapometer) SCH (Corneometer CM825) Sites: lower leg	No significant correlation was found between skin barrier function and all nutritional status indices.
Luebberding et al. (2013) [29] Germany	Cross-sectional	Controlled environment Temperature: 20.0 ℃ Humidity: 50.0%	P = 120 healthy older participants (50–59 and 60–74 years age groups; n = 60 per group) O = 180 healthy participants (20–29, 30–39, and 40–49 years age groups; n = 60 per group)	Sex	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: volar forearm, dorsal hand, forehead, cheek, and neck	TEWL in the forearms of older adults (50–59 and 60–74 years age groups) was significantly higher in females than that in males (respectively, $P<.001$); however, no significant sex differences were observed in SCH.

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Fujimura et al. (2016) [30] Japan	Cross-sectional	Single hospital Temperature: 22.0–28.0 ℃ Humidity: 63.0–85.0% Controlled environment Temperature: 22.0–25.0 ℃ Humidity: 50.0–70.0%	P = 35 bedridden older patients with incontinence (mean age: 83.5 [9.7] years) C = 41 healthy older adults (mean age: 75.9 [5.6] years) and 20 middle-aged participants (mean age: 41.3 [2.8] years)	ADL (bedridden and incontinent)	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: forearm and gluteal region	In the forearms, no significant differences were observed in TEWL and SCH among the three groups. In the gluteal region, TEWL and SCH were significantly higher in the bedridden older adults with incontinence than in the healthy older adults (*P*<.05 in both cases).
Iizaka (2017) [31] Japan	Cross-sectional	Three community-dwelling settings Temperature: 20.4 [4.7] ℃ Humidity: 62.6 [9.7] %	P = 118 community-dwelling older adults (mean age: 74.4 [4.7] years)	Dry skin Lifestyle-related factors (bathing and skin care habits, outdoor activities, and hospitalization experience)	SCH (Mobile Moisture HP10-N) Sites: lower leg	SCH was negatively associated with dry skin (r = -0.46, *P*<.001). Multiple regression analysis revealed that factors negatively associated with SCH were hospitalization in the past year (*P*=.008), excessive bathing habits (*P*=.014), and outdoor hobbies (*P*=.007).
Hahnel et al. (2017) [32] Germany	Cross-sectional	Ten long-term care facilities Temperature: 22.9 [1.5] ℃ Humidity: 45.0 [9.2] %	P = 223 older nursing home residents (mean age: 83.6 [8.0] years)	ADL (Barthel index) Dry skin	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: volar forearm and lower leg	Skin barrier function was not associated with care dependency. In multiple regression analysis, SCH of the lower legs revealed a significant negative association with dry skin (*P*=.002) and a significant positive association with skin tear (*P*=.013). TEWL of forearms revealed a significant negative association with skin dry skin (*P*=.003).

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Iizaka et al. (2017) [33] Japan	Cross-sectional	Three community-dwelling settings Temperature: 20.4 [4.7] ℃ Humidity: 62.6 [9.7] %	P = 118 community-dwelling older adults (mean age: 74.1 [4.8] years)	BMI Malnourished status Habitual dietary intake	SCH (Mobile Moisture HP10-N) Sites: lower leg	No significant differences were observed in SCH between the malnutrition risk and well-nourished groups, or obese (BMI ≥25 kg/m^2) and non-obese groups. Nutrient intake or food group intake was not significantly associated with SCH.
Mehta et al. (2018) [34] India	Cross-sectional	Unknown Temperature: 20.0–27.0 ℃ Humidity: 10.0–60.0%	P = 95 healthy older participants (51–70 years) O = 110 children-adolescents (5–20 years), 169 young participants (21–35 years), and 126 middle-aged participants (36–50 years)	Sex	TEWL (Dermalab instrument) SCH (Dermalab instrument) Sites: forearm, leg, scalp, and forehead	No significant sex differences in TEWL and SCH were observed in the forearms and legs of the older adult group (51–70 years).
Iizaka (2018) [35] Japan	Cross-sectional	Community-dwelling settings Temperature: 23.6 [1.7] ℃ Humidity: 72.2 [6.2] %	P = 128 community-dwelling older adults (mean age: 74.5 [6.3] years)	Frailty BMI	SCH (Mobile Moisture HP10-N) Sites: volar forearm	No significant associations were found between SCH and frailty or BMI.

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Kimori et al. (2018) [36] Japan	Cross-sectional	Single hospital Temperature (median [IQR]): 23.8 [23.0–25.0] ℃ Humidity: 29.0 [25.0–34.5] %	P = 50 older patients (median age [IQR]: 84 [77–89] years)	Venipuncture-induced hematoma	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: volar forearm	Venipuncture-induced hematoma sites had significantly lower SCH (*P*<.001) than non-hematoma sites; however, no significant differences were observed in TEWL.
Nagase et al. (2020) [37] Japan	Cross-sectional*	Single long-term care hospital Temperature: unknown Humidity: unknown	P = 31 bedridden older patients (median age [range]: 85 [71–100] years) C = 19 healthy younger participants and 18 ambulatory older participants	ADL (bedridden)	TEWL (VapoMeter) SCH (Derma Unit SSC3) Sites: sacral region	SCH was not significantly different in all groups; TEWL was significantly lower in ambulatory older adults (*P*<.01) and bedridden older patients (*P*<.01) than in healthy younger participants.
Ma et al. (2020) [38] China	Cross-sectional	Controlled environment Temperature: 23.0 ℃ Humidity: 50.0%	P = 20 patients with senile pruritus (mean age: 69.1 [6.4] years) C = 20 age- and sex-matched healthy participants	Senile pruritus	TEWL (Tewameter TM300) Sites: knee	Patients with senile pruritus had significantly higher TEWL than controls (*P*<.01).
Huang et al. (2021) [39] China	Cross-sectional	Unknown	P = 25 patients with senile pruritus (mean age: 70.6 [9.8] years) C = 28 age- and sex-matched healthy participants	Senile pruritus	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: back	Patients with senile pruritus had significantly lower SCH than controls (*P*=.014); however, no significant difference was observed in TEWL.

Authors (year) and country	Study design	Setting and environment	Participants	Risk factors	Outcomes	Main findings
Konya et al. (2021) [40] Japan	Randomized crossover trial	Single hospital Temperature: 26.3 [0.6] °C Humidity: 59.6 [4.0] %	P = 44 older patients (mean age: 82.1 [8.6] years)	Chronic kidney disease Diabetes/dyslipidemia	TEWL (Tewameter TM300) SCH (Corneometer CM825) Sites: volar forearm	In subgroup analysis, the presence of diabetes/dyslipidemia (*P*=.036) and chronic kidney disease (*P*=.006) were significantly associated with clusters in which SCH was particularly reduced by ordinary wiping pressure during bed baths.

Notes: Population (P), target population of interest; Comparator (C), control group of the target population of interest; Others (O), other population included in study; *, A paper by Nagase et al [33] was described as a "cohort study"; however, it was interpreted as a cross-sectional study because the results related to skin barrier function were obtained from cross-sectional analyses.
Abbreviations: ADL, activities of daily living; BMI, body mass index; SD, standard deviation; IQR, interquartile range; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

2.4.3. Risk of bias in studies

The level of agreement between the two reviewers had a Cohen's κ coefficient of 0.85 (95% confidence interval: 0.79–0.93), indicative of "almost perfect." The results of the risk of bias assessment for each study are illustrated in Figure 2. Regarding the overall risk of bias, seven, six, and seven studies had a high, moderate, and low risk of bias, respectively, with many studies having a moderate to high risk of bias. Of the 19 cross-sectional studies, 16 failed to adequately "identify and address confounding factors (questions 5 and 6)," resulting in a high risk of bias. Moreover, 14 of these studies did not provide reliable and validated measures of the skin barrier function.

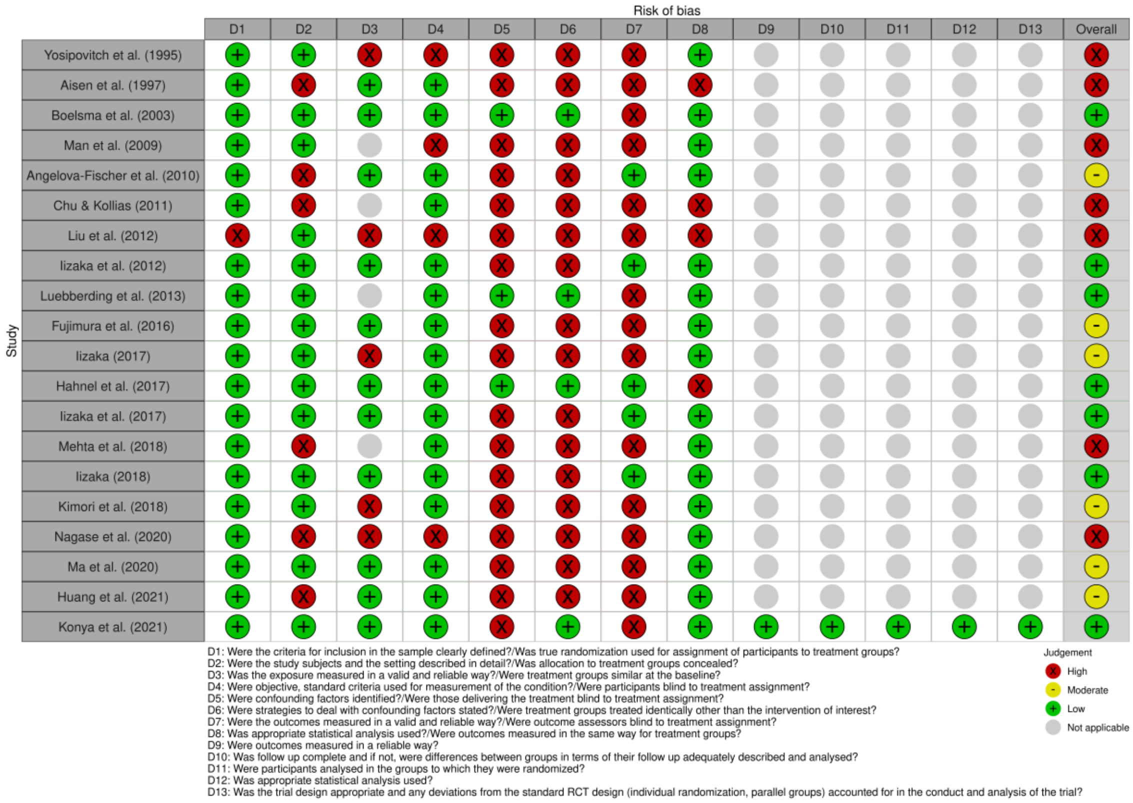

Figure 2. Risk of bias in the included studies

2.4.4. Risk factors of skin barrier dysfunction in older adults

Demographic characteristics

Three cross-sectional studies investigated the association between sex and skin barrier function in older adults. One study (low-risk) reported that TEWL in the forearms of females was significantly higher than that in the forearms of males (with no significant sex differences in SCH) [29], while two studies (high-risk) reported no sex differences in TEWL and SCH [24, 34]. Another study (high-risk) examined the association between ethnicity and skin barrier function and reported that White females had higher TEWL than African American females, regardless of age and site [26].

Functional characteristics

Five cross-sectional studies investigated the association between activities of daily living (ADL) and skin barrier function. One study (high-risk) demonstrated that SCH of all sites in bedridden older patients was significantly lower than that in healthy older adults [22]. Two studies (high- and moderate-risk) demonstrated that TEWL and SCH in the gluteal or sacral regions of bedridden older patients were significantly higher than those in the healthy participants [30, 37]. However, three studies (one moderate- and two low-risk) reported no explainable association between skin barrier function in the extremities and ADL-related functional characteristics (Barthel index, bedridden, and frailty) [30, 32, 35].

Chronic disease

Two cross-sectional studies and a subgroup analysis in the RCT examined the association between chronic disease and skin barrier function. Two studies (high- and low-risk) reported an association between chronic kidney disease (CKD) and lower SCH of the forearm [21, 40]. In addition, the RCT (low-risk) reported an association between diabetes/dyslipidemia and lower SCH of the forearm [40]. Another study (moderate-risk) reported an association between chronic venous insufficiency and increased TEWL in the lower leg [25].

Nutritional status

Four cross-sectional studies examined the association between nutritional status and skin barrier function. One study (low-risk) reported a negative association between SCH and dietary intake of total, saturated, and monounsaturated fats, even after adjusting for confounders (sex, age, and smoking) [23]. However, three studies (low-risk) found no significant association between skin barrier function and various nutritional status indicators, such as body mass index, serum albumin level, and dietary intake [28, 33, 35].

Skin conditions

Five cross-sectional studies evaluated the association between skin conditions and skin barrier function. Two studies (moderate- and low-risk) reported a significant association between dry skin in the lower extremities and lower SCH [31, 32]. Two other studies (moderate-risk) reported that patients with senile pruritus had significantly higher TEWL [38] and lower SCH than controls [39]. However, Huang et al. [39] suggested that TEWL was not associated with pruritus. One study (moderate-risk) reported that venipuncture-induced hematoma sites had significantly lower SCH than non-hematoma sites; however, no significant difference was observed in TEWL [36].

Environmental factors

Two cross-sectional studies examined the relationship between environmental factors and skin barrier function. One study (high-risk) reported that SCH was significantly lower in the sun-exposed group than in the non-sun-exposed group, only in older females [27]. Iizaka (moderate-risk) [31] examined the association between SCH and daily life-related factors such as bathing and skin care habits and medications used in community-dwelling older adults. Multiple regression analysis revealed that factors negatively associated with SCH were hospitalization in the past year, excessive bathing habits, and outdoor hobbies [31].

2.4.5. Synthesis of findings

Table 3 shows the narrative synthesis results and process for the review question, "what are the risk factors associated with skin barrier dysfunction in older adults?" The risk factors (Level A) were CKD and dry skin. The others were potential risk factors (Level B) or non-associated factors (Level C) considering the risk of bias and inconsistent results across studies.

Table 3. Synthesis of findings for risk factors of skin barrier dysfunction in older adults

	Consistent results across multiple studies		Risk of bias	Level A	Level B	Level C
	Criteria 1)	Criteria 2)	Criteria 3)			
	Statistical significance observed	Multiple studies agreeing on the results	At least one study having low-risk bias	Risk factors	Potential risk factors	Non-associated factors
Demographic characteristics						
Ethnicity	Yes	No (a)	No	-	Yes	-
Sex	Yes	No (b)	Yes	-	Yes	-
Functional characteristics						
Activities of daily living	Yes	No (b)	Yes	-	Yes	-
Frailty	No	No (a)	Yes	-	-	Yes
Chronic diseases						
Chronic kidney disease	Yes	Yes	Yes	Yes	-	-
Chronic venous insufficiency	Yes	No (a)	No	-	Yes	-
Diabetes/dyslipidemia	Yes	No (a)	Yes	-	Yes	-
Nutritional status						
Albumin levels	No	No (a)	Yes	-	-	Yes
Arm muscle area	No	No (a)	Yes	-	-	Yes
Body mass index	No	Yes	Yes	-	-	Yes
Dietary intake	Yes	No (b)	Yes	-	Yes	-
Involuntary weight loss	No	No (a)	Yes	-	-	Yes
Malnourished status	No	No (a)	Yes	-	-	Yes
Prealbumin levels	No	No (a)	Yes	-	-	Yes
Skin conditions						
Dry skin	Yes	Yes	Yes	Yes	-	-
Senile pruritus	Yes	Yes	No	-	Yes	-
Venipuncture-induced hematoma	Yes	No (a)	No	-	Yes	-
Environmental factors						
Lifestyle-related factors	Yes	No (a)	Yes	-	Yes	-
Sun-exposed	Yes	No (a)	No	-	Yes	-

Notes: **Risk factors** (Level A), Factors that met criteria 1) and 2) for "consistent results across multiple studies" and criteria 3) for "risk of bias"; **Potential risk factors** (Level B), Factors that met criteria 1) but did not meet either criteria 2) or 3) or both. There were two possible reasons for the occurrence of criterion 2): (a) no multiple studies and (b) inconsistent results across multiple studies; **Non-associated factors** (Level C), Factors that did not meet criterion 1).

2.5. Discussion

This systematic review attempted to identify the risk factors for skin barrier dysfunction in older adults. Notably, 13 of the 20 studies had a moderate to high risk of bias, mainly owing to inadequate identification and handling of confounding factors. Furthermore, because all the results were obtained from a cross-sectional analysis, addressing the causal association between the identified factors and skin barrier function proved impossible. Consequently, the results were narratively synthesized according to the risk of bias and inconsistency of the results.

This review identified CKD [21, 40] and dry skin [31, 32] as risk factors for skin barrier dysfunction in older adults. Other relevant reviews, not restricted by age groups, have suggested associations between skin barrier function and factors such as ethnicity, sex, skin type, anatomical sites, lifestyle, and body mass index, among others [12, 13]. Thus, our results clearly demonstrate distinct findings from existing reviews. By focusing specifically on older adults in the search strategy, we were able to identify risk factors unique to this demographic.

Globally, CKD has become a prominent health issue in the aging population, reportedly affecting 38.1% of those in the United States of America [41]. This disease is characterized by persistent decreased renal function that requires dialysis or renal transplantation in advanced stages [41]. The vulnerability of the skin barrier caused by CKD may be due to metabolic imbalances, endocrine disorders, and peripheral neuropathy [42]. Although Konya et al. showed that CKD patients with skin barrier dysfunction had different stages from G2 to G5, we could not conclude the influence of the CKD stage on the skin barrier dysfunction [40]. Additional research on the influence of different CKD stages is needed; however, evaluation of CKD would definitely be necessary.

Dry skin (xerosis cutis) is defined as skin deficient in hydrolipids [43] and is closely associated pathologically and bidirectionally with skin barrier dysfunction [11]. There is substantial evidence supporting that dry skin is associated with decreased SCH [11]. Dry skin in older adults has a high prevalence (95% confidence interval) in all clinical settings (53 % [36–69 %]), nursing homes (64% [43–84%]), hospitals (38% [30–47%]), and community (54% [50–57%]) [44]. Therefore, clinical assessment of dry skin can help provide effective skin care in older adults.

Although this review identified the potential risk factors and non-associated factors, their relation to skin barrier dysfunction could not be determined owing to the low quality of the evidence. Many studies had a moderate to high risk of bias and inconsistent results presumably because 84.2% of the studies failed to control for important confounders, and 70% did not report reliable outcome measurements. In addition to the methodological quality of these studies, a possible lack of clinical relevance cannot be ruled out.

Other factors that were not addressed in this review require further investigation. For example, skin conditions such as purpura and edema, diseases such as cancer, and drugs such as diuretics, steroids, and anticancer agents may cause skin barrier dysfunction [44]. Although several studies were found to have had addressed these factors, many were excluded based on the age-limit criteria (<50 years); this indicated the difficulty of conducting clinical studies in older patients. Therefore, the evidence addressed in this review, including potential risk factors and non-associated factors, requires additional research, as the number of factors examined and studies, and methodological quality need further improvement.

2.5.1. Implications for future research

Research in the area of skin barrier function is strengthened by the availability of measurement guidelines and reliable and validated instruments. However, many studies have a risk of bias owing to a lack of knowledge of confounding factors, correct measurement methods, and reporting approaches for skin barrier function. In this regard, we propose three recommendations for future research. First, vital confounding factors (e.g., age, measurement site, sweat, skin diseases, skin care, and habitual indulgences) should be recognized and addressed. According to international guidelines [16], many of these confounding factors can be controlled by study design and procedures. For example, patients with skin diseases such as atopic dermatitis should be excluded or distinguished from healthy participants or other patients. Age and measurement sites should be stratified because they influence the value of TEWL or SCH. To minimize the effects of sweat, the measurement site can be exposed to open air for at least 10 min, with an acclimation period of 15–30 min. In addition, skin care products should be avoided 12 h before the measurement, and habitual indulgences (smoking, spices, and caffeine intake) should be avoided for 3 h before the measurement [16]. Second, the reliability of measurements (e.g., assessors' information, assessment training, and inter- and intra-rater reliability) should be recognized as necessary information, the reporting of which will help reduce measurement bias. Third, a higher-quality cohort study that considers the above recommendations will help determine the association between skin barrier function and each factor.

2.5.2. Implications for clinical practice

Our systematic review identified unique risk factors for skin barrier dysfunction in older adults (CKD and dry skin). Because these are highly prevalent health problems in older adults, our results will contribute to pre- and post- skin care assessments for older adults in all settings. Specifically, nurses and caregivers can perform an initial assessment of the risk of skin barrier dysfunction by evaluating the presence of CKD and dry skin, without using expensive skin barrier analysis instruments. The Overall Dry Skin Score, the most widely used five-point scale, assesses the presence and severity of dry skin through four symptoms (scaling, roughness, redness, and cracks), with demonstrated reliability and validity [11, 45]. A score of ≥ 1 indicates the presence of dry skin [32], enabling clinicians to evaluate this condition easily and accurately. In conclusion, our results provide a rationale for selecting the appropriate skin care for each skin type. These practices may be used to develop safe, effective, and personalized skin-care programs.

2.5.3. Strengths and limitations

The strength of this review is its rigorous process based on the PRISMA statement. In particular, an experienced librarian conducted a systematic search strategy, and two reviewers performed the screening, risk of bias assessment, and data extraction in a blinded and independent manner. Nevertheless, this study has some limitations. First, the inclusion of only English-language literature could have introduced a language bias.

Second, owing to the heterogeneity of the studies and results, conducting a meta-analysis, examining reporting bias, or assessing the certainty of the evidence proved impossible, thereby preventing a high-quality discussion.

2.6. Conclusions

Factors extracted from our review results were classified into six categories: demographic characteristics, functional characteristics, chronic diseases, nutritional status, skin conditions, and environmental factors. However, only CKD and skin dryness were considered as risk factors owing to the high risk of bias and inconsistent results across studies. Evaluating CKD and dry skin in older adults may contribute to the development of safe, effective, and personalized skin care programs. High-quality cohort studies that consider confounding factors and the reliability of measurements must be conducted to further investigate the association between more risk factors and skin barrier function.

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Supplementary Table 1. Search strategy (original searches: April 19, 2023)

1) MEDLINE (via PubMed)

#	Search strategy (April 19, 2023)	Articles
1	"aged"[MeSH Terms] OR "geriatric patient*"[Title/Abstract] OR "older"[Title/Abstract] OR "old age"[Title/Abstract] OR "elderly"[Title/Abstract]	3781068
2	"Skin aging"[MeSH Terms] OR "skin integrity"[Title/Abstract] OR "skin barrier"[Title/Abstract] OR "transepidermal water loss"[Title/Abstract] OR "TEWL"[Title/Abstract] OR "water loss, insensible"[MeSH Terms] OR "insensible water loss*"[Title/Abstract] OR "stratum corneum hydration"[Title/Abstract] OR "skin hydration"[Title/Abstract]	20690
3	#1 AND #2 ("aged"[MeSH Terms] OR "geriatric patient*"[Title/Abstract] OR "older"[Title/Abstract] OR "old age"[Title/Abstract] OR "elderly"[Title/Abstract]) AND ("Skin aging"[MeSH Terms] OR "skin integrity"[Title/Abstract] OR "skin barrier"[Title/Abstract] OR "transepidermal water loss"[Title/Abstract] OR "TEWL"[Title/Abstract] OR "water loss, insensible"[MeSH Terms] OR "insensible water loss*"[Title/Abstract] OR "stratum corneum hydration"[Title/Abstract] OR "skin hydration"[Title/Abstract])	**3592**

2) CINAHL (via EBSCOhost)

#	Search strategy (April 19, 2023)	Articles
1	MH "Aged+" OR TI "geriatric patient*" OR AB "geriatric patient*" OR TI "older" OR AB "older" OR TI "old age" OR AB "old age" OR TI "elderly" OR AB "elderly"	1066070
2	MH "Skin Aging" OR TI "skin integrity" OR AB "skin integrity" OR TI "skin barrier" OR AB "skin barrier" OR TI "transepidermal water loss" OR AB "transepidermal water loss" OR TI "TEWL" OR AB "TEWL" OR MH "Water Loss, Insensible" OR TI "insensible water loss*" OR AB "insensible water loss*" OR TI "stratum corneum hydration" OR AB "stratum corneum hydration" OR TI "skin hydration" OR AB "skin hydration"	4702
3	#1 AND #2 (MH "Aged+" OR TI "geriatric patient*" OR AB "geriatric patient*" OR TI "older" OR AB "older" OR TI "old age" OR AB "old age" OR TI "elderly" OR AB "elderly") AND (MH "Skin Aging" OR TI "skin integrity" OR AB "skin integrity" OR TI "skin barrier" OR AB "skin barrier" OR TI "transepidermal water loss" OR AB "transepidermal water loss" OR TI "TEWL" OR AB "TEWL" OR MH "Water Loss, Insensible" OR TI "insensible water loss*" OR AB "insensible water loss*" OR TI "stratum corneum hydration" OR AB "stratum corneum hydration" OR TI "skin hydration" OR AB "skin hydration")	870
4	Limit Research Article	**493**

3) Cochrane Database of Systematic Reviews (CDSR) (via Wiley), and Cochrane Central Register of Controlled Trials (CENTRAL) (via Wiley)

#	Search strategy (April 19, 2023)	Articles
1	MeSH descriptor: [Aged] explode all trees	254822
2	(geriatric NEXT patient*):ti,ab,kw	1811
3	older:ti,ab,kw	69025
4	"old age": ti,ab,kw	2487
5	elderly:ti,ab,kw	57251
6	{OR #1-#5}	336095
7	MeSH descriptor: [Skin Aging] explode all trees	1035
8	"skin integrity":ti,ab,kw	184
9	"skin barrier":ti,ab,kw	870
10	"transepidermal water loss":ti,ab,kw	1267
11	TEWL:ti,ab,kw	895
12	MeSH descriptor: [Water Loss, Insensible] explode all trees	333
13	("insensible water" NEXT loss*):ti,ab,kw	31
14	"stratum corneum hydration":ti,ab,kw	159
15	"skin hydration":ti,ab,kw	597
16	{OR #7-#15}	3,322
17	#6 AND #16 in Cochrane Reviews and Trials	**699**

4) Rerunning searches: October 12, 2023 (please see Figure 1)

MEDLINE (n = 3619); CINAHL (n = 507); CENTRAL (n = 704); CDSR (n = 3); Total (n = 4833)

Supplementary Table 2. JBI critical appraisal tools

1) Checklist for cross-sectional studies

No.	Criteria
1	Were the criteria for inclusion in the sample clearly defined?
2	Were the study subjects and the setting described in detail?
3	Was the exposure measured in a valid and reliable way?
4	Were objective, standard criteria used for measurement of the condition?
5	Were confounding factors identified?
6	Were strategies to deal with confounding factors stated?
7	Were the outcomes measured in a valid and reliable way?
8	Was appropriate statistical analysis used?

2) Revised checklist for randomized controlled trials

No.	Criteria
1	Was true randomization used for assignment of participants to treatment groups?
2	Was allocation to treatment groups concealed?
3	Were treatment groups similar at the baseline?
4	Were participants blind to treatment assignment?
5	Were those delivering the treatment blind to treatment assignment?
6	Were treatment groups treated identically other than the intervention of interest?
7	Were outcome assessors blind to treatment assignment?
8	Were outcomes measured in the same way for treatment groups?
9	Were outcomes measured in a reliable way
10	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?
11	Were participants analysed in the groups to which they were randomized?
12	Was appropriate statistical analysis used?
13	Was the trial design appropriate and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

Supplementary Table 3. Excluded studies and reasons in full-text screening (n = 25)

No.	Authors (years)	Title	Reason for exclusion
1	Ståhle-Bäckdahl (1988)	Stratum corneum hydration in patients undergoing maintenance hemodialysis	Participants' age is lower than 50 years.
2	Cua et al. (1990)	Frictional properties of human skin: relation to age, sex and anatomical region, stratum corneum hydration and transepidermal water loss	Simple comparisons between older and younger adults.
3	Ramsing et al. (1995)	Effect of systemic treatment with cholesterol-lowering drugs on the skin barrier function in humans	Participants' age is lower than 50 years.
4	Tercedor et al. (1995)	Multivariate analysis of cutaneous markers of aging in chronic hemodialyzed patients	Participants' age is lower than 50 years.
5	Palevsky et al. 1996)	Hypernatremia in hospitalized patients	No measurement of skin barrier function.
6	Morton et al. (1996)	Pruritus and skin hydration during dialysis	Participants' age is lower than 50 years.
7	Manuskiatti et al. (1998)	Influence of age, anatomic site and race on skin roughness and scaliness	Simple comparisons between older and younger adults.
8	Grimes et al. (2004)	Evaluation of inherent differences between African American and white skin surface properties using subjective and objective measures	Participants' age is lower than 50 years.
9	Sakai et al. (2004)	Functional properties of the stratum corneum in patients with diabetes mellitus: similarities to senile xerosis	Participants' age is lower than 50 years.
10	Seirafi et al. (2008)	Biophysical characteristics of skin in diabetes: a controlled study	Participants' age is lower than 50 years.
11	Mutanu Jungersted et al. (2010)	Ceramides and barrier function in healthy skin	Not addressing risk factors associated with skin barrier dysfunction.
12	Zhu et al. (2011)	Characterization of skin friction coefficient, and relationship to stratum corneum hydration in a normal Chinese population	Participants' age is lower than 50 years.
13	Luebberding et al. (2013)	Age-related changes in male skin: quantitative evaluation of one hundred and fifty male subjects	Simple comparisons between older and younger adults.
14	Killaars et al. (2015)	Biomechanical Properties of the Skin in Patients with Breast Cancer-Related Lymphedema Compared to Healthy Individuals	Participants' age is lower than 50 years.
15	Kang et al. (2015)	Quantitative changes in skin composition parameters due to chemotherapy in breast cancer patients: a cohort study	Participants' age is lower than 50 years.
16	Xin et al. (2016)	Heavy Cigarette Smokers in a Chinese Population Display a Compromised Permeability Barrier	Participants' age is lower than 50 years.
17	Mercurio et al. (2016)	Morphological, structural and biophysical properties of French and Brazilian photoaged skin	Participants' age is lower than 50 years.
18	Takai et al. (2017)	Relationship between biochemical factors and skin symptoms in chronic venous disease	Participants' age is lower than 50 years.
19	Ibuki et al. (2018)	Aging-like physiological changes in the skin of Japanese obese diabetic patients	Participants' age is lower than 50 years.
20	Akdeniz et al. (2018)	Effect of Fluid Intake on Hydration Status and Skin Barrier Characteristics in Geriatric Patients: An Explorative Study	Not addressing risk factors associated with skin barrier dysfunction.
21	Lechner et al. (2019)	Comparing skin characteristics and molecular markers of xerotic foot skin between diabetic and non-diabetic subjects: An exploratory study	Participants' age is lower than 50 years.
22	Phipps et al. (2019)	Time of Onset to Changes in Skin Condition During Exposure to Synthetic Urine: A Prospective Study	Not addressing risk factors associated with skin barrier dysfunction.
23	Namgoong et al. (2019)	Influence of Peripheral Neuropathy and Microangiopathy on Skin Hydration in the Feet of Patients with Diabetes Mellitus	Participants' age is lower than 50 years.
24	Ye et al. (2022)	Correlation of Body Mass Index with Epidermal Biophysical Properties Varies with Gender in Chinese	Participants' age is lower than 50 years.
25	Amano et al. (2022)	Prediction and association analyses of skin phenotypes in Japanese females using genetic, environmental, and physical features	Participants' age is lower than 50 years.

Reference list of excluded studies in full-text screening

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17. Mercurio DG, Jdid R, Morizot F, Masson P, Maia Campos PM. Morphological, structural and biophysical properties of French and Brazilian photoaged skin. Br J Dermatol. 2016;174(3):553-61.
18. Takai Y, Hiramoto K, Nishimura Y, Ooi K. Relationship between biochemical factors and skin symptoms in chronic venous disease. Arch Dermatol Res. 2017;309(4):253-8.
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25. Amano S, Yoshikawa T, Ito C, Mabuchi I, Kikuchi K, Ooguri M, et al. Prediction and association analyses of skin phenotypes in Japanese females using genetic, environmental, and physical features. Skin Res Technol. 2023;29(1):e13231.

Supplementary Table 4. Additional information of included studies (n = 20)

Title	Author	Journal	Other outcomes	Analysis	Funding
Sweat secretion, stratum corneum hydration, small nerve function and pruritus in patients with advanced chronic renal failure	Yosipovitch et al. (1995) Israel	The British journal of dermatology	Pruritus Xerosis Sweat collection Thermal sensory analyzer	Two-way ANOVA (chronic renal failure and sex)	Unknown
Sebum and water content in the skin of aged immobilized patients	Aisen et al. (1997) Israel	Acta dermato-venereologica	Sebum	One-way ANOVA	Unknown
Human skin condition and its associations with nutrient concentrations in serum and diet	Boelsma et al. (2003) Netherlands	The American Journal of Clinical Nutrition	Skin-surface pH Sebum	Multiple linear regression with adjustment for potential confounders (sex, age, and smoking)	Unknown
Variation of skin surface pH, sebum content and stratum corneum hydration with age and gender in a large Chinese population	Man et al. (2009) China	Skin Pharmacology and Physiology	Skin-surface pH Sebum	One-way ANOVA and post hoc (Tukey) test	National Institutes of Health (AR 19098) and Medical Research Service, Department of Veterans Affairs Medical Center, San Francisco, Calif., USA
Noninvasive bioengineering assessment of the skin barrier function in patients with chronic venous insufficiency	Angelova-Fischer et al. (2010) Germany	The British journal of dermatology	Skin color symmetrically	One-way ANOVA and post hoc (Tukey) test	Unknown
Documentation of normal stratum corneum scaling in an average population: features of differences among age, ethnicity and body site	Chu & Kollias (2011) United States of America	The British journal of dermatology	Corneocyte detachment	Restricted maximum likelihood estimation method and post hoc (Tukey) test	Johnson & Johnson Consumer and Personal Products Worldwide
Sun-induced changes of stratum corneum hydration vary with age and gender in a normal Chinese population	Liu et al. (2012) China	Skin Research & Technology	None	Student' t-test with Welch's correction	National Institutes of Health grants AR 19098
Evaluation of nutritional status and skin condition among elderly residents in a long-term care hospital	Iizaka et al. (2012) Japan	The journal of nutrition, health & aging	Skin-surface pH Skin color Skin morphology	Spearman's rank correlation coefficient	None

Title	Author	Journal	Other outcomes	Analysis	Funding
Skin physiology in men and women: in vivo evaluation of 300 people including TEWL, SC hydration, sebum content and skin surface pH	Luebberding et al. (2013) Germany	International journal of cosmetic science	Skin-surface pH Sebum	Mann Whitney U-Test	University of Hamburg, Division of Cosmetic Science
The influence of incontinence on the characteristic properties of the skin in bedridden elderly subjects	Fujimura et al. (2016) Japan	International Journal of Dermatology	Skin-surface pH Bacteria	Student' t-test with Bonferroni correction	Kao Corporation
Skin hydration and lifestyle-related factors in community-dwelling older people	Iizaka (2017) Japan	Archives of Gerontology and Geriatrics	Dry skin Subjective perception of dry skin	Multiple linear regression analysis with adjustment for confounding variables (setting and survey year)	JSPS KAKENHI (25893060)
Associations between skin barrier characteristics, skin conditions and health of aged nursing home residents: a multi-center prevalence and correlational study	Hahnel et al. (2017) Germany	BMC geriatrics	Skin-surface pH Skin-temperature Dry skin	Pearson correlation coefficients Multivariable logistic and linear regression analyses	Galderma Pharma SA (Switzerland) Clinical Research Center for Hair and Skin Science, Department of Dermatology and Allergy, Charité-Universitätsmedizin Berlin.
Nutritional Status and Habitual Dietary Intake Are Associated with Frail Skin Conditions in Community-Dwelling Older People	Iizaka et al. (2017) Japan	The journal of nutrition, health & aging	Dry skin Dermal condition	Spearman's rank correlation coefficient. Mann–Whitney U test.	JSPS KAKENHI (25893060)
A cross-sectional study of variations in the biophysical parameters of skin among healthy volunteers	Mehta et al. (2018) India	Indian Journal of Dermatology, Venereology and Leprology	Elasticity Sebum Skin-surface pH	Mann–Whitney test	Indian Association of Dermatology, Venereology and Leprosy through its L'Oreal grant 2013

Title	Author	Journal	Other outcomes	Analysis	Funding
Frailty and body mass index are associated with biophysical properties of the skin in community-dwelling older adults	Iizaka (2018) Japan	Journal of Tissue Viability	Dry skin Skin elasticity Dermal condition	Linear mixed model	JSPS KAKENHI (15K20927)
Venipuncture-Induced Hematomas Alter Skin Barrier Function in the Elderly Patients	Kimori et al. (2018) Japan	SAGE open nursing	Sebum Skin elasticity Skin-surface pH	Wilcoxon signed-rank test	JSPS KAKENHI (15K15803)
Distinct Skin Microbiome and Skin Physiological Functions Between Bedridden Older Patients and Healthy People: A Single-Center Study in Japan	Nagase et al. (2020) Japan	Frontiers of Medicine	Skin Microbiome	Steel–Dwass test	JSPS KAKENHI (JP17H04428 and JP18K10142) Research budget of Kanazawa University SAKIGAKE Project
Lipidomics profiling of skin surface lipids in senile pruritus	Ma et al. (2020) China	Lipids in Health and Disease	Skin surface lipids Pruritus severity	Welch's t-test	Peking University International Hospital (YN2018QN04) and National Natural Science Foundation of China (81673079 and 81472903)
Patients with senile pruritus have a distinct skin microbiota and epidermal barrier in comparison with healthy controls	Huang et al. (2021) China	The Journal of Dermatology	Skin microbiota Sebum Skin-surface pH	Mann-Whitney U test (rank sum test)	Sichuan Science and Technology Program (grant no. 2018JY0406/2019YFS0537/ 2020YFS0456) and Health and Scientific Research for Cadres in Sichuan Province (granted no. 2018-1502/2017-1501)
Effectiveness of weak wiping pressure during bed baths in hospitalized older adults: A single-blind randomized crossover trial	Konya et al. (2021) Japan	Geriatric Nursing	None	Student's t-test Pearson's chi-square test	JSPS KAKENHI (JP 20K10984)

Chapter 3

Reliability and validity of the Japanese version of the overall dry skin score in older patients

(Konya et al., *Skin Research & Technology*, 2022;28:28–34)

3.1. Abstract

Background

Dry skin is the most common skin problem, especially in the elderly. However, there is no effective instrument to assess dry skin in Japan. This study aimed to evaluate the reliability and validity of the Japanese version of the overall dry skin score (ODS-J), the gold standard for dry skin assessment.

Methods

A cross-sectional study was conducted on 47 patients aged >65 years. Images of skin on their limbs were captured using a digital camera; both upper and lower limbs were assessed (n = 4/patient). One dermatologist; two wound, ostomy, and continence nurses; and three nursing researchers independently evaluated the images using the ODS-J to assess the intraclass correlation coefficient (ICC) for inter-rater reliability. Stratum corneum hydration (SCH) and transepidermal water loss (TEWL) were the external criteria used to verify concurrent and known-groups validity.

Results

In total, 182 sites at which the SCH and TEWL could be measured were evaluated for the ODS-J. The ICC for inter-rater reliability of the six raters was 0.939 ($P < .001$). A higher ODS-J was associated with lower SCH ($\rho = -0.374$; $P < .001$) and lower TEWL ($\rho = -0.287$; $P < .001$) values. The ODS-J for the lower legs was significantly higher than that of the forearms ($P < .001$).

Conclusions

The ODS-J showed good inter-rater reliability, concurrent validity, and known-groups validity. It can be used by clinical nurses in Japan to observe patients' skin and is an effective indicator for the evaluation of skin care.

3.2. Background

Dry skin is one of the most frequent skin problems in health care settings and in daily life [1]. This skin abnormality can occur during any stage of life due to a variety of adverse factors, including inflammatory skin lesions, unfavorable environmental conditions, age-related skin changes, chronic diseases such as diabetes and chronic kidney disease, and multiple medications [1,2]. In general, dry skin is a condition in which the stratum corneum is too dry. This condition is caused due to its inability to adequately sustain a water concentration gradient between the skin surface and the living epidermal cells [1]. Symptoms of dry skin include pruritus and scaling, and if the symptoms worsen, redness and cracking with a high risk of secondary infection can occur [3]. Although these conditions are considered "minor" and are not treated or cured unless they progress, they are risk factors and signs of severe skin lesions, such as skin tears and pressure ulcers [4]. Therefore, early detection and assessment of these signs are essential first steps in preventing skin problems.

The parameters such as stratum corneum hydration (SCH), transepidermal water loss (TEWL), and skin surface pH are established skin assessment methods that have been used in a variety of dermatological and skin care research [5–8]. These parameters can non-invasively and sensitively detect the skin condition (namely, barrier function) at the level of manifestation, so that skin dryness and its changes can be appropriately assessed [8]. However, the use of these methods is limited to the research field in non-clinical settings due to a lack of a short and simple instrument [9]. Thus, it is difficult for all the medical workers to use it in any practical situation. Regardless of whether the instrument can be used in clinical settings, medical workers are always required to evaluate the skin condition of patients for early prevention of skin abnormalities, and to provide them treatment and care.

Visual observation is one of the common skin assessment methods that all the medical workers can practice. The overall dry skin score is a standardized instrument to clinically assess the presence and severity of dry skin [10]. It is a five-point scale that ranges from 0 (no dry skin) to 4 (severe scales, roughness, inflammation, and cracks). The reliability of this instrument has been verified [9], and it has been reported as the gold standard for skin dryness evaluation in the systematic review of skin health assessment methods [7]. In addition, it is widely used before and after skin care practices because it can easily quantify skin dryness, and thus helps in evaluating the effects of skin care [1,4,11].

Dry skin is especially prevalent among older adults [3]. According to systematic reviews and recent studies reporting on the epidemiology of skin conditions in the older adults, the prevalence of dry skin is high in all clinical settings; general practice: 55.6%, hospitals: 5.4-85.5%, community and outpatient care settings: 48-85%, institutional long-term care: 45.3-99.1%, and home care: 51.7% [1,12–14]. Japan has the highest proportion of older adults in the world; the percentage of the population aged 65 and above is 28.4% [15]. Given this situation, it is expected that a large proportion of people have dry skin in Japan. Therefore, the assessment of dry skin must be properly and adequately performed in Japan. Although some medical facilities have recorded skin dryness with their own methods, no common clinical scale is present for medical workers to assess it across the various facilities. In addition, there is no instrument for skin assessment with a certain standard that can be useful before and after skin care.

Therefore, the aim of this study was to evaluate the reliability and validity of the Japanese version of overall dry skin score (ODS-J) which is the gold standard for dry skin assessment. The ability of this scale to properly assess the presence and degree of skin dryness will contribute to the improvement of patients' skin conditions, prevention of skin disorders, and high-quality skin care.

3.3. Methods

3.3.1. The translation process of the ODS-J

The ODS was translated into Japanese using back-translation methods after permission from the original author. First, the ODS was forward-translated in Japanese by a translator and two researchers in the nursing field with expertise in skin care. Second, a native speaker of English back-translated in English to test semantic equivalence. Lastly, the back-translated version was checked by the original authors and approved as equivalent in content, and the Japanese version (ODS-J) was completed. In addition, the validity of ODS-J was confirmed by a Japanese dermatologist and two Wound, Ostomy and Continence Nurses (WOCNs).

3.3.2. Design, setting, and sample

A cross-sectional study was conducted in July 2020 at general hospital A, in a local city of northern Japan. Participants were 47 patients aged over 65 years. The skin of their limbs (right forearm, left forearm, right lower leg, and left lower leg) were assessed for ODS-J, and one site was considered as one case for assessment (n = 4/patient). The inclusion criteria were: 1) patients with relatively stable disease, and no complaints such as fever or pain; 2) patients who did not receive hygienic care, and did not apply moisturizer or ointment to the target skin just before data collection; and 3) patients who could communicate daily, and provided verbal and written informed consent. Patients with severe dermatological disorders were excluded from the study.

3.3.3. Outcome measures

Participant' characteristics

The most recent information of participants from the hospital medical records was filled out in a structured data form. This data form consisted of age, body mass index, sex, main diseases, presence of main treatment, the degree of independence of disabled older patients in performing activities of daily living as designated by the Japanese Ministry of Health (J: independent living, A: requires assistance to leave home, B: nearly bedridden, C: completely bedridden). In addition, we interviewed the participants about the presence of pruritus, frequency of bathing and moisturizer treatment, and type of bathing.

ODS-J

This ODS-J is a five-point scale to assess the presence and the severity of dry skin; 0 point indicates no skin dryness and 4 point indicates severe scales, roughness, inflammation, and cracks. The sites for assessment in this study were the limbs (right forearm, left forearm, right lower leg, and left lower leg), which easily show signs of dryness. A color chart for image correction (color and size matching sticker; CASMATCH, BEAR Medic Corporation) was attached to these sites. Thereafter, skin images were captured under the consistent conditions using a digital camera (Tough TG-6, Olympus Corporation: A mode, diaphragm value: 2.8). A black matte paper was placed under the photographed area to ensure uniformity of imaging conditions, taking into consideration the lighting and sunlight exposure to the skin. The images were taken by a researcher, who was trained in using the camera, maintaining a constant distance from the photographed area.

Color and size corrections of skin images were performed using Adobe Photoshop (Adobe Systems Co., Ltd.). Thereafter, one dermatologist; two WOCNs; and three nursing researchers: one professor, one doctoral student, and one master's student, independently evaluated the skin images using the ODS-J.

SCH

SCH is defined as the water content of the stratum corneum [8]. It was measured using Corneometer®CM825 (Courage+Khazaka), which is the gold standard of SCH measurement. The measurements were taken five times, and the average of the three values excluding the maximum and minimum values was used as the measured value. The measurements of SCH are based on the difference between the dielectric constants of water and other substances by measuring the capacitance of a dielectric medium and are displayed in arbitrary units [7]. We followed the guidelines reported by the European Group on Efficacy Measurements and Evaluation of Cosmetics and Other Products to minimize measurement errors [8]. Specifically, the instruments were calibrated prior to use, and a well-trained researcher conducted measurements in a hospital room unaffected by air convection while room temperature and humidity were measured. The patients were allowed an acclimatization period of at least 15 minutes in the state of their forearms exposed to ambient air to eliminate sweating.

A previous study on older residents randomly sampled from the 10 long term care facilities reported that a higher ODS was associated with lower SCH values [11]. Dry skin is a state of reduced SCH due to decreased skin barrier function and reduced moisturizing capacity [16]. Thus, this outcome measure was used as external criteria to verify concurrent validity of the outcome of the ODS-J.

TEWL

TEWL is defined as the flux density of water diffusing from the dermis and epidermis through the stratum corneum to the skin surface [5]. It was measured using Tewameter®TM300 (Courage+Khazaka), which is the gold standard of TEWL measurement. The measurements were conducted for 30 seconds, and the average value was employed. These measurements are founded on the principle of evaluating the water vapor pressure gradient just above the skin surface and are represented in units of $g/m^2/h$ [8]. As with the SCH measurement method, the measurement error was minimized.

A previous study on older residents reported that a higher ODS was associated with lower TEWL values [11]. Higher TEWL values are often associated with skin barrier impairments in adults. However, the skin of the elderly is generally dry due to decreased sebum production and hypertrophy of keratinocytes, and TEWL tends to be low [17]. Therefore, this outcome measure was used as external criteria to verify concurrent validity of the outcome of the ODS-J.

3.3.4. Study protocol

1） In general hospital A, a researcher captured images of the limbs of older patients using a digital camera and measured the skin barrier function (SCH and TEWL).
2） The color and size correction in skin images was performed by using Adobe Photoshop.
3） The sample images were selected as a standard for the ODS-J from the captured

images. The validity of the sample images was confirmed by all the raters.

4） Using the sample images and ODS-J, all the raters performed a 10-minute guidance session, in advance.

5） The skin images projected on the personal computer screen were independently evaluated by all the raters without looking at the sample image.

6） The intraclass correlation coefficient (ICC) was calculated to evaluate the inter-rater reliability from the data, which the six raters had evaluated in the first round.

7） After the final scores of the ODS were discussed and determined by the raters, the validity was evaluated in conjunction with the results of SCH and TEWL.

3.3.5. Statistical analysis

Continuous variables are presented as means and standard deviations, and categorical variables are shown as frequencies and percentages. The ICC assessing the inter-rater reliability was calculated from the data that the six raters evaluated in the first round. An ICC value of 0.61-0.80 suggests “substantial reliability”, whereas an ICC value of 0.81-1.00 suggests “almost perfect reliability” [18]. Spearman's rank-order correlation coefficient (ρ) between skin barrier function and the ODS-J was analyzed to assess concurrent validity. In general, the skin of the lower legs is most often affected by skin dryness than the skin of the forearms [19]. Therefore, the ODS between the forearm and lower legs was compared using the unpaired t-test to assess known-groups validity. Statistical analysis was performed using JMP® 14 (SAS Institute Inc.). *P*-values < .05 were considered statistically significant.

3.3.6. Ethical considerations

The nursing administrators enrolled participants who met the eligibility criteria in this study. The study aims, methods, and anonymity were explained verbally and in writing to those who expressed an interest in participating. The present study was approved by the Ethical Review Board of the authors' affiliated university (reference no. 19–89) and the participating hospital. This study was conducted according to the Declaration of Helsinki.

3.4. Results

3.4.1. Participant' characteristics

A total of 47 participants (mean age [standard deviation]: 82.1 [8.4]) were included in this analysis (Table 1). In total, 182 sites where SCH and TEWL could be measured, were evaluated for ODS-J, and 6 sites were missing due to peripheral venous catheterization or venipuncture.

The main participants' characteristics associated with skin dryness are shown in Tables 1 and 2. The main diseases were diabetes/dyslipidemia (40.4%) and chronic kidney disease (21.3%), and 34% of the patients complained of pruritus. Regarding prescriptions, none of the patients were using steroids, insulin, or anticancer drugs that may cause strong skin symptoms as side effects. Habitually, patients who bathed in the bathtub were the most common (76.6%).

Table 1. Participants characteristics (n = 47)

Characteristics	
Age: Mean (SD): years	82.1 (8.4)
BMI: Mean (SD): kg/m^2	21.6 (4.1) [a]
Sex: N (%): Female	37 (78.7)
Pruritus: N (%): [yes]	16 (34.0)
Diabetes mellitus: N (%) [yes]	19 (40.4)
Dyslipidemia: N (%) [yes]	19 (40.4)
Chronic kidney disease: N (%) [yes]	10 (21.3)
Hemodialysis: N (%): [yes]	3 (6.4)
Use of diuretic: N (%) [yes]	13 (27.7)
Use of anticoagulant: N (%) [yes]	5 (10.6)
Degree of independence: N (%)	
J	3 (6.4)
A	28 (59.6)
B	16 (34.0)

Notes: BMI, body mass index; Degree of independence, the degree of independence of disabled elderly persons in performing activities of daily living; SD, standard deviation; a = 44.

Table 2. Participants skin care habits (n = 47)

Characteristics	
Frequency of bathing: Mean (SD) [time / week]	3.7 (2.1)
Frequency of moisturizer treatment: Mean (SD) [time / week]	1.9 (2.5)
Type of bathing: N (%)	
Bathtub	36 (76.6)
Shower	10 (21.3)
Bed bath	1 (2.1)

Note: SD, standard deviation.

3.4.2. Inter-rater reliability

The ICC for the inter-rater reliability of the six raters was 0.939 (95% confidence interval [CI]: 0.918–0.955, $P < .001$), thereby reflecting “almost perfect” reliability (Table 3).

Table 3. Results of the inter-rater reliability (n = 182)

	Raters			Inter-rater reliability
	Dermatologist (n = 1)	WOCNs (n = 2)	Nursing researchers (n = 3)	ICC [95% CI]
Case for assessment: N	182	182	182	0.939 [0.918–0.955]
ODS-J.: Mean (SD)	0.81 (0.71)	1.18 (0.83)	0.87 (0.81)	

Notes: CI, confidence interval; ICC, Intraclass correlation coefficient; ODS-J, Japanese version of overall dry skin score; SD, standard deviation; WOCN, wound, ostomy and continence nurses.

3.4.3. Concurrent validity

A higher ODS-J was associated with lower SCH ($\rho = -0.374$; $P < .001$) and lower TEWL ($\rho = -0.287$; $P < .001$) values (Table 4).

Table 4. Results of the concurrent validity (n = 182)

Variables		Spearman's rank-order correlation coefficient (ρ)	*P*-value
ODS-J	SCH	−0.374	< .001
ODS-J	TEWL	−0.287	< .001
SCH	TEWL	0.292	< .001

Notes: ODS-J, Japanese version of overall dry skin score; SCH, stratum corneum hydration; TEWL, transepidermal water loss.

3.4.4. Known-groups validity

Ninety-three sites on the lower legs and 89 sites on the forearms were analyzed (Table 5). The ODS of the lower legs was significantly higher than that of the forearms (mean difference [95%CI] = 0.46 [0.23–0.69]; P <.001). The SCH and TEWL of the lower legs were also significantly lower than those of the forearms (respectively P =.020, $P < .001$).

Table 5. Results of the known-groups validity (n = 182)

Variables	Forearms (n = 89)	Lower legs (n = 93)	MD [95%CI]	*t*-value	Cohen's *d*	*P*-value
	Mean (SD)	Mean (SD)				
ODS-J	0.85 (0.75)	1.31 (0.81)	0.46 [0.23–0.69]	3.97	0.59	< .001
SCH (A.U.)	41.41 (9.47)	38.15 (9.18)	3.26 [0.53–5.99]	2.36	0.35	.020
TEWL ($g/m^2/h$)	9.70 (3.47)	6.94 (2.34)	2.76 [1.90–3.63]	6.31	0.93	< .001

Notes: CI, confidence interval; MD, mean difference; ODS-J, Japanese version of overall dry skin score; SCH, stratum corneum hydration; SD, standard deviation, TEWL, transepidermal water loss.

3.5. Discussion

3.5.1. Reliability and validity of the ODS-J

Since dry skin causes various health problems, such as skin infections and skin lesions, the assessment of dry skin is as important as its management [20,21]. In particular, despite the fact that Japan has one of the world's most advanced super-aging societies, there has been a major problem of lacking a reliable and valid assessment tool for skin dryness. In this study, we translated the overall dry skin score, the international gold standard for dry skin assessment, into Japanese and validated its reliability and validity. The results showed that the ODS-J had good inter-rater reliability, concurrent validity, and known-groups validity.

In the studies used as evidence for the reliability of the ODS, the ICC for inter-rater reliability between community pharmacists and a dermatologist using the ODS was around 0.5–0.6 [9]. That is, the ODS showed moderate reliability even among professionals with different areas of expertise. On the contrary, the ICC of ODS-J was very high at 0.939 (95% CI: 0.918-0.955), indicating almost perfect reliability. There were two possible reasons for this result. The first is the difference in the expertise of the evaluators. In addition to dermatologists and WOCNs, the evaluators in this study were nurses, who have more opportunities to assess patients' skin than community pharmacists. Nurses play the most important role in the management of wounds, such as pressure ulcers [22] and skin tears [23], and in assessment and practice during daily skin care [21]. Therefore, the fact that the raters in this study had more knowledge and experience in skin assessment than the raters in the previous study [9] may have influenced the results. The second is the difference in the evaluation target. In the previous study, community pharmacists assessed the actual skin and a dermatologist assessed the skin images [9]. All the raters had been trained twice, but the ICC may have been reduced due to the different evaluation targets. In this study, we were able to accurately verify only the inter-rater reliability by unifying the evaluation targets with skin images that were corrected by a strict procedure.

The validity of the original version of the ODS has not been verified in the previous study [9]. Therefore, the attempt to test concurrent and known-groups validities using skin barrier function is a major strength of this study. Dry skin is caused by a disrupted skin barrier function due to factors such as skin inflammation, physical and chemical irritation, internal disease, drugs, or genetic factors [24]. In particular, skin dryness in the elderly is caused by a decrease in SCH and TEWL with aging [13,25]. According to the established theory, an increase in TEWL indicates a decrease in skin barrier function. However, according to meta-analyses [5,17], TEWL tends to be low in the elderly. The reason for this phenomenon is not entirely understood today. However, the following reasons with aging may be associated. First, the diffusion resistance of stratum corneum for water increases with increase in the corneocyte surface areas and sizes [17,26]. Second, since the water diffusion coefficient of lipids is assumed to be 10 times higher than the that of corneocytes, an overall reduction of lipids in stratum corneum can lead to decrease in the mean of diffusion coefficient of the whole stratum corneum thickness [27]. In the present study, the results supported this suggestion, namely, a high ODS-J was significantly correlated with low SCH and TEWL. Furthermore, the correlation coefficients were similar to those of previous study [11]. Thus, the ODS-J suggested concurrent validity. The legs and forearms are usually the first to be affected by dry skin, and the prevalence of dry skin in the legs is particularly higher than that in the forearms [3,13,20,21]. The same results were obtained in this study, and therefore the ODS-J had also known-groups validity.

3.5.2. Relevance to practice and research

The prevalence of dry skin in elderly is high in all clinical settings such as general practitioners, hospitals, community and outpatient care settings, institutional long-term care, and home care [1,12–14]. In addition, there is a wide range of occupations of medical professionals who support the elderly in this environment. Therefore, the introduction of a scoring system, such as the ODS-J, that allows medical professionals to assess skin dryness in a common manner across institutions and professions is very significant. The ODS-J is highly versatile because it can be assessed at any time under the timing and judgment of the user. We believe that the best assessment can be made in any clinical setting by using the ODS-J or instruments for measuring skin barrier function (for example, TEWL and SCH) according to the application and demand.

In a clinical field, skin care to improve dry skin is fundamental and easy, but it can be a powerful nursing intervention when properly implemented [13]. Therefore, dry skin is a diagnosis that should be effectively assessed especially by nurses [20]. In Japan, we believe that the ODS-J will be useful especially in situations where the assessment of dry skin and evaluation for the effectiveness of care are conducted before and after providing skin care.

In the research field, Germany has a high level of concern about skin dryness and skin care, and the ODS is used as a primary outcome in large national surveys [13,19,22,24]. Thus, the usefulness of the ODS for objectively quantifying skin dryness on a research basis has been demonstrated. The ODS-J can also be used to accumulate such clinical data and apply it to research in Japan. In addition, artificial intelligence (AI) has made great progress in the field of image classification in recent years. Image classification is regarded as the forefront of machine learning research, and visual pattern recognition plays more important role in dermatology than in any other medical specialty [28]. Using these techniques, algorithms to diagnose skin lesions, especially melanoma, have been developed [28,29]. In Japan, the application of the above innovations to the ODS-J may also contribute to the development of AI for automatic diagnosis of dry skin by skin images. Such technology can be useful not only for hospitals but also for telemedicine and self-skin care of the people with dry skin.

3.5.3. Limitations

There are two possible limitations in this study. First, the participants were limited to older patients. Dry skin is common in the older patients, so this was a reasonable target population. However, considering the generalizability, it is necessary to expand the range of the target requiring skin assessment in the future (for example, patients with atopic dermatitis, patients with side effects of treatment, children, etc.). Second, we were not able to examine whether the ODS-J can evaluate the improvement of dry skin. In future, it will be necessary to verify longitudinally whether the ODS-J can evaluate the improvement of dry skin before and after interventions such as skin care.

3.6. Conclusions

This study evaluated the reliability and validity of the ODS-J, the gold standard for dry skin assessment. Our results showed good inter-rater reliability, concurrent validity, and known-groups validity of the ODS-J. We conclude that this scale can be used by clinical nurses in Japan to observe older patients' skin and is an effective indicator for the evaluation of skin care.

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Chapter 4

Minimum wiping pressure and number of wipes that can remove dirt during bed baths using disposable towels: A multi-study approach

(Konya et al., *BMC Nursing*, 2023;22:18)

4.1. Abstract

Background

Friction irritation by wiping increases the risk of skin problems. In bed baths with cotton towels, wiping three times with weak pressure (10–20 mmHg ≈ 1333–2666 Pa) can remove dirt while maintaining skin barrier function. However, few studies have examined the appropriate frictional irritation with disposable towels. This study aimed to analyze the wiping pressure and number of wipes currently applied by nurses when using disposable towels during bed baths and propose the minimum values for removing dirt from the skin.

Methods

This multi-study approach consisted of cross-sectional and crossover design components. In Study 1, 101 nurses in two hospitals were observed by recording the wiping pressure and number of wipes when using both disposable (nonwoven) and cotton (woven) towels. Wiping pressure and number of wipes by towel materials were analyzed using a linear mixed model. In Study 2, 50 adults received oily and aqueous dirt on their forearms, which were wiped six-times with disposable towels, applying randomly assigned pressure categories. We used color image analysis and a linear mixed model to estimate the dirt removal rate for each combination of wiping pressure and number of wipes.

Results

Study 1 showed that although wiping pressure did not differ by towel material, the number of wipes was significantly higher for disposable wipes than cotton wipes. Approximately 5% of nurses applied strong wiping pressure or wiped too often. In Study 2, wiping three times with disposable towels at least 5–10 mmHg achieved dirt removal rates of ≥80%.

Conclusions

Some nurses excessively wiped using disposable towels, which might cause skin problems. However, excessive wiping is not required to adequately remove dirt, regardless of the towel material used in various clinical situations. We recommend wiping at 10−20 mmHg of pressure (just like stroking gently) at least three times to improve the quality of bed baths. These findings highlight the need to develop skin-friendly bed bath educational programs, particularly using appropriate frictional irritation to reduce the risk of skin problems.

4.2. Background

The older population is growing rapidly worldwide, and one in six people will be aged ≥65 years by 2050 [1]. With aging, the skin of the older adults becomes more vulnerable and prone to various skin lesions [2]. Thus, the demand for high-quality skin care that guarantees skin integrity, cleanliness, and comfort is expected to increase in various healthcare settings.

Skin care, including bathing, showering, and bed bathing, is a core nursing practice in most hospitals worldwide [3]. Among which, bed baths are the most fundamental way of cleaning the skin of patients who have difficulty bathing or showering. Typically, cotton (woven) towels with water and soap or disposable (nonwoven) towels without water are used [4]. In Europe, at least 15% of people aged ≥65 have severe difficulties in bathing [5], and 15% of Danish patients and 29% of Japanese recipients of in-home care are provided daily bed baths [6,7]. Moreover, the three goals of improving the quality of skin care, namely skin cleanliness, skin integrity, and comfort enhancement, are interrelated [8]. Removing dirt (including oily dirt such as sebum and old stratum corneum, and aqueous dirt such as sweat [4,9–11]) from the skin is a prerequisite in achieving these three goals for those receiving bed baths. However, nurses often perform this care based on empirical principles [12], and evidence to establish the best practice is lacking [13].

Given that personal hygiene is a basic human need [14], skin cleanliness (specifically, how to remove dirt from the skin) should be a primary consideration in developing high-quality bed bath methods. The degree of topical dirt removal in bed baths is strongly related to frictional irritation (wiping pressure, WP; and number of wipes, NW [11]). However, excessive frictional irritation decreases patients' skin barrier function and increases the risk of skin tears. Skin tears are traumatic wounds caused by mechanical forces [15,16], and are a serious problem causing severe pain, decreased quality of life, and prolonged hospitalization [15]. One of the leading causes of these lesions is extrinsic frictional irritation that occurs while patients are being assisted with activities of daily living [17]. For example, frictional irritation by wiping during bed bath exposes patients at high-risk to skin tears [18–20]. The Japanese Society of Wound, Ostomy, and Continence Management [21] showed that friction during bathing and bed bathing is among the main cause of skin tears in Japan (ranked 4/29: top 4.1%). Therefore, WP and NW during bed baths are essential factors that determine skin cleanliness and integrity. Nursing staff must acquire appropriate techniques that do not cause skin tears [22] and should practice bed baths that keep the body clean while protecting the patient's vulnerable skin.

A descriptive study of bed baths found that 85% of nurses rubbed vigorously on patients' skin [12]. Excessively intense WP when using cotton towels was identified as a problem with some nurses [23]. In bed baths with cotton towels, 10–20 mmHg of pressure was sufficient to remove oily and aqueous dirt with three wipes [11]. Furthermore, wiping three times with 23–25 mmHg, which nurses routinely practice, significantly decreased skin barrier function in older patients compared with wiping with 12–14 mmHg [24]. There was no significant difference in the patient satisfaction across the different WPs, and none of the WPs caused discomfort [24]. These results suggest the effectiveness of weak pressure using cotton towels, and evidence regarding optimal frictional irritation during bed baths is accumulating.

In recent years, the use of disposable towels (also known as washing without water) has increased remarkably in the United States and Europe [7,25,26]. Disposable wipes have the advantages of hygienic towel management and ease of use compared to cotton wipes. Although the use of cotton and disposable towels has been reported at 71.0% and 12.2%, respectively [27], disposable towels became the first choice in bed baths for infected patients [28] during the COVID-19 pandemic. Moreover, two systematic reviews have shown that disposable wipes are no less effective than cotton wipes in preventing skin lesions and removing bacteria in older adults [13,26]. Furthermore, disposable wipes have been shown to be a valuable alternative to cotton wipes in terms of comfort of the care recipients [29].

Previous studies on disposable wipes did not consider the effects of frictional irritation, which requires critical evaluation. Generally, disposable towels are thinner than cotton towels and have a different sensation on the user. Considering the surface structure of the towels, cotton towels have bits of thread that protrude (also called as pile) from the main surface, resulting in a rough feeling. In contrast, disposable towels have a smooth surface [30], which may absorb less dirt than cotton towels. Thus, the WP and NW required when disposable towels are used may differ from those needed for cotton wipes. However, the actual conditions in clinical practice remain unclear, and directly transferring the evidence of frictional irritation from cotton wipes to disposable wipes would be inaccurate. Additionally, nurses must remove dirt with minimal frictional irritation to maintain skin cleanliness and integrity. Nevertheless, the WP and NW for bed baths with disposable towels that meet these two requirements are unknown.

Therefore, we aimed to quantify the WP and NW currently applied by nurses during bed baths when using disposable towels and propose the minimum values for removing skin dirt. To achieve this objective, we adopted a multi-study approach based on the following research questions:

1. Study 1: What are the actual conditions of WP and NW when clinical nurses use disposable towels?
2. Study 2: What is the minimal effective WP and NW for removing dirt from the skin during bed baths when using disposable towels?

This multi-study approach allows us in addressing the limited evidence of frictional irritation on the use of disposable towel in the skin care process. Subsequently, this study should provide an optimal bed bath technique when removing dirt from the skin while considering skin integrity and cleanliness.

4.3. Study 1: Methods

4.3.1. Study design, setting, and sample

Study 1 employed a two-center, descriptive, cross-sectional design. This study was conducted from October to November 2021 at two general hospitals in northern Japan that are of different population. Hospital A had approximately 500 beds and 480 registered nurses, while Hospital B had approximately 170 beds and 60 registered nurses. The eligibility criteria for the participants were as follows: 1) registered nurses with three or more years of clinical practice and 2) experience in bed baths using disposable towels. This study excluded novice and advanced-beginner nurses as we have anticipated that clinical experience would influence bed bath skills; nurses with three or more years of clinical experience were previously classified as competent or above [31]. All 105 nurses who met the eligibility criteria were recruited by the hospital nursing managers (Hospital A, n = 53; Hospital B, n = 52) and were directly informed of the purpose, methods, and anonymity of the study. Those who signed an informed consent form were included in the study. Overall, 101 nurses (Hospital A, n = 50; Hospital B, n = 51) agreed to be included in the study. This study was approved by the ethical review board of the affiliated university and participating hospitals (approval no. 21–51). The study is in accordance with the Declaration of Helsinki and Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [32].

Based on a previous study [23], nurses were asked to wipe the flexed forearm of a simulated patient using disposable towels under three conditions. The application of WP and NW were classified into: A) ordinary (WP and NW applied in daily bed baths); B) weak (WP and NW for patients with vulnerable skin); and C) strong (WP and NW for patients with heavily contaminated skin). We also requested the nurses to perform the same procedure using cotton towels, which will serve as a reference.

4.3.2. Outcomes

Questionnaire on participant characteristics and daily practice of bed baths

A questionnaire was used to investigate the demographic and clinical characteristics of the participants, including age, nursing experience, sex, department, education, professional qualifications, frequency of bed baths, towels mainly used for daily use, skin care learning, experience with skin problems during skin care, and control of WP.

WP and NW

WP is defined as the force applied vertically to the skin surface during bed baths [23]. We measured WP using a pressure sensor (SR Soft Vision; Sumitomo Riko Co., Ltd., Nagoya, Japan) [23]. According to previous studies [11, 23, 24], the unit of wiping pressure used was in mmHg (1 mmHg = 101325/760 Pa [≈133 Pa]). The forearm of the simulated patient (healthy adult) was set on a table at an angle of 30°, imitating the position of a bedridden patient for a bed bath. Nurses were instructed to wipe at least three times, the area from the patient's wrist to the elbow either peripherally to centrally or a round trip to the back. The average of the three wipes in the central area of the forearm where the pressure was uniformly applied was used for the analysis. A video camera was used to record the NW.

4.4. Study 2: Methods

4.4.1. Study design and setting

Study 2 was a single-blind, crossover, quasi-experimental study in which participants underwent two procedures on the same day in the laboratory. Two types of pseudo-skin dirt, (A) oily and (B) aqueous, were randomly administered to the flexed right and left forearms of each participant, respectively. Each participant was wiped six times using disposable towels with one of four randomly assigned magnitudes of pressure. The block randomization sequence was based on computer-generated random numbers (block size: forearm and dirt type = 4; pressure category = 8). The random assignment was blinded only to the participants. We conducted the study from February to April 2022 in a controlled laboratory at a room temperature of 20–24℃, 40–60% humidity, and illuminance of 910 lx. This study is in accordance with the Transparent Reporting of Evaluations with Non-randomized Designs (TREND) guidelines [33].

4.4.2. Participants

This study included healthy adults aged ≥20 years. The exclusion criteria were as follows: 1) participants with skin abnormalities or diseases, such as excessive sweating, redness, swelling, or edema at the forearm; 2) participants with thyroid disease; and 3) participants with a history of skin abnormalities caused by disinfection or cosmetic use. In addition, we requested that the participants avoid the following situations to minimize potential bias: 1) alcohol consumption 8 h prior to study participation; 2) caffeinated beverages and spices on the day of the study; 3) applying moisturizers, sunscreen, or ointments to the forearms on the day of the study; 4) exercise that may cause sweating on the day of the study; and 5) eating 1 h before data collection. Informed consent was obtained from those who indicated willingness to participate in the study. This study was approved by the ethical review board of the affiliated university (approval no. 21–80) in accordance with the Declaration of Helsinki.

The sample size was calculated using G Power software ver. 3.19 [34]. Referring to a previous study on the cleaning effect of cotton wipes [11], the minimum sample size was 48, with an effect size of 0.25, a significance level of 0.05, and a power of 0.80. Therefore, 50 individuals were recruited for this study.

4.4.3. Interventions

Bed bath methods

Disposable towels (Hakujuji Co., Ltd., Tokyo, Japan) were selected from products that are widely used in clinical settings (Figure 1). The towels were heated in a microwave to a surface temperature of approximately 45°C and folded to a palm size. The towels contained the following ingredients: aqua, propylene glycol (humectant), 1,3-butylene glycol (humectant), glycereth-26 (humectant), polyquaternium-51 (humectant), benzalkonium chloride (preservative, disinfectant), iodopropynyl butylcarbamate (preservative), methylisothiazolinone (preservative), cetrimonium chloride (antistatic). The towel did not contain detergents, which did not adversely influence our primary outcome, the dirt removal rate.

Figure 1. Disposable towel used in this study

WP was measured as described in Study 1. The well-trained researcher wiped six times with disposable towels at one of four randomly assigned pressure categories (WP in mmHg: 5≤WP<10, 10≤WP<20, 20≤WP<30, 30≤WP<40). The range of 5–40 mmHg was determined by the results of Study 1 (range of ordinary condition). The range of wipes was 1–6 times based on the results of a previous study [11] and Study 1 (interquartile range for ordinary condition). We used a new disposable towel for each wipe and wiped the participant's forearm from the peripheral to the central direction at a speed of 1 time/s.

Adhesion of the pseudo-dirt

Previous studies on bed baths have used the microorganism count to indicate skin cleanliness [35,36]. However, this method is limited such that the degree of contamination prior to data collection cannot be standardized because of the frequency of skin care and associated skin contamination of the patient, which may not allow for precise evaluation. Therefore, methods for intentionally applying dirt and evaluating the removal rate have been used to precisely evaluate the degree of dirt removal based on differences in wiping methods [9,13]. Thus, this study visualized skin cleanliness using color image analysis according to previous methods [11]. We used two types of pseudo-skin dirt: (A) an oily lipstick (Lipstick S578 red series; Chifure Holdings Co., Ltd., Kawagoe, Japan) and (B) povidone-iodine (Swabsticks Apliswab 12[LT]; Hakujuji Co., Ltd., Tokyo, Japan). The main composition of this lipstick is wax esters, triglyceride, and oleic acid, like skin surface lipids and sebum. So, previous studies have used this as a model of oily dirt [9,11]. The povidone-iodine is an aqueous solution commonly used in clinical settings, and its prolonged persistence on the skin causes dermatitis. Therefore, it was used as a model of aqueous dirt that needed to be wiped off [11]. Each skin dirt was applied uniformly over a 9-cm^2 area at the center of each flexed forearm (right and left), and the wiping method described above was performed approximately 3 min later.

4.4.4. Outcomes

Participant characteristics

We asked participants to complete questionnaires regarding age, sex, body mass index, and Japanese skin type (JST) during a 15-min resting period before the study began. The JST, a Japanese version of the Fitzpatrick skin phototype [37], was examined to assess whether the participant's skin color affected color image analysis. This scale classifies skin into three types according to susceptibility to sunburn (J-I: sensitive and tanned less than average, J-II: intermediate, and J-III: insensitive and developed a dark tan). In addition, because the participant's skin barrier function before wiping could influence the results, two representative parameters were measured according to previous guidelines [38]. First, the transepidermal water loss was measured using a VapoMeter SWL5001 (Delfin Technologies Ltd., Kuopio, Finland) for approximately 10 s; one single measurement was used for the data. Stratum corneum hydration was measured using a Moisture Meter SC Compact (Delfin Technologies Ltd., Kuopio, Finland). We took three measurements and used the average value as the data.

Dirt removal rate

The wiping area was captured with a digital camera (OLYMPUS PEN Lite E-PL6, Olympus Corporation, Tokyo, Japan) at a fixed height and position before wiping, after applying skin dirt, and after each wipe. The 3 cm central side of the wiping site was also included in the field of photography to confirm the degree of contamination stretched by wiping. We captured the skin images with the same settings for pixel count, shutter speed, diaphragm value, ISO sensitivity, and white balance as in a previous study [11]. Moreover, we used a color chart (CASMATCH, BEAR Medic Corporation, Kuji, Japan) and Adobe Photoshop (Adobe Inc, San Jose, CA, USA) for skin image color standardization and size correction.

We calculated the skin dirt removal rates (%) from images captured before and after each wipe using color analysis software (Feelimage Analyzer; VIVA Computer Inc., Osaka, Japan). The software description and details of the formula for calculating dirt removal rates are shown in a previous study that developed digital image color analysis [11]. In this method, a dirt removal rate of ≥80% can be considered as sufficient dirt removal.

To obtain clinical reference data for assessing whether the dirt had been sufficiently removed, we calculated the dirt removal rate by washing. After wiping six times, each piece of skin dirt was applied again without overlapping the area to which the dirt was previously applied. Subsequently, following a previous study [39] and a skin care guidebook [40], the washing method recommended for protecting the skin of older adults and removing dirt (after applying foaming body soap, rub with the hands gently clockwise for 30 s at a rate of 1 time/s, and then wash with hot water for 20 s) was performed.

4.5. Statistical analysis

We presented continuous variables as the mean and standard deviation (SD) or median and interquartile range, and categorical variables as the frequency and percentage. All analyses were performed using JMP® 16 Pro (SAS Institute Inc.) with a significance level of 5%.

In Study 1, a linear mixed model with WP and NW as the dependent variable was constructed. This model included nurses as a random effect, and towel material (cotton and disposable towel), condition (strong, ordinary, and weak), and their interaction as a fixed effect. The Bonferroni method for multiple comparisons within conditions was used if any interaction or main effect was significant. In addition, the Wilcoxon signed-rank test was used to compare the towel materials for each condition. The partial η^2 and r were calculated as effect sizes [41,42].

Using a separate linear mixed model, Study 2 analyzed the relationship between the two types of dirt removal rates and explanatory variables. This model used participants as a random effect, and WP (four categories), NW (six categories), and their interaction as a fixed effect. We then estimated the least squares means (LSMs) of the two types of dirt removal rates for each combination of WP and NW. The relationship between skin barrier function or skin type and the dirt removal rate was confirmed using Spearman's rank correlation coefficient and one-way ANOVA, respectively. We calculated the intraclass correlation coefficient (ICC) and standard error of measurement to evaluate the intra-rater reliability of the WP measurements. The ICC considered almost perfect reliability to be 0.81–1.00 [43].

4.6. Study 1: Results

4.6.1. Questionnaire on participant characteristics and daily practice for bed baths

The participants' mean nursing experience was 18.7 (SD, 9.7) years, and 87.1% were female (Table 1). A total of 62.4% belonged to hospital wards and 37.6% belonged to outpatient and other departments. Moreover, 9.9% (n = 10/101) of the nurses had experienced skin problems during bed baths, which was more common than in other hygiene care practices. Skin problems during bed baths included redness (36.4%), epidermal peeling (36.4%), skin tears (9.1%), petechia (9.1%), and bleeding due to laceration (9.1%), all of which were reported to have occurred during wiping.

Table 1. Participant characteristics and daily practice for bed baths in Study 1 (n = 101)

Variables	Values
Age [years]: Mean (SD)	41.6 (10.1)
Nursing experience [years]: Mean (SD)	18.7 (9.7)
Sex: N (%)	
Female	88 (87.1)
Male	13 (12.9)
Department: N (%)	
Hospital wards	63 (62.4)
Outpatient or other	38 (37.6)
Education: N (%)	
Vocational school	90 (89.1)
University	6 (5.9)
Graduate school (Master course)	2 (2.0)
Other	3 (3.0)
Professional qualifications: N (%)	
Yes	15 (14.9)
No	86 (85.1)
Frequency of bed bath: N (%)	
More than 4 times a week	28 (27.7)
3-4 times a week	20 (19.8)
1-2 times a week	11 (10.9)
Rarely	42 (41.6)
Towel used mainly for daily use [a]: N (%)	
Disposable towel	61 (61.0)
Cotton towel	28 (28.0)
Both	11 (11.0)
Skin care learning: N (%)	
Yes	62 (61.4)
No	39 (38.6)
Experience with skin problems during skin care: N (%)	
Bed bath	10 (9.9)
Bathing	1 (1.0)
Shower	1 (1.0)
Perineal care	1 (1.0)
Other	4 (3.9)
None	84 (83.2)
Control of wiping pressure: Disposable wipes: N (%)	
Yes	80 (79.2)
No	6 (5.9)
Not used at all	15 (14.9)
Control of wiping pressure: Cotton wipes: N (%)	
Yes	67 (66.3)
No	2 (2.0)
Not used at all	32 (31.7)

Notes: SD, standard deviation; a, n = 100.

4.6.2. WP and NW by towel material

The box plots in Figure 2 show the WP and NW used in clinical practices. Approximately 5% of nurses (outliers) applied strong wiping pressure or wiped too often. The details of statistical information are shown in Supplementary Table 1. Four of the ten nurses whose patients had experienced skin problems during bed baths recorded outliers in either WP or NW. Approximately 15% of the nurses performed patting only in the weak condition. In the model for WP, although the main effect of condition was significant ($F_{[2, 471]}$ = 400.36, partial η^2 = 0.63, P <.001), that of towel ($F_{[1, 468]}$ = 0.09, partial η^2 = 0.00, P = .762) and their interaction ($F_{[2, 468]}$ = 2.15, partial η^2 = 0.01, P = .117) was not (Figure 2[A]). Many nurses responded to the questionnaire claiming that they controlled their WP (Table 1); concordantly, multiple comparisons of condition by towel material showed significant differences for all combinations. The model for NW showed significant effects of condition ($F_{[2, 468]}$ = 19.32, partial η^2 = 0.08, P <.001) and towel type ($F_{[1, 466]}$ = 5.18, partial η^2 = 0.01, P = .023), but their interaction was not significant ($F_{[2, 466]}$ = 0.94, partial η^2 = 0.00, P = .391: Figure 2[B]). Disposable towels were wiped significantly more often than cotton towels. Owing to an exploratory analysis, no statistically significant associations between WP or NW and the other questionnaire items or hospitals were found.

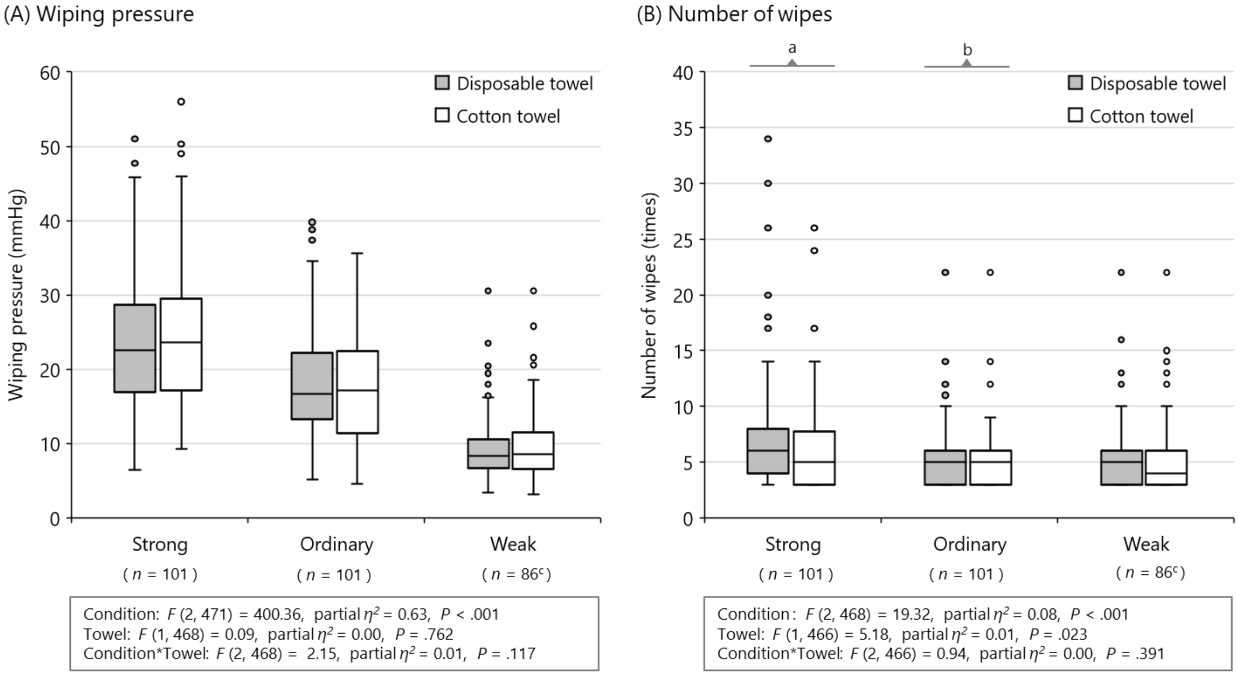

Figure 2. Box plots indicating distributions of wiping pressure and number of wipes by towel materials

Notes: Box plots of (A) wiping pressure (WP) and (B) number of wipes (NW) by towel materials. The median is denoted by the line within the box; 25th percentile, bottom border of box; 75th percentile, top border of box; variability outside the interquartile range, whiskers; and outside values, dots. The nurses applied WP and NW based on three classifications: ordinary (WP and NW applied in daily bed baths); weak (WP and NW for patients with vulnerable skin); and strong (WP and NW for patients with heavily contaminated skin). See Supplementary Table 1 for details of statistical information; Interaction and main effect were analyzed in a linear mixed model for two-way repeated-measures ANOVA (Effect size was calculated as partial η^2); Wilcoxon signed-rank test showed that the number of wipes using disposable towel was significantly more often than that of cotton towel under the strong (a, P <.001) and ordinary (b, P = .018) condition. c, approximately 15% of the nurses performed patting only in the weak condition (Cotton towel; n = 84).

4.7. Study 2: Results

4.7.1. Participant characteristics and experimental reliability

A total of 50 healthy adults participated in the study with a mean age (SD) of 24.6 (4.5) years, and 58.0% were female. Table 2 shows the participant characteristics from Study 2. No statistically significant associations were observed between skin barrier function, skin type, and dirt removal rate. The ICC of WP for six wipes was 0.990 (95% confidence interval [CI], 0.985–0.994) for the removal of oily dirt and 0.989 (95% CI, 0.984–0.994) for the removal of aqueous dirt, showing almost perfect reliability (Table 3).

Table 2. Participant characteristics in Study 2 (n = 50)

Variables	Values
Age [years]: Mean (SD)	24.6 (4.5)
Body Mass Index [kg/m^2]: Mean (SD)	21.0 (2.7)
Sex: N (%)	
Female	29 (58.0)
Male	21 (42.0)
TEWL [g/m^2/h]: Mean (SD)	
Right	9.6 (2.8)
Left	10.0 (2.9)
SCH [AU]: Mean (SD)	
Right	21.7 (11.2)
Left	22.0 (12.8)
JST: N (%)	
J-1	11 (22.0)
J-2	24 (48.0)
J-3	15 (30.0)

Notes: JST, Japanese skin type; SCH, stratum corneum hydration; SD, standard deviation; TEWL, transepidermal water loss.

Table 3. Intra-rater reliability of the wiping pressure performed six times for two types of skin dirt

Skin dirt	SEM	ICC	95%CI		*P*-value
			LL	UL	
Oily	2.57	0.990	0.985	0.994	<.001
Aqueous	2.76	0.989	0.984	0.994	<.001

Notes: Aqueous, wiping pressure for pseudo-aqueous dirt; CI, confidence interval; ICC, intraclass correlation coefficients; LL, lower limit; Oily, wiping pressure for pseudo-oily dirt; SEM, standard error of measurement and it equals the square root of the error variance; UL, upper limit.

4.7.2. Oily dirt removal rate by wiping with disposable towels

The LSMs of the oily dirt removal rate estimated using the linear mixed model (Supplementary Table 2) are shown in Figure 3[A]. The combinations of the NW and WPs that achieved an oily dirt removal rate ≥80% (including 95% CI) were as follows: one wipe with 20≤WP<30 and 30≤WP<40; two wipes with 10≤WP<20, 20≤WP<30, and 30≤WP<40; three wipes with 5≤WP<10, 10≤WP<20, 20≤WP<30, and 30≤WP<40. Similarly, four to six wipes showed a sufficient dirt removal rate, regardless of the WP. Furthermore, we confirmed no transition of skin contamination in the wipe direction for any combination (Supplementary Table 3). In contrast, the oily removal rate was 13.0% (95% CI: 7.2–18.9%) when washing with foaming soap and warm water.

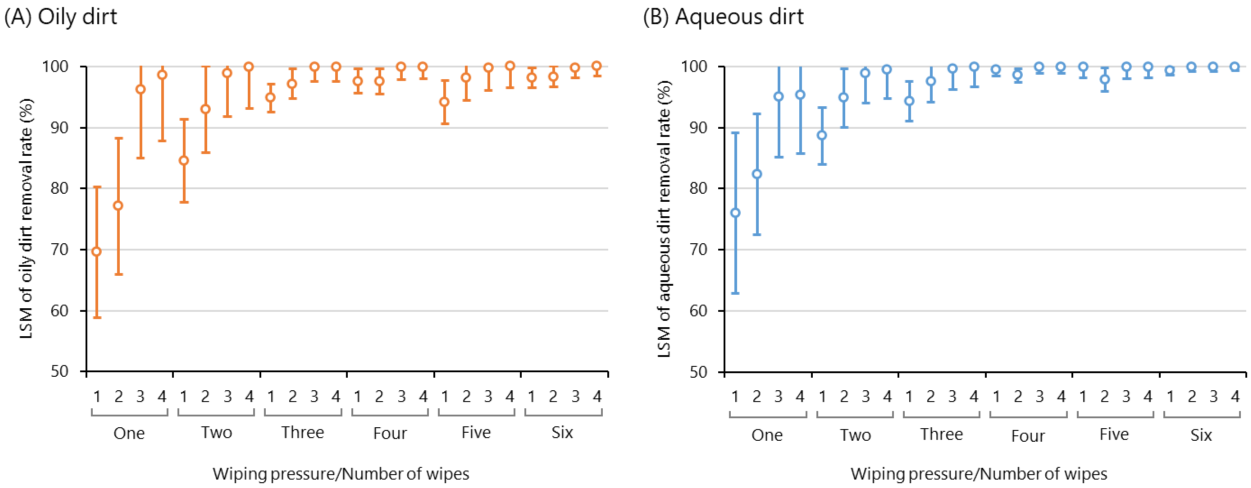

Figure 3. Least square mean (LSM) of skin dirt removal rate by wiping using disposable towel

Notes: LSM of removal rate for (A) oily dirt and (B) aqueous dirt by categories of wiping pressures or number of wiping (n = 50); In the digital image color analysis, a dirt removal of rate ≥80% can be considered as a sufficient dirt removal. The circles indicate the LSM as determined by a linear mixed model as a function of the combination of wiping pressure and number of wipes; The error bars indicate the 95% confidence interval; The wiping pressure (WP: mmHg) is classified into four categories represented by the numbers on the x-axis;1, 5≤WP<10; 2, 10≤WP<20; 3, 20≤WP<30; 4, 30≤WP<40.

4.7.3. Aqueous dirt removal rate by wiping with disposable towels

The LSMs of the aqueous dirt removal rate estimated using the linear mixed model (Supplementary Table 2) are shown in Figure 3[B]. The combinations of the NW and WPs that achieved an aqueous dirt removal rate of ≥80% were as follows: one wipe with 20≤WP<30 and 30≤WP<40; two wipes with 5≤WP<10, 10≤WP<20, 20≤WP<30, and 30≤WP<40. Similarly, wiping three to six times resulted in a sufficient dirt removal rate regardless of the WP. There was no transition of skin contamination in the wipe direction (Supplementary Table 3). The removal rate after washing was 100% for all the participants.

4.7.4. Integration of the results of studies 1 and 2

In Study 1, 13.9% (n = 14/101) of nurses practiced wiping three times at 5−10 (n = 2) or 10−20 (n = 12) mmHg during disposable wipes (Figure 4).

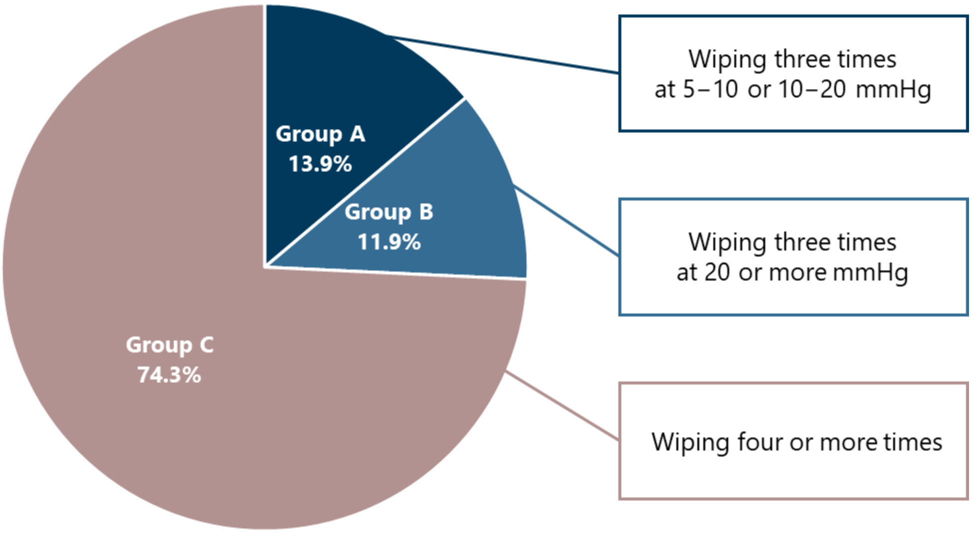

Figure 4. Nurses who performed the minimal effective wiping pressure and number of wipes during disposable wipes

Notes**:** Group A (n = 14), the group of nurses who performed the minimal effective wiping pressure and number of wipes (i.e., wiping three times at 5−10 or 10−20 mmHg); Group B (n = 12), the group of nurses who wiped three times at 20 or more mmHg; and Group C (n = 75), the group of nurses who wiped four or more times.

4.8. Discussion

4.8.1. WP and NW applied by nurses during bed baths using disposable towels

To the best of our knowledge, Study 1 was the first cross-sectional study to visualize WP and NW applied by the clinical nurses when using disposable towels during bed baths.

We expected that the WP would differ between disposable and cotton towels according to the surface, thinness, and sensation felt by nurses during use. However, no statistically significant differences were observed for each pressure condition. As most nurses reported that they controlled their WP in their daily practice, multiple comparisons of WP by towel material showed significant differences in all combinations. In other words, nurses could control the WP according to different patient situations, regardless of the towel material.

Interestingly, the NW was higher for disposable wipes than cotton wipes, although the effect size was relatively small. Disposable towels generally have smooth surfaces without piles [30]. Thus, nurses may wipe more due to potential perceptions that disposable wipes require more effort to remove dirt. Previous studies have also reported that some care recipients perceive that the use of cotton towels with water and soap more effectively removes dirt and makes them feel "really" cleaner than disposable wipes [7,29,44]. Therefore, we inferred that the nurses in this study had a similar perception, which was evident in their practice (i.e., NW).

We found that approximately 10% of the nurses had experienced skin problems such as skin tears due to wiping, 40% of whom were outliers in either WP or NW. Although most nurses controlled WP, the tendency for some nurses to apply excessive WP was consistent with a prior study [23]. In particular, many outliers under weak conditions were observed regardless of the towel material. This indicates that some nurses apply strong WP or wipe too often and perceive it as weak friction irritation. Such inappropriate practices [16,22] may lead to skin problems during bed baths. Although a previous study did not distinguish between the prevalence of skin tears by bathing and bed bathing [21], our results showed that frictional irritation by bed bathing may be more related to skin problems than bathing. These results reaffirm the value of our research, which aimed to identify the optimal frictional irritation during bed baths to reduce patient risk.

4.8.2. Combination of minimum WP and NW to remove skin dirt with disposable towels

Study 1 was used to determine the methodology and interpret the results of Study 2. The current study revealed that wiping three times with 5–10 mmHg using disposable towels was sufficient to remove oily and aqueous skin dirt. For robust oily dirt, the 95% CI of the removal rate exceeded 80% by wiping at ≥10 mmHg, even with only two wipes. However, the estimated accuracy was higher with three wipes than two, suggesting that wiping at least three times with a disposable towel is desirable. Furthermore, this minimum combination may apply to the older adults, as our results indicated that the cleaning effect of wiping was higher than that of the washing method recommended for older patients.

Wiping three times at 10–20 mmHg using cotton towels can sufficiently remove skin dirt while maintaining skin barrier function of older patients [11,24]. We expected that the cleaning effect of disposable wipes might be lower than that of cotton wipes owing to differences in towel surface construction; however, the results did not support this hypothesis. The need to wipe three times was consistent with a previous study [11], but disposable wipes (5–10 mmHg) could remove oily dirt with a weaker WP than cotton wipes (10–20 mmHg). While cotton towels have piles creating a small gap between the skin surface and the towel when the WP is weak, disposable towels have a smooth surface, which allows the towel to adhere to the skin surface even when the WP is weak. Thus, nurses can suggest that patients use disposable towels when their skin is highly contaminated by oily dirt, diarrhea, or excessive sweating.

This study was consistent with a previous study [11] in that both types of towels could adequately remove dirt by wiping three times with 10–20 mmHg despite the structural differences between the two towels. A phenomenological qualitative study by Veje et al. [7] reported that hospitalized patients generally preferred cotton wipes, but preferred disposable wipes under certain circumstances, such as pain and diarrhea. They also recommended that nurses acknowledge and incorporate patients' preferences in decisions regarding the appropriate bed bath method [7,45]. In line with these results, our findings could aid in performing bed baths with respect to patients' preferences of towels. Moreover, the educational advantage of teaching evidence-based WP techniques, regardless of the towel material, could contribute to their application in clinical practice.

Overall, we suggest that nursing staff do not need to excessively wipe with disposable towels during bed baths. Instead, they can adequately remove dirt from the skin by wiping three times with weak pressure. In Study 1, 13.9% (n = 14/101) of nurses applied wiping three times at 5−10 or 10−20 mmHg (Figure 4), indicating that few nurses performed the appropriate practice during bed baths with disposable towels. Therefore, these findings are vital for clinical practice and could reduce harm to patients, and thus lead to desirable bed bath practices in terms of skin integrity and cleanliness.

4.8.3. Study limitations

This study had several limitations. First, the generalizability of the bed bath methods reported in Study 1 is limited because the simulated patients were standardized and first- and second-year nurses were excluded. This was unavoidable because we prioritized the reliability and validity of the WP measurements. We encouraged the nurses to wipe as usual to reflect the actual clinical situation in our data. Second, whether the proposed combination has a similar cleaning effect on the skin of babies, children, and older adults is uncertain. The skin barrier undergoes a period of optimization following birth [46]. Children have a highly permeable skin barrier, which matures to the same level as adults by approximately 5 years old [47]. With aging, the skin of older adults becomes more vulnerable [2,46]. Therefore, further studies on friction irritation due to disposable wipes in these populations (babies, children under 5 years old, and older adults) with vulnerable skin are needed.

4.9. Conclusions

This study determined the WP and NW currently applied by the nurses when using disposable towels during bed baths and proposed the minimum values that can remove skin dirt. In Study 1, the WP of disposable wipes and cotton wipes did not differ, but the NW was higher for disposable wipes than for cotton wipes. Some nurses apply strong WP or wipe too often, which could lead to skin problems such as skin tears. Study 2 quantitatively indicated that wiping using disposable towels at a minimum of three times, with a 5–10 mmHg of pressure was adequate to remove oily and aqueous skin dirt. In conclusion, nurses do not need to excessively wipe using disposable towels to adequately remove skin dirt in bed baths. Considering the cleaning effect of cotton wipes, we recommend wiping at least three times with weak pressure (10–20 mmHg).

4.9.1. Relevance to clinical practice

Clinical nursing staff must practice bed baths that keep the body clean while protecting vulnerable skin. However, the decision to use disposable or cotton towels may be influenced by patient preferences and differences in hospital philosophy, financial situation, and international background. This study suggests that nurses can adequately remove dirt by wiping at least three times with a 10–20 mmHg of pressure ("wiping with a towel just like stroking gently against the skin surface [24]"), using either type of towel in various clinical situations. Additionally, nurses and patients could select a disposable towel, which has a higher cleaning effect even when wiped at a weaker pressure (5−10 mmHg), or when the patient's skin is highly contaminated with oily dirt, diarrhea, or excessive sweating. Finally, this study provides a framework for future education on friction irritation during bed baths. Developing skin-friendly bed bath educational programs for nurses and caregivers on the appropriate application of WP and NW is expected to reduce the risk of skin problems such as skin tears.

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Supplementary Table 1. The details of statistical information for wiping pressure and number of wipes by towel materials

	Condition [c]			Main effect						Interaction		
	Strong	Ordinary	Weak	Condition			Towel			Condition × Towel		
	(n = 101)	(n = 101)	(n = 86 [d])	*F* (df)	partial η^2	*P* [a]	*F* (df)	partial η^2	*P* [a]	*F* (df)	partial η^2	*P* [a]
Wiping pressure (mmHg)												
Disposable towel												
Mdn (IQR)	22.6 (16.9-28.6)	16.7 (13.2-22.2)	8.3 (6.7-10.6)									
M (SD)	23.5 (9.2)	18.6 (7.6)	9.5 (4.6)									
Cotton towel				400.36 (2, 471)	0.63	<.001	0.09 (1, 468)	0.00	.762	2.15 (2, 468)	0.01	.117
Mdn (IQR)	23.7 (17.1-29.5)	17.1 (11.4-22.4)	8.6 (6.6-11.5)									
M (SD)	24.4 (9.6)	17.6 (7.4)	9.9 (5.4)									
r-value	0.15	0.14	0.02									
P-value [b]	.143	.172	.881									
Number of wipes (times)												
Disposable towel												
Mdn (IQR)	6.0 (4.0-8.0)	5.0 (3.0-6.0)	5.0 (3.0-6.0)									
M (SD)	7.0 (5.3)	5.6 (3.0)	5.5 (3.1)									
Cotton towel				19.32 (2, 468)	0.08	<.001	5.18 (1, 466)	0.01	.023	0.94 (2, 466)	0.00	.391
Mdn (IQR)	5.0 (3.0-7.8)	5.0 (3.0-6.0)	4.0 (3.0-6.0)									
M (SD)	6.3 (4.6)	5.3 (2.9)	5.2 (3.3)									
r-value	0.36	0.23	0.21									
P-value [b]	<.001	.018	.051									

Notes: df, degree of freedom; M (SD), mean (standard deviation); Mdn (IQR), median (interquartile range); The nurses wiped with three conditions of WP and NW: ordinary (WP and NW applied in daily bed baths); weak (WP and NW for patients with vulnerable skin); and strong (WP and NW for patients with heavily contaminated skin).
a, Interaction, and main effect were analyzed in a linear mixed model for two-way repeated-measures ANOVA (Effect size was calculated as partial η^2)
b, Wilcoxon signed-rank test (Effect size was calculated as *r*)
c, Bonferroni method for multiple comparisons of pressure condition by each towel material (*, $P < .05$; **, $P < .01$)
d, Approximately 15% of the nurses performed patting only in the weak condition (Cotton towel; n = 84).

Supplementary Table 2. The linear mixed model for skin dirt removal rate

	Oily dirt removal rate				Aqueous dirt removal rate			
	Estimate	SE	*t*-value	*P*-value	Estimate	SE	*t*-value	*P*-value
Constant	95.528	0.928	102.950	<.001	96.548	0.649	148.850	<.001
Number of wipes								
One	-10.162	1.892	-5.370	<.001	-9.367	1.739	-5.390	<.001
Two	-1.473	0.930	-1.580	.120	-1.084	0.751	-1.440	.269
Three	2.424	0.634	3.820	<.001	1.337	0.575	2.330	.529
Four	3.229	0.641	5.030	<.001	2.956	0.564	5.240	.001
Five	2.440	1.038	2.350	.023	2.911	0.748	3.890	.005
Six	Reference				Reference			
Wiping pressure								
5≤WP<10	-5.741	1.586	-3.62	<.001	-3.595	1.181	-3.04	.036
10≤WP<20	-1.986	1.629	-1.22	.229	-1.352	1.113	-1.22	.289
20≤WP<30	3.536	1.629	2.17	.035	2.377	1.113	2.14	.097
30≤WP<40	Reference				Reference			
Number of wipes* Wiping pressure								
One* 5≤WP<10	-10.057	3.233	-3.11	.003	-7.580	3.606	-2.1	.045
One* 10≤WP<20	-6.274	3.321	-1.89	.065	-3.434	2.808	-1.22	.232
One* 20≤WP<30	7.316	3.321	2.2	.033	5.474	2.808	1.95	.062
Two* 5≤WP<10	-3.802	1.589	-2.39	.021	-3.183	1.346	-2.36	.123
Two* 10≤WP<20	0.905	1.632	0.55	.582	0.728	1.296	0.56	.624
Two* 20≤WP<30	1.250	1.632	0.77	.448	1.068	1.296	0.82	.486
Three* 5≤WP<10	2.617	1.084	2.42	.020	0.045	1.064	0.04	.980
Three* 10≤WP<20	1.145	1.113	1.03	.309	1.056	0.980	1.08	.663
Three* 20≤WP<30	-1.564	1.113	-1.41	.167	-0.643	0.980	-0.66	.752
Four* 5≤WP<10	4.592	1.096	4.19	<.001	3.556	1.047	3.4	.011
Four* 10≤WP<20	0.826	1.126	0.73	.467	0.407	0.961	0.42	.684
Four* 20≤WP<30	-2.407	1.126	-2.14	.038	-1.888	0.961	-1.97	.090
Five* 5≤WP<10	1.859	1.773	1.05	.300	4.097	1.342	3.05	.017
Five* 10≤WP<20	2.134	1.821	1.17	.247	-0.232	1.291	-0.18	.862
Five* 20≤WP<30	-1.811	1.821	-0.99	.325	-1.836	1.291	-1.42	.195
Six* 30≤WP<40	Reference				Reference			

Notes: SE = standard error; WP, wiping pressure expressed in mmHg

Supplementary Table 3. The transition of skin contamination in the wipe direction

	Oily dirt transition rate (%)						Aqueous dirt transition rate (%)					
	One	Two	Three	Four	Five	Six	One	Two	Three	Four	Five	Six
5≤WP<10												
ID：42	0	0	0	0	0	0	0	0	0	0	0	0
ID：12	0	0	0	0	0	0	0	0	0	0	0	0
ID：38	0	0	0	0	0	0	0	0	0	0	0	0
ID：8	**2**	0	0	0	0	0	0	0	0	0	0	0
ID：28	0	0	0	0	0	0	0	0	0	0	0	0
10≤WP<20												
ID：23	0	0	0	0	0	0	0	0	0	0	0	0
ID：14	0	0	0	0	0	0	0	0	0	0	0	0
ID：9	0	0	0	0	0	0	0	0	0	0	0	0
ID：26	0	0	0	0	0	0	0	0	0	0	0	0
ID：44	0	0	0	0	0	0	0	0	0	0	0	0
20≤WP<30												
ID：15	**4**	0	0	0	0	0	0	0	0	0	0	0
ID：31	0	0	0	0	0	0	0	0	0	0	0	0
ID：24	0	0	0	0	0	0	0	0	0	0	0	0
ID：40	0	0	0	0	0	0	0	0	0	0	0	0
ID：46	0	0	0	0	0	0	0	0	0	0	0	0
30≤WP<40												
ID：7	**2**	0	0	0	0	0	0	0	0	0	0	0
ID：48	0	0	0	0	0	0	0	0	0	0	0	0
ID：37	**1**	0	0	0	0	0	0	0	0	0	0	0
ID：30	0	0	0	0	0	0	0	0	0	0	0	0
ID：11	0	0	0	0	0	0	0	0	0	0	0	0

Notes: Bold is shown that the transition of skin contamination in the wipe direction occurred; Five participants were randomly extracted from each wiping pressure categories. WP, wiping pressure expressed in mmHg.

Chapter 5

Effects of consecutive bed bathing with weak versus ordinary pressure on skin barrier recovery of hospitalized older adults: A within-person randomized controlled trial

5.1. Abstract

Background

Wiping pressure during bed baths is essential to maintain skin integrity and care quality for older adults. However, effects of different wiping pressures on skin barrier recovery over multiple days remain unclear. This study evaluated and compared the effects of consecutive bed bathing with weak pressure and that with ordinary pressure on skin barrier recovery of hospitalized older adults.

Methods

This within-person, randomized, controlled trial involved 254 forearms (127 patients) and was conducted at a general hospital. Forearms were blinded and randomly assigned a site and sequence of two bed bathing sessions: wiping three times with weak (10–20 mmHg) and ordinary pressure (20–30 mmHg) once per day for 2 consecutive days. The skin barrier was assessed daily based on transepidermal water loss (TEWL) and stratum corneum hydration (SCH) before and 15 min after the interventions. Dry skin was assessed using the overall dry skin score.

Results

A linear mixed model showed that the time courses of TEWL and SCH differed significantly between groups. Impaired skin barrier function caused by ordinary pressure on the first day did not recover to baseline values the next day, whereas weak pressure did not cause significant changes. During subgroup analyses, TEWL of patients with dry skin was more likely to increase with ordinary pressure.

Conclusions

Despite decreased skin barrier recovery experienced by older adults, our findings suggest the safety of weak pressure and highlight the importance of wiping pressure during bed

baths. Weak pressure is particularly desirable for patients with dry skin.

5.2. Background

Globally, the number of people 65 years of age or older is expected to double over the next three decades [1]. Ageing is inevitably associated with chronic diseases, functional disabilities, and care dependency, which have led to increased numbers of older adults living in nursing settings [2]. The skin barrier in the stratum corneum (SC) is vital in preventing external threats and water loss, but it is greatly affected by ageing [3,4]. Impaired skin barrier function increases the risk of skin disorders, such as dry skin, infections, inflammation, pressure ulcers, and skin tears [4–6]. Therefore, high-quality daily skin care is required to maintain skin integrity in older adults [7].

Bed baths are the most basic form of skin care used to maintain cleanliness in patients with difficulty bathing [8]. However, excessive wiping during bed baths can lead to skin barrier dysfunction and skin tears [9–11]. Some clinical nurses have reportedly applied excessively strong pressure while wiping the skin, regardless of the towel material used [12,13]. Therefore, wiping pressure (WP), which is the core of wiping frictional irritation, is an essential aspect of patient safety [12], and an optimal WP that can remove dirt and provide comfort without impairing the skin barrier function has been sought. A recent umbrella review focused on weak WP as a low-irritation practice that maintains skin integrity [14]. Single bed bathing with ordinary pressure (23–25 mmHg, as routinely practiced by clinical nurses) significantly reduced the skin barrier function of older hospitalized adults compared with that with weak pressure (12–14 mmHg, assuming vulnerable skin) [15]. Furthermore, the effectiveness of weak pressure has been supported because it could remove dirt regardless of the towel material [12] and provide patient satisfaction similar to that achieved with ordinary pressure [15].

However, that previous study only assessed the skin barrier 15 min after one bed bath per day [15]. Therefore, whether the decreased skin barrier function caused by a single bed bath with ordinary pressure remains impaired or recovers the next day is unknown. The importance of this discussion stems from skin barrier recovery [16,17]. The baseline skin barrier function of older adults is similar to that of younger adults [17–19]. However, when it is impaired, recovery is delayed and function normalization occurs slowly [18,20]. Furthermore, the prolonged opening of the epidermal "window" allows moisture loss and penetration of the skin by harmful substances; therefore, skin barrier dysfunction is associated with various skin disorders [18]. Evaluating whether consecutive interventions with weak pressure are safe for improving skin barrier function in older adults is clinically important.

This study aimed to evaluate and compare the effects of consecutive bed bathing with weak pressure and that with ordinary pressure on skin barrier recovery of hospitalized older adults. We hypothesized that ordinary pressure for 2 consecutive days would decrease skin barrier function over time compared with weak pressure.

5.3. Methods

5.3.1. Trial design

This single-blind, within-person, randomized, controlled trial (RCT) included participants who received two interventions; each intervention was applied to one of the randomized left or right forearms [21]. Within-person RCTs avoid possible imbalances between interventions for participant-level variables because inter-intervention comparisons are performed within individuals for two or more body sites. Thus, it is an efficient design primarily used in ophthalmology, dentistry, and dermatology fields [21]. Furthermore, the possibility of carry-across effects is unlikely because skin barrier functions of the left and right forearms are symmetrical [22] and can be reliably measured [23]. This study followed the CONSORT 2010 statement, which is an extension checklist for reporting within-person randomized trials [21] after trial registration (UMIN000048838).

5.3.2. Participants

This study was conducted from October 2022 to March 2023 (autumn and winter). It involved older adults hospitalized in a general hospital in a secondary medical area of northern Japan. Japanese patients 65 years of age or older who could communicate daily were included in this study. Exclusion criteria were as follows: excessive sweating; dermatological diseases, skin infections, and severe skin abnormalities; pain or fever; paralysis or peripheral venous catheter or hemodialysis shunt of both forearms; application of moisturizer or ointment on the forearm on the day of bed bathing; and receiving skin care on the day of bed bathing. Nursing managers enrolled patients based on these criteria. The patients were directly informed in writing and orally by the researcher about the study purpose, about their right to decline to participate without detriment, and that anonymity and confidentiality would be ensured. For patients who provided consent, informed written consent for publication was obtained. The study was conducted according to the Declaration of Helsinki after approval by the Ethical Review Committee of the affiliated university (register no: 22-46).

5.3.3. Interventions

Two types of bed baths using a cotton towel were sequentially administered to the volar forearm and randomized according to the site (right or left) and sequence (first or second). The intervention interval was approximately 1 min. Bed bathing with weak pressure was defined as wiping three times at 10 to 20 mmHg (gently stroking the skin surface), and intervention with ordinary pressure was defined as wiping three times at 20 to 30 mmHg (pressing until the skin surface sank slightly) [15]. These interventions were conducted for 2 consecutive days because that was the maximum period during which patients could abstain from receiving other skin care in the clinical setting. Figure 1 shows the detailed study procedures for controls other than differences in WP.

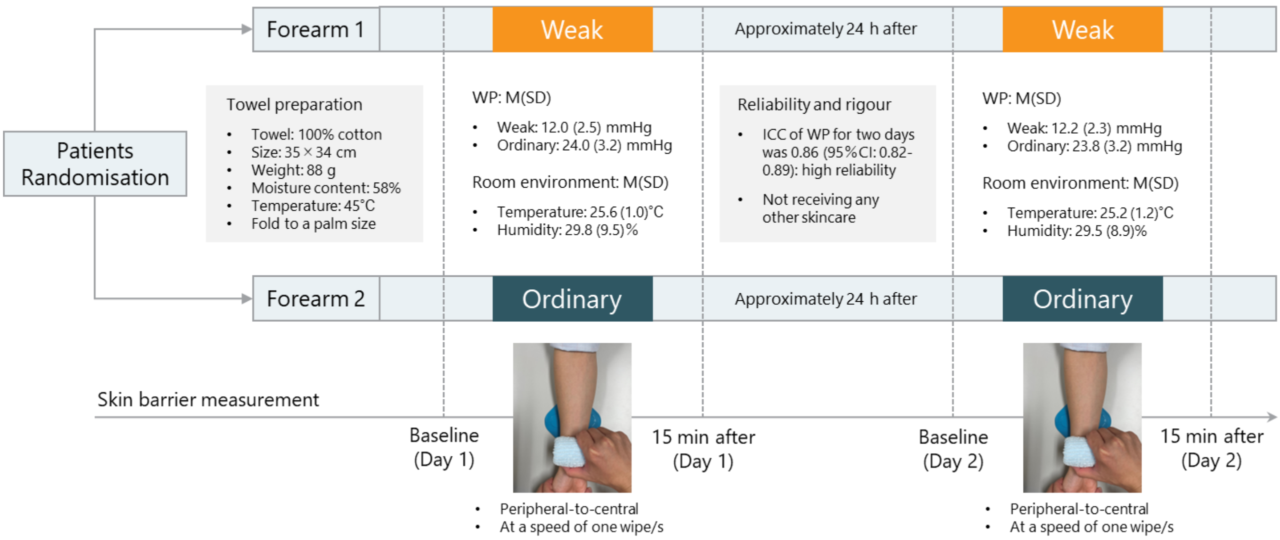

Figure 1. Study procedures

Notes: The towel temperature was controlled by a towel warmer. WP was assessed using a Palm Q® (portable interface pressure sensor; CAPE Co., Ltd., Yokosuka, Japan). CI, confidence interval; ICC, intraclass correlation coefficients for intra-rater reliability; M (SD), mean (standard deviation); Ordinary, bed bathing with 20–30 mmHg; Weak, bed bathing with 10–20 mmHg; WP, wiping pressure.

5.3.4. Randomization

A person without involvement in this study generated the allocation sequence using computer-generated random numbers and then performed simple randomization (1:1 ratio) of the body sites and interventions. The intervention was conducted by a researcher who was not involved in the randomization and who was a part-time registered nurse with 3 years of clinical experience specializing in hygiene care. However, the nature of the intervention made concealing the allocation from the interventionist impossible. Allocation was concealed in a password-protected file until the intervention was implemented. The randomization and allocation processes were concealed from the nursing managers who performed patient enrolment and were blinded to the patients.

5.3.5. Outcomes

Transepidermal water loss

The primary outcome was transepidermal water loss (TEWL) in each forearm. TEWL ($g/m^2/h$) indicates the flux density of water through the SC; increased TEWL is associated with skin barrier dysfunction [24,25]. TEWL was assessed using a VapoMeter SWL5001 (Delfin Technologies Ltd., Kuopio, Finland) with a closed chamber system that was not affected by the environment or airflow and was suitable for field studies [24,25]. Following international guidelines to minimize influences of related factors (e.g., acclimatization period, limiting intake of caffeinated beverages and spices prior to measurement) [25], measurements were performed before and 15 min after bed baths on days 1 and 2. As a reference value, we calculated the smallest detectable change (SDC), which represents the actual change beyond the measurement error, by measuring the baseline twice [26,27] (Supplementary Table 1).

Stratum corneum hydration

The secondary outcome was forearm stratum corneum hydration (SCH). SCH (arbitrary units [A.U.]) indicates the water content of the SC; a decreased SCH is associated with skin barrier dysfunction [24,25]. SCH was assessed using a MoistureMeter SC Compact (Delfin Technologies Ltd., Kuopio, Finland). The measurement points and SDC calculations were similar to those used for TEWL. SCH was assessed after TEWL measurements because consecutive measurements at the same site can affect TEWL [28].

Baseline data of patients and study forearms

The most recent patient information was obtained from the electronic medical records. The data included age, sex, body mass index, hospitalization days, activities of daily living (Barthel index), comorbidities, and medications that may cause skin symptoms. Forearm skin dryness was assessed using the Japanese version of the overall dry skin score (ODS-J) [29]. The ODS is an international 5-point scale used to assess the presence and severity of skin dryness [30], and the ODS-J has good reliability and validity [29]. Based on a previous study, an ODS score ≥1 indicated dry skin [31].

5.3.6. Statistical analyses

Statistical analyses were performed using JMP®16 Pro (SAS Institute Inc., Cary, NC, USA) at a significance level of 5%. The primary analysis (two-way repeated-measures analysis of variance) used a linear mixed model with TEWL and SCH as dependent variables. In this model, fixed effects were set as WP, time, and their interaction (WP × time), and random effects were set as patients. Paired t-tests were used for between-group comparisons, and Dunnett's test (control = baseline on day 1) was used for within-group multiple comparisons. The effect size was calculated as partial η^2 and Cohen *dz* values [32].

The clinical appearance of skin barrier dysfunction is often characterized by dry skin [3]. Therefore, exploratory subgroup analyses were performed to examine the heterogeneity of the results according to dry skin. A separate mixed model was constructed by adding the interaction of the three factors (WP × time × dry skin).

To estimate the sample size for the interaction of the primary analysis, we used G Power software [33] with the following parameters: a two-sided significance level of 0.05; power of 0.90; partial η^2 of 0.01; and correlation between forearms of 0.40 [15]. The effect size was estimated to be smaller than that reported by previous studies [15] because this study evaluated skin barrier recovery [16,17]. The minimum sample size required was 212.

5.4. Results

5.4.1. Participants

Overall, 300 forearms (150 patients) were examined after excluding 14 patients who declined participation (Figure 2). None of the patients experienced any adverse events. One patient was excluded on the first day because of excessive sweating, and 22 patients could not receive the intervention for 2 consecutive days for various reasons (Figure 2). Finally, 254 forearms (127 patients) were analyzed. Baseline data of the patients and forearms are shown in Table 1. The mean patient age (SD; range) was 82.7 years (7.9 years; 65–99 years), and 59.8% of the patients were female. The prevalence of dry skin was 60.6% and homogeneous among the groups.

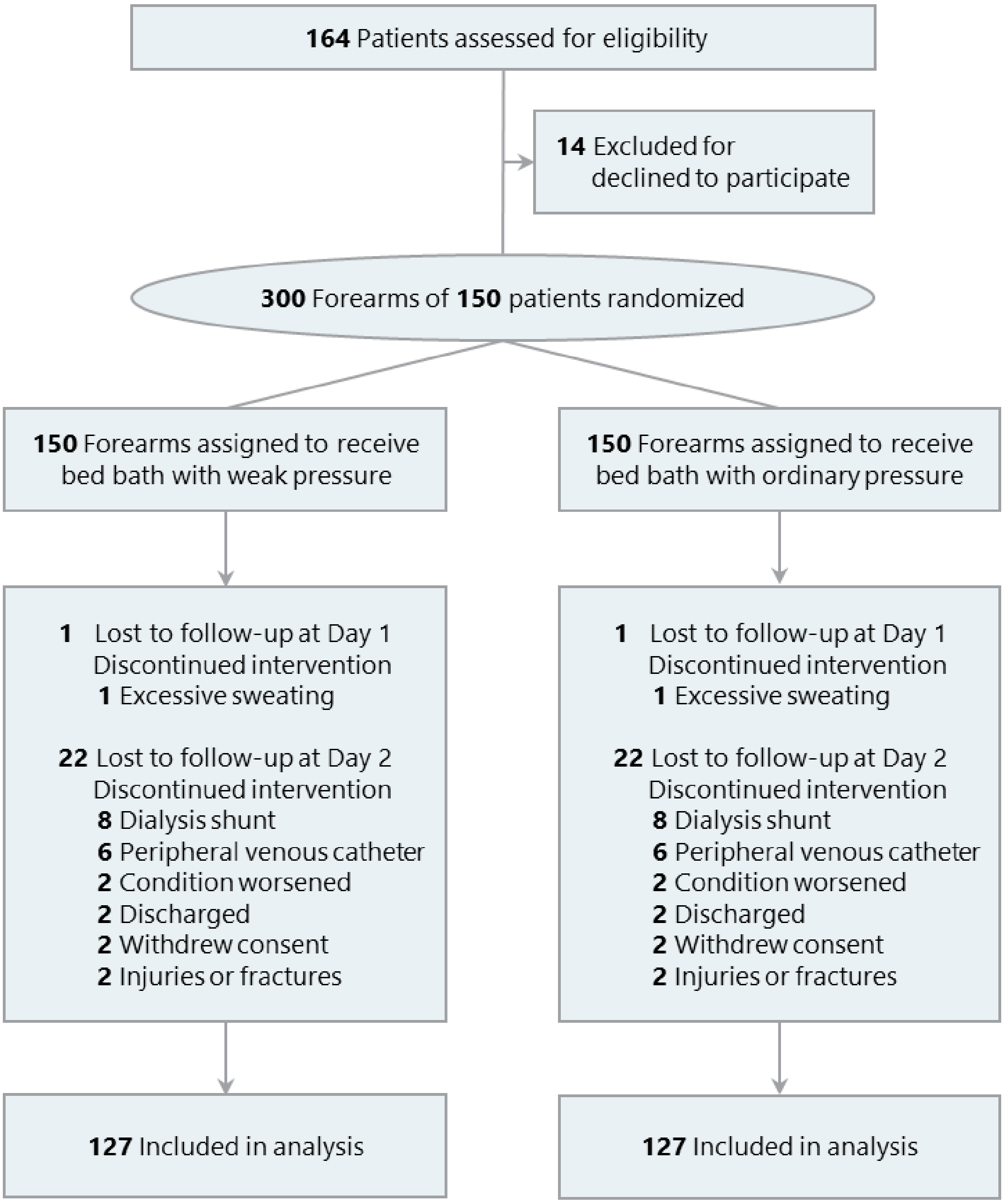

Figure 2. Study flow diagram

Table 1. Baseline data of patients and study forearms (n = 127)

Patients' characteristics	Mean (standard deviation) or N (%)	
Age [years]	82.7 (7.9)	
Sex [female]	76 (59.8%)	
Body mass index [kg/m^2]	22.5 (4.7)	
Hospitalization days [days]	29.5 (150.5)	
Barthel index [score]	49.4 (29.0)	
Diabetes mellitus [yes]	81 (63.8%)	
Diabetic complications [yes]	15 (11.8%)	
Dyslipidemia [yes]	36 (28.3%)	
Chronic kidney disease [yes]	28 (22.0%)	
Stroke [yes]	30 (23.6%)	
Heart failure [yes]	53 (41.7%)	
Cancer [yes]	19 (15.0%)	
Use of steroid [yes]	10 (7.9%)	
Use of diuretic [yes]	33 (26.0%)	
Medications [n]	6.0 (4.7)	
	Weak pressure	Ordinary pressure
Overall dry skin score (ODS) of forearms	0.8 (0.8)	0.8 (0.8)
Forearms with dry skin (ODS ≥1) [yes]	77 (60.6%)	77 (60.6%)

5.4.2. TEWL

Significant main effects of WP ($F_{[1, 252]} = 19.02$; partial $\eta^2 = 0.07$; $P < .001$), the main effect of time ($F_{[3, 756]} = 16.23$; partial $\eta^2 = 0.06$; $P < .001$), and their interaction ($F_{[3, 756]} = 16.62$; partial $\eta^2 = 0.06$; $P < .001$) were observed (Figure 3[A]). Although there was no significant difference between the two groups at baseline (day 1), TEWL with ordinary pressure was significantly higher than that with weak pressure according to all subsequent measurements, with the mean difference exceeding the SDC $_{\text{group level}}$ (Supplementary Table 1 and 2). During within-group comparisons, only ordinary pressure showed significantly higher values for all subsequent measurements than at baseline (day 1), with differences higher than the values of the SDC $_{\text{group level}}$.

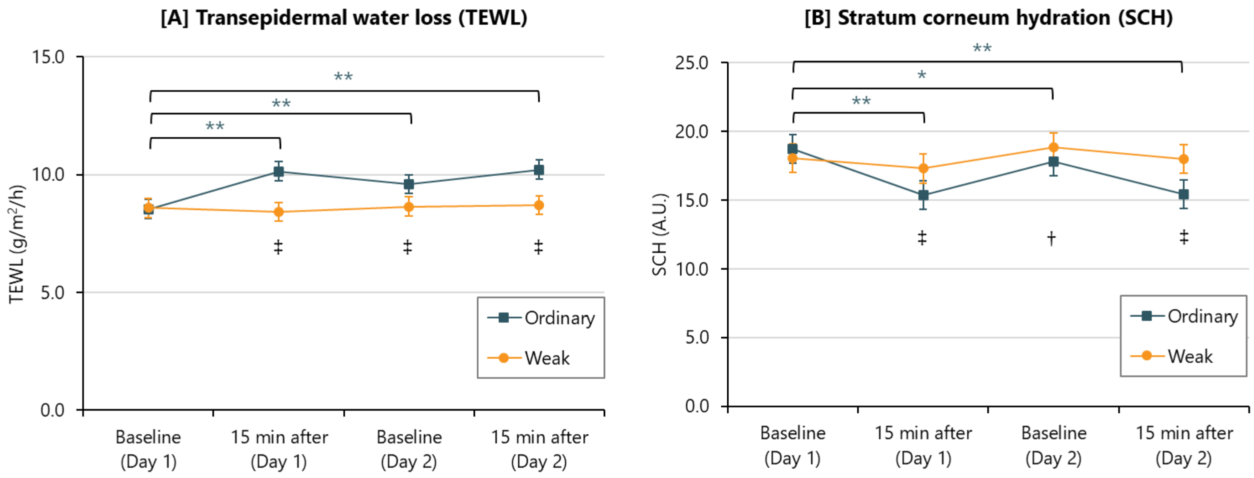

Figure 3. Comparisons of the effects of weak and ordinary pressure on skin barrier recovery (n = 127)

Notes: Circles and squares, the least square means as estimated by the mixed model; error bar, 95% confidence interval; Ordinary, bed bathing with 20–30 mmHg; Weak, bed bathing with 10–20 mmHg. Paired t-test: †, $P < .05$; ‡, $P < .001$. Dunnett test (control = baseline on day 1): *, $P < .05$; **, $P < .001$.

5.4.3. SCH

The main effect of WP was not significant ($F_{[1, 252]} = 3.06$; partial $\eta^2 = 0.01$; $P = .081$), but there was a significant main effect of time ($F_{[3, 756]} = 40.85$; partial $\eta^2 = 0.14$; $P < .001$) and interaction ($F_{[3, 756]} = 17.22$; partial $\eta^2 = 0.06$; $P < .001$) (Figure 3[B]). No significant difference was observed between the two groups at baseline (day 1); the SCH with ordinary pressure was significantly lower than that with weak pressure in all subsequent measurements, with the mean difference exceeding the SDC $_{\text{group level}}$ (Supplementary Table 1 and 2). During within-group comparisons, only ordinary pressure showed significantly lower values for all subsequent measurements than at baseline (day 1), with differences above the SDC $_{\text{group level}}$.

5.4.4. Exploratory subgroup analysis

Subgroup analyses were used to examine the heterogeneity of the primary results with and without dry skin (Supplementary Table 3). The TEWL with weak pressure did not increase regardless of dry skin. However, the TEWL of the ordinary with dry skin group increased more rapidly than that of the ordinary without dry skin group, and this trend was observed on both days (WP × time × dry skin: $F_{[3, 750]} = 3.72$; partial $\eta^2 = 0.01$; $P = .011$) (Figure 4[A]). Although there was no significant three-factor interaction for SCH, dry skin had a significant main effect ($F_{[1, 250]} = 26.95$; partial $\eta^2 = 0.10$; $P < .001$ (Figure 4[B]). The SCH of the ordinary with dry skin group was the lowest after 2 days.

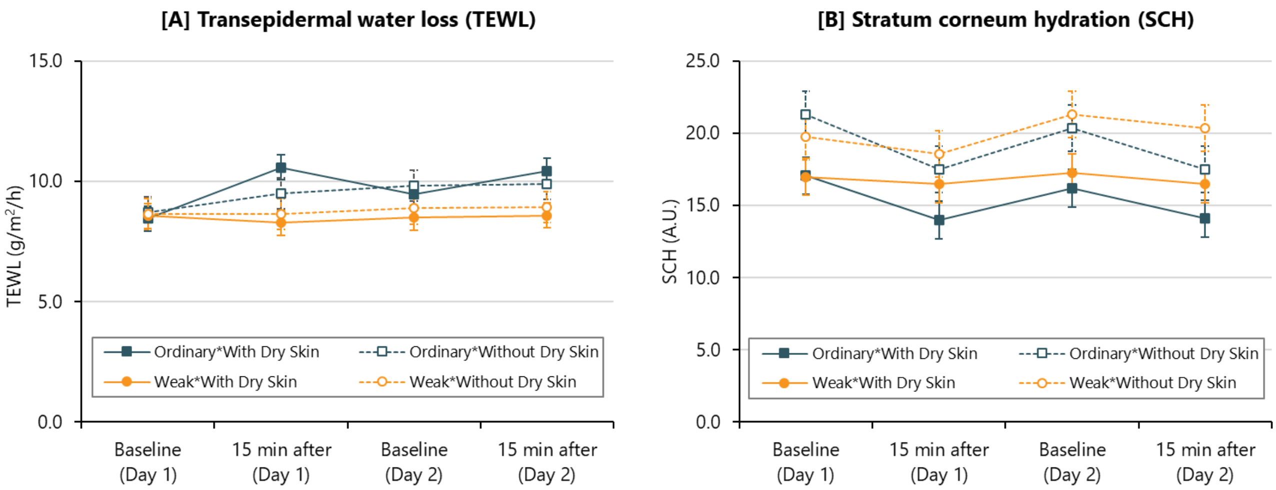

Figure 4. Comparisons of the effects of weak and ordinary pressure on skin barrier recovery according to dry skin (n = 127)

Notes: Circles and squares, least square means as estimated by the mixed model; error bar, 95% confidence interval; Ordinary, bed bathing with 20–30 mmHg; Weak, bed bathing with 10–20 mmHg.

5.5. Discussion

This study evaluated the effects of consecutive bed bathing with weak pressure compared with ordinary pressure on skin barrier recovery among older patients. The time courses of TEWL and SCH for 2 days significantly differed between the two groups, and the results supported our hypothesis. Considering skin barrier recovery over multiple days [16,17], our results suggest that consecutive bed bathing with weak pressure is safe for older patients.

In line with the results of a previous study, ordinary pressure on day 1 significantly reduced the skin barrier function in older patients compared with weak pressure [15]. Notably, the differences in TEWL and SCH between the groups persisted until day 2. Within-group comparisons showed that the skin barrier with weak pressure did not change from that at baseline, whereas that impaired by ordinary pressure did not recover until day 2. A previous laboratory study indicated that increased TEWL values attributable to mechanical friction remained high from days 2 to 6 [34]. Moreover, some components of natural moisturizing factors in the SC were altered for 3 days [34]. These results support the findings of the present study. Friction irritation caused by ordinary pressure distorts keratinocytes in the SC [35], leading to delayed skin barrier recovery among older adults [18]. This mechanism is responsible for the observed increase in TEWL and decrease in SCH during our study.

Disruption of the skin barrier results in dry skin, pruritus, cutaneous infections, inflammatory dermatoses, and possible systemic inflammation [36–38]. Moreover, consecutive bed bathing with ordinary pressure may chronically decrease the skin barrier function and increase the risk of skin tears [39] and pressure ulcers [6]. Because these severe skin lesions interfere with patient recovery, thereby leading to prolonged hospitalization and reduced quality of life [39,40], the importance of skin-friendly daily care is apparent. Conversely, weak pressure that does not adversely affect the skin barrier even after consecutive applications can contribute to skin integrity. Given that weak pressure is not inferior to ordinary pressure in terms of cleanliness and comfort [12,15], our findings provide novel evidence supporting its effectiveness.

Subgroup analyses suggested that weak pressure had no adverse effects on TEWL, regardless of skin dryness. In contrast, ordinary pressure was associated with an increased risk of TEWL, particularly for patients with dry skin. Baseline TEWL values among the four groups were similar (Figure 4[A]), and the TEWL of patients with dry skin appeared normal. However, there were differences in responsiveness for 2 days after bed baths (indicating a significant three-factor interaction), which are supported by the results of previous studies [17–19]. Dry skin refers to chronic barrier dysfunction with inadequate moisture retention in the SC [30,41,42]. The high reactivity of TEWL to ordinary pressure could be explained by the consistently low SCH of patients with dry skin over the course of consecutive days (Figure 4[B]). These results highlight the importance of assessing dry skin during bed baths. Furthermore, weak pressure can be recommended for patients at high risk for skin barrier dysfunction with dryness.

5.5.1. Relevance to clinical practice

Daily skin care is a fundamental aspect of nursing practice, and improving skin integrity is an overarching goal [14]. Skin care guidelines recommend cleaning the patients' skin once daily [43]. This study revealed that bed bathing with weak pressure for consecutive days did not adversely affect the skin barrier, even among patients with vulnerable dry skin. The clinical validity of the experimental tape-stripping method and sodium lauryl sulphate exposure, which are used as conventional interventions to assess skin barrier recovery, has been criticized [17]. However, the WP validated by this study was defined based on the clinical practice of nurses [12,13]; therefore, the results of the present study are clinically relevant. Given the high prevalence of dry skin among older adults in nursing settings worldwide (30–90%) [5], bed bathing with weak pressure can be widely used by nurses and caregivers as a low-irritation skin care practice [14].

5.5.2. Study limitations

First, measurement bias may have occurred because the interventionist and outcome assessors were the same, and the researcher knew the allocation immediately before the interventions. This was unavoidable because of the skill required to perform the measurement technique and the limited access of the investigators to the hospital. Second, the subgroup analyses did not examine factors (e.g., diseases and medications) related to skin barrier dysfunction other than dry skin. Because many factors are associated with barrier dysfunction, examining all of them during a single study is difficult. Further studies are needed to analyze other factors. This study used a within-person RCT design to avoid imbalances between interventions for patient-level variables, which may be potential confounding factors. Third, although the sample size was adequate, this study was conducted at a single hospital in Japan. Skin barrier function differs according to race [44]; therefore, multicenter, international studies are required to expand the generalizability of our findings.

5.6. Conclusions

This study revealed that ordinary pressure applied for 2 consecutive days impaired skin barrier recovery compared with weak pressure. An increase in TEWL and decrease in SCH caused by ordinary pressure on the first day did not recover to baseline values the next day, whereas weak pressure presented no adverse effects. Even when considering skin barrier recovery over multiple days, our results suggest the safety of weak pressure and highlight the importance of WP during bed baths. Subgroup analyses showed that weak pressure was applicable for patients with dry skin. Thus, our findings can contribute to the development of safe and high-quality daily skin care for older adults.

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Supplementary Table 1. Reliability and agreement among skin barrier measurements at a hospital

	Baseline 1 mean (SD)	Baseline 2 mean (SD)	ICC (95%CI)	SEM	SDC $_{individual\ level}$	SDC $_{group\ level}$
TEWL [a] (g/m ^{2} /h, data on day 1: n = 149)						
Instrument: VapoMeter SWL5001						
Ordinary	8.5 (2.2)	8.7 (2.1)	0.89 (0.85-0.92)	0.72	1.99	0.16
Weak	8.5 (2.2)	8.5 (2.3)	0.86 (0.81-0.89)	0.86	2.39	0.20
SCH [b] (A.U., data on day 1: n = 149)						
Instrument: MoistureMeter SC Compact						
Ordinary	18.3 (6.4)	19.0 (6.9)	0.95 (0.94-0.97)	1.35	3.76	0.31
Weak	17.9 (5.7)	18.2 (6.0)	0.96 (0.95-0.97)	1.14	3.15	0.26

Notes: CI, confidence interval; SCH, stratum corneum hydration; SD, Standard deviation; TEWL, transepidermal water loss.
[a], each measurement of TEWL was performed for approximately 10 seconds; [b], each measurement of SCH was performed three times, and the average value was used.

Based on previous studies [26,27], we calculated ICC, SEM, and SDC.
ICC, intraclass correlation coefficients for intra-rater reliability
SDC, smallest detectable change
SDC $_{individual\ level} = 1.96 \times \sqrt{2} \times SEM$
SDC $_{group\ level}$ = SDC $_{individual\ level} / \sqrt{n}$
SEM, standard error of measurement

Supplementary Table 2. Details of statistical information in Figure 3

	T1		T2		T3		T4		Dunnett test								
	Baseline (Day 1)		15 min after (Day 1)		Baseline (Day 2)		15 min after (Day 2)		T1-T2			T1-T3			T1-T4		
	M	95%CI	M	95%CI	M	95%CI	M	95%CI	MD	95%CI	*P*	MD	95%CI	*P*	MD	95%CI	*P*
TEWL ($g/m^2/h$)																	
Ordinary	8.5	8.1, 8.9	10.1	9.7, 10.6	9.6	9.2, 10.0	10.2	9.8, 10.6	1.60	1.15, 2.06	<.001	1.05	0.60, 1.51	<.001	1.67	1.22, 2.13	<.001
Weak	8.6	8.2, 9.0	8.4	8.0, 8.8	8.6	8.2, 9.0	8.7	8.3, 9.1	0.16	−0.62, 0.29	.733	0.06	−0.40, 0.51	.981	0.13	−0.33, 0.58	.845
MD	0.04	−0.22, 0.29	1.73	1.23, 2.23	0.96	0.73, 1.17	1.51	1.13, 1.88									
t-value	0.29		6.88		8.67		7.99										
Cohen's *dz*	0.03		0.61		0.77		0.71										
Correlation	0.78		0.48		0.84		0.68										
P-value [a]	.773		<.001		<.001		<.001										
SCH (A.U.)																	
Ordinary	18.7	17.7, 19.8	15.4	14.3, 16.4	17.8	16.8, 18.9	15.4	14.4, 16.5	3.34	2.55, 4.13	<.001	0.88	0.09, 1.68	.024	3.28	2.49, 4.07	<.001
Weak	18.1	17.0, 19.1	17.3	16.2, 18.3	18.8	17.8, 19.9	18.0	16.9, 19.0	0.77	−0.02, 1.56	.057	0.77	−0.02, 1.56	.058	0.07	−0.72, 0.86	.993
MD	0.64	−1.51, 0.22	1.92	1.03, 2.82	1.01	0.11, 1.91	2.57	1.71, 3.43									
t-value	1.47		4.27		2.23		5.91										
Cohen's *dz*	0.13		0.38		0.20		0.52										
Correlation	0.70		0.60		0.68		0.66										
P-value [a]	.143		<.001		.028		<.001										

Notes: CI, confidence interval; M, mean; MD, mean difference; SCH, stratum corneum hydration; TEWL, transepidermal water loss; a, paired t-test.
Smallest detectable change (SDC) $_{\text{group level}}$ of TEWL = 0.16–0.20 $g/m^2/h$, SDC $_{\text{group level}}$ of SCH = 0.26–0.31 A.U.

Supplementary Table 3. Details of statistical information in Figure 4

Analysis of variance results	*F*-value (df)	Partial η^2-value	*P*-value
TEWL			
Main effect of WP	16.16 (1, 250)	0.06	<.001
Main effect of time	14.53 (3, 750)	0.05	<.001
Main effect of dry skin	0.01 (1, 250)	0.00	.927
Interaction between WP and time	13.39 (3, 750)	0.05	<.001
Interaction between WP and dry skin	1.24 (1, 250)	0.00	.267
Interaction between dry skin and time	2.55 (3, 750)	0.01	.055
Interaction between WP, time, and dry skin	3.72 (3, 750)	0.01	.011
SCH			
Main effect of WP	2.87 (1, 250)	0.01	.092
Main effect of time	42.42 (3, 750)	0.15	<.001
Main effect of dry skin	26.95 (1, 250)	0.10	<.001
Interaction between WP and time	18.09 (3, 750)	0.07	<.001
Interaction between WP and dry skin	0.22 (1, 250)	0.00	.638
Interaction between dry skin and time	2.42 (3, 750)	0.01	.065
Interaction between WP, time, and dry skin	1.88 (3, 750)	0.01	.132

Notes: SCH, stratum corneum hydration; TEWL, transepidermal water loss; WP, wiping pressure.

Chapter 6

A dynamic nomogram to predict skin barrier dysfunction during bed baths in hospitalized older adults: A prospective study

6.1. Abstract

Background

Poor bed bath methods (e.g. excessive wiping) cause skin barrier dysfunction in older patients, thereby inducing various skin disorders. Nurses should appropriately predict the risk of skin barrier dysfunction to practice high-quality bed baths considering the patient's skin and comfort. However, no clinical tools exist to assess this risk, inhibiting the selection of patient-specific care. This study aimed to develop a nomogram for predicting skin barrier dysfunction during bed baths in hospitalized older adults.

Methods

This prospective observational study was conducted at a hospital in northern Japan between September 2022 and March 2023. The volar forearms of 150 older patients underwent a wiping friction test with reliability and validity. Transepidermal water loss was assessed before and 15 min after the test. Skin barrier dysfunction was defined based on a cut-off value. Candidate variables were obtained from medical records and skin assessments. A nomogram was constructed using multivariate logistic regression analysis. The model's performance was internally validated using 1000-bootstrap resampling and evaluated for discrimination, calibration, and clinical usefulness.

Results

Of the 149 patients included in the analysis, 26.2% developed skin barrier dysfunction. Predictors included chronic kidney disease, purpura, dry skin, activities of daily living, and body mass index. C-statistics before and after bootstrapping were 0.800 and 0.760, respectively, indicating good discrimination. The Hosmer–Lemeshow test and calibration plot showed adequate calibration. Decision curve analysis suggested the model's clinical utility. Finally, we developed a dynamic nomogram that can be accessed online

(https://konya2023.shinyapps.io/launch/).

Conclusions

A dynamic nomogram to predict skin barrier dysfunction caused by bed baths showed satisfactory internal validity. The novel nomogram is simple and user-friendly because of five easily available predictors. Thus, this nomogram can assist nurses in selecting tailored bed bath methods to prevent skin disorders and incorporate patient preferences, enhancing the quality of skin care for older adults in clinical settings. Additional external validations are required in multicenter settings with different patients, magnitudes, and countries.

6.2. Background

In a super-aged society, skin health and care are core nursing topics [1]. Aging is associated with chronic diseases, functional disabilities, and care dependency, and the skin is greatly affected [2]. The skin barrier in stratum corneum has a vital physiological function, preventing water loss and foreign substance penetration [3]. When skin barrier function is damaged in older adults, the recovery process is protracted and may not be fully reversible [4]. This impairment is linked to various skin disorders, including dry skin, infections, inflammation, pressure ulcers, and skin tears [2, 3]. Therefore, daily skin care to prevent skin barrier dysfunction is vital for older patients; however, there is a lack of high-quality evidence regarding skin assessments and interventions [5].

Bed baths are a fundamental skin care method that involves the mild friction-induced removal of dirt by wiping with wet towels. This practice is often performed on patients with high-level dependence and requires appropriate wiping skills and skin assessments by nurses [6]. One reason for this is the association between wiping pressure and the risk of skin damage. Excessive wiping during bed baths can result in skin barrier dysfunction and skin tears [7, 8]. Bed bathing with ordinary pressure (20–30 mmHg), which nurses routinely practice, decreased skin barrier function in older patients compared with weak pressure (10–20 mmHg) [6]. Furthermore, weak pressure has been supported for ensuring skin cleanliness and comfort [7]. Thus, this method is an effective low-irritation practice that maintains skin integrity [5].

Although skin integrity is crucial, practices disregarding patient preferences and requests can hinder comfort enhancement, which is one of the primary objectives of skin care [9]. Nurses should integrate patient preferences into shared decision-making concerning bed bath methods [10], as these practices lead to patient-centered care [11]. We hypothesized that screening patients at high risk of skin barrier dysfunction before bed baths could assist nurses in prioritizing the maintenance of skin integrity and meeting patient preferences, further guiding the selection of patient-specific care. Thus, it is essential to identify risk factors for skin barrier dysfunction.

A previous study reported that chronic kidney disease and diabetes are risk factors for skin barrier dysfunction during bed baths in older patients [6]. In addition, skin conditions [12] and nutritional status [13] are potential risk factors. However, a recent umbrella review of skin assessments and interventions for maintaining skin integrity emphasized the urgent need to identify risk factors for skin conditions [5]. Despite the importance of clinical assessment, the skin barrier dysfunction is often underestimated; therefore, creating a user-friendly, precise risk-screening tool has become imperative.

A nomogram is a graphical representation of a prediction model that generates individual numerical probabilities of a clinical event by integrating diverse variables. This tool facilitates clinical decision-making and enables personalized care [14]. If a nomogram for predicting skin barrier dysfunction caused by bed baths is developed, nurses can precisely select skin-friendly care for high-risk patients. For low-risk patients, nurses can avoid unnecessary care and prioritize patient preferences. Therefore, this study aimed to develop a nomogram to predict skin barrier dysfunction during bed baths in hospitalized older adults.

6.3. Methods

6.3.1. Study design, setting, and participants

We used part of a randomized controlled trial (RCT) dataset. This RCT compared the effects of two consecutive days of bed bathing with ordinary (control group) and weak (intervention group) pressure on skin barrier recovery in older patients [chapter 5]. In the current study, data before the intervention on the first day for the control group were used. RCTs are a special subset of prospective observational studies that can be used to develop predictive models [15]. This study was conducted at a public core hospital in a secondary medical care area in northern Japan between 26 September 2022 and 29 March 2023. Our predictive modelling study was categorized as Type 1b, in which the entire dataset was used for model development, and internal validation was performed using a resampling technique [15]. Before recruitment, this study was registered in the University Hospital Medical Information Network (UMIN) (registration number: UMIN000048838, date: 05/09/2022). Furthermore, this study followed the Transparent Reporting of a multivariable prediction model for the Individual Prognosis Or Diagnosis (TRIPOD) statement [15].

The inclusion criteria were Japanese patients aged ≥65 years with the ability to communicate daily. The exclusion criteria were patients 1) with excessive sweating to the degree that the skin became moist; 2) who had skin conditions requiring further dermatological treatment; 3) who had a fever of 37.5°C or higher or severe pain; and 4) with paralysis, peripheral venous catheter, or hemodialysis shunt to both forearms.

6.3.2. Wiping friction test

The approach to predicting outcomes induced by standardized intervention tests followed that used in a previous study for predicting outcomes induced by exercise tests [16]. The wiping friction test involved bed bathing with ordinary pressure (wiping three times at 20–30 mmHg) [6, 7]. This practice reflects the wiping pressure and number of wipes that nurses routinely use during bed baths and is assumed to reflect frictional irritation caused by skin care, including bed baths in clinical settings [6, 7]. A well-trained researcher wiped from the periphery to the central area using a controlled towel (100% cotton; size, 35 × 34 cm; weight, 38 g; temperature, 45°C). The intraclass correlation coefficient assessing the intra-rater reliability of wiping pressure was 0.86 (95% confidence interval [CI]: 0.82–0.89), indicating high reliability. The mean (standard deviation [SD]) wiping pressure applied to all participants was 24.0 (3.2) mmHg, which was a valid test.

6.3.3. Outcomes

Transepidermal water loss (TEWL: $g/m^2/h$) is one of the most reliable parameters for assessing skin barrier function and is widely used in clinical studies [3]. This parameter is the gold standard for skin barrier function, which indicates the flux density of water through the stratum corneum, with a high value indicating decreased skin barrier function [17]. Skin barrier dysfunction was defined by focusing on the "amount of change in TEWL" caused by the wiping friction test. This is because TEWL has more clinical relevance in terms of the amount of change within individuals than in terms of absolute values [18]. A well-trained researcher assessed TEWL on the volar forearm using a VapoMeter SWL5001 (Delfin Technologies Ltd., Kuopio, Finland) before and 15 min after the wiping test. Although blinded assessments were impossible in this study, the evaluator received adequate training to mitigate bias according to international guidelines [17] to minimize the influence of related factors. The participants were controlled to ensure they did not receive any other skin care on the day of data collection. The condition of the measurement environment (mean [SD]) was a room temperature of 25.6 (1.0) °C and a humidity of 29.8 (9.5) %, which did not affect sweating.

The volar forearm was selected because it is less affected by body hair and photoaging, allowing the most stable measurements [19], and therefore, is the site commonly measured in skin research [18]. The forearm is the most common area where skin tears occur [20], with 56.4% occurring on the forearm in Japan [21]. We judged that this vulnerable site was most suitable for risk prediction in terms of not underestimating the safety of the entire body.

The smallest detectable change was used as the cut-off value for TEWL (1.99 $g/m^2/h$). The value represents the real change beyond the measurement error calculated by measuring the baseline twice [22], which is comparable to that in a previous study [6]. Patients with a change in TEWL greater than the cut-off value were classified as experiencing skin barrier dysfunction. The clinical significance of skin barrier dysfunction 15 min after bed bathing with ordinary pressure is supported by several previous studies. The elevated TEWL of older adults after friction, heat, and moisture stimulation by bed baths usually returns to baseline after 15 min [23]. However, the elevated TEWL of older patients who received ordinary pressure did not recover to baseline after 15 min [6]; furthermore, this skin barrier dysfunction did not recover even on the next day [chapter 5]. Therefore, skin barrier dysfunction, as defined in this study, is an important predictive outcome for preventive skin care.

6.3.4. Candidate predictors

Candidate predictors were selected based on previous studies [6, 12, 13]. Variables that were routinely accessible to nurses in various clinical settings were selected. Before the wiping test and outcome assessment, the following data were extracted from electronic medical records:

- **Demographic characteristics**: Age, sex, and hospitalization days were recorded.
- **Functional characteristics**: Activities of daily living (ADL) were assessed using the Barthel Index [24]. The scale is used by various medical workers worldwide, with a maximal score of 100 indicating independence in ADL. We recorded validated data assessed at admission or regularly by a physical therapist at the facility.
- **Medical histories**: Diabetes mellitus, dyslipidemia, chronic kidney disease, hemodialysis, stroke, heart disease, cancer, skin tears, and pressure ulcers were recorded. We selected medical history rather than illness as the reason for hospitalization as the predictor. This was because many participants had missing or unknown values in the latter information. This selection is reasonable because ambiguous definitions of predictors are undesirable in the clinical prediction model [25].
- **Medications**: Steroids, anticoagulants, antiplatelets, diuretics, insulin, and polypharmacy were recorded. Polypharmacy is defined as the daily intake of five or more medications containing different pharmaceutical agents [2].

- **Nutritional status**: Body mass index (BMI: kg/m^2) was recorded. Patients were categorized as underweight (BMI < 18.5), normal weight (18.5 ≤ BMI < 25.0), or overweight (BMI ≥ 25.0) [26].
- **Skin condition**: A trained nursing researcher directly evaluated the skin conditions of the forearm, including dry skin, edema, purpura, pigmentation, and pruritus. Dry skin was assessed using the Japanese version of the overall dry skin score [27] and was defined as a score of ≥1 [28].

6.3.5. Sample size

The sample size was calculated using an interactive tool to develop a clinical prediction model (https://mvansmeden.shinyapps.io/BeyondEPV/). This tool does not rely on empirical rules for the sample size of binary outcomes [29] and has often been used in recent prediction studies. Based on a similar outcome proportion of 0.48 [6], an error rate of 0.10, and five predictor variables, the minimum sample size was 140 (13.8 events per variable). Ideally, the number of predictors in the final model is 5–10 because larger models are less practical [25]; we assumed five variables would be included in the final model.

6.3.6. Statistical analysis

We used JMP® 17 Pro (SAS Institute Inc., Cary, NC, USA) and R version 4.3.1 (R Foundation, Vienna, Austria) at a significance level of 5%. Continuous variables and categorical variables are presented as medians (interquartile ranges) and frequencies (%), respectively. Multiple imputations by chained equations were performed because the BMI had three missing data points at random. This method effectively and validly handles missing data and minimizes selection bias caused by excluding such patients [15]. We used the R package "mice" to create and integrate 20 datasets based on final predictors.

Predictor selection

The final predictor selection was guided by subject knowledge and a preliminary analysis of the distribution of candidate predictors [15,25]. A four-step process was used to select the final model from the candidate variables.

1. **Selection based on a systematic review**

   We conducted a systematic review to identify the risk factors for skin barrier dysfunction in older adults [chapter 2]. Based on the review findings, the following candidate variables were obtained in this study: sex, ADL, BMI, diuretic use, and presence of chronic kidney disease, diabetes mellitus, dry skin, purpura, and pruritus. In particular, presence of chronic kidney disease and dry skin were regarded as essential factors.

2. **Preliminary analysis for the distribution of candidate predictors**

   After confirming the data distribution and analyzing the bivariate associations with events for all candidate variables, the following candidate variables were regarded as appropriate for data distributions and were significantly related to the outcome: ADL, steroid use, and presence of chronic kidney disease, heart disease, dry skin, edema, and purpura.

3. **Exploratory final model evaluation**

   Among the above variables, sex, diuretic use, and presence of diabetes and pruritus were excluded because of lack of predictive performance. Subsequently, the combination with the highest goodness of fit based on the Akaike information criterion was analyzed (Supplementary Table 1 and 2), The five-factor model was optimal, except for the presence of heart disease and edema and steroid use.

4. **Validation by an expert opinion**

   The process was rigorously discussed by an expert team comprising a statistician, a dermatologist, and nursing researchers until a consensus was reached. The final five-factor model was considered clinically relevant and practical.

Development of nomogram and evaluation of model performance

We conducted a multivariate logistic regression analysis using the final predictors to create a nomogram for predicting skin barrier dysfunction during bed baths. We used the "shiny" and "DynNom" packages to develop a web-based dynamic nomogram. The model performance was evaluated using discrimination, calibration, and clinical usefulness. For internal validation to correct this optimism, we employed 1000 bootstrap resampling. Discrimination was assessed using the c-statistic, equivalent to the area under the receiver operating characteristic curve (AUC). An AUC value ≥ 0.7 indicated good discriminative performance [25]. Calibration involved drawing a calibration plot to evaluate the degree of agreement between the observed outcomes and the predicted probabilities, and the Hosmer-Lemeshow test was performed. Clinical utility was evaluated using decision curve analysis (DCA), illustrating the threshold probability on the x-axis and net benefit on the y-axis. A higher net benefit model is preferable for various threshold probabilities (preferences) [30]. We employed several R packages, including "rms", "boot", "dcurves", "tidyverse", and "ggplot2", for the assessment of model performance.

6.3.7. Ethical considerations

Nursing managers conducted patient enrolment based on the eligibility criteria. All enrolled patients received written and oral communications from the researcher detailing the purpose of the study. They were informed about their right to decline participation without any negative consequences and assured that their anonymity and confidentiality would be maintained throughout the study. Written informed consent for study participation and publication was obtained from willing patients. This study was conducted following the Declaration of Helsinki after approval by the Ethical Review Committee of the Faculty of Health Sciences, Hokkaido University (approval no. 22–46).

6.4. Results

6.4.1. Participant characteristics

A total of 164 patients were initially assessed for eligibility; 14 declined to participate, and one was excluded due to sweating during the wiping friction test. Consequently, the final analysis included 149 patients, 26.2% (n = 39) of whom developed skin barrier dysfunction during bed baths. Table 1 presents the demographic and clinical characteristics of patients at baseline. The median age, hospitalization days, ADL, and BMI were 84 (range: 65–99) years, 9 (2–1695) days, 55 (0–100) points, and 21.9 (13.3–46.9) kg/m^2, respectively. Only five patients were independent in ADLs, and nearly 90% of the patients required partial to full assistance.

Table 1. Baseline characteristics and univariate analyses of study populations

Characteristics	Total (n = 149)	Skin barrier dysfunction (n=39)	Non-skin barrier dysfunction (n=110)	Statistics	*P*-value
Age [years]	84 (77–88)	84 (81–88)	83 (76–88)	1.29	.200 [a]
ADL (BI) [point]	55 (25–75)	50 (10–65)	55 (35–75)	−2.66	.008 [b]
Hospitalization days [days]	9 (5–20)	11 (5–22)	9 (5–19)	0.56	.574 [b]
BMI [kg/m^2] *	21.9 (19.7–24.2)	21.8 (19.2–26.5)	21.9 (20.0–23.7)	0.41	.679 [b]
Underweight	25 (17.1%)	8 (20.5%)	17 (15.9%)		
Normal weight	93 (63.7%)	20 (51.3%)	73 (68.2%)	3.91	.142 [c]
Overweight	28 (19.2%)	11 (28.2%)	17 (15.9%)		
Sex					
Female	85 (57.0%)	22 (56.4%)	63 (57.3%)	0.01	.926 [c]
Male	64 (43.0%)	17 (43.6%)	47 (42.7%)		
Diabetes mellitus					
Yes	100 (67.1%)	28 (71.8%)	72 (65.5%)	0.52	.469 [c]
No	49 (32.9%)	11 (28.2%)	38 (34.5%)		
Dyslipidemia					
Yes	41 (27.5%)	15 (38.5%)	26 (23.6%)	3.17	.075 [c]
No	108 (72.5%)	24 (61.5%)	84 (76.4%)		
CKD					
Yes	40 (26.8%)	20 (51.3%)	20 (18.2%)	16.06	<.001 [c]
No	109 (73.2%)	19 (48.7%)	90 (81.8%)		
Hemodialysis					
Yes	10 (6.7%)	4 (10.3%)	6 (5.5%)	1.06	.303 [c]
No	139 (93.3%)	35 (89.7%)	104 (94.5%)		
Stroke					
Yes	36 (24.2%)	8 (20.5%)	28 (25.5%)	0.38	.536 [c]
No	113 (75.8%)	31 (79.5%)	82 (74.5%)		
Heart disease					
Yes	71 (47.7%)	24 (61.5%)	47 (42.7%)	4.08	.043 [c]
No	78 (52.3%)	15 (38.5%)	63 (57.3%)		
Cancer					
Yes	22 (14.8%)	5 (12.8%)	17 (15.5%)	0.16	.690 [c]
No	127 (85.2%)	34 (87.2%)	93 (84.5%)		
Steroid					
Yes	14 (9.4%)	7 (17.9%)	7 (6.4%)	4.54	.003 [c]
No	135 (90.6%)	32 (82.1%)	103 (93.6%)		
Anticoagulant					
Yes	12 (8.1%)	4 (10.3%)	8 (7.3%)	0.35	.556 [c]
No	137 (91.9%)	35 (89.7%)	102 (92.7%)		
Antiplatelet					
Yes	16 (10.7%)	6 (15.4%)	10 (9.1%)	1.19	.275 [c]
No	133 (89.3%)	33 (84.6%)	100 (90.9%)		
Diuretic					
Yes	40 (26.8%)	13 (33.3%)	27 (24.5%)	1.13	.287 [c]
No	109 (73.2%)	26 (66.7%)	83 (75.5%)		
Insulin					
Yes	10 (6.7%)	4 (10.3%)	6 (5.5%)	1.06	.303 [c]
No	139 (93.3%)	35 (89.7%)	104 (94.5%)		
Polypharmacy					
Yes	76 (51.0%)	25 (64.1%)	51 (46.4%)	3.63	.057 [c]
No	73 (49.0%)	14 (35.9%)	59 (53.6%)		

Characteristics	Total (n = 149)	Skin barrier dysfunction (n=39)	Non-skin barrier dysfunction (n=110)	Statistics	*P*-value
History of skin tear					
Yes	7 (4.7%)	3 (7.7%)	4 (3.6%)	1.06	.304 [c]
No	142 (95.3%)	36 (92.3%)	106 (96.4%)		
History of pressure ulcer					
Yes	11 (7.4%)	2 (5.1%)	9 (8.2%)	0.39	.531 [c]
No	138 (92.6%)	37 (94.9%)	101 (91.8%)		
Dry skin (ODS≥1)					
Yes	89 (59.7%)	32 (82.1%)	57 (51.8%)	10.94	<.001 [c]
No	60 (40.3%)	7 (17.9%)	53 (48.2%)		
Edema					
Yes	19 (12.8%)	9 (23.1%)	10 (9.1%)	5.06	.025 [c]
No	130 (87.2%)	30 (76.9%)	100 (90.9%)		
Purpura					
Yes	41 (27.5%)	19 (48.7%)	22 (20.0%)	11.91	<.001 [c]
No	108 (72.5%)	20 (51.3%)	88 (80.0%)		
Pigmentation					
Yes	21 (14.1%)	9 (23.1%)	12 (10.9%)	3.52	.061 [c]
No	128 (85.9%)	30 (76.9%)	98 (89.1%)		
Pruritus					
Yes	35 (23.5%)	12 (30.8%)	23 (20.9%)	1.56	.212 [c]
No	114 (76.5%)	27 (69.2%)	87 (79.1%)		

Notes: ADL (BI), activities of daily living (Barthel index); BMI, body mass index; CKD, chronic kidney disease; ODS, overall dry skin score; Skin barrier dysfunction, participants with a change in transepidermal water loss greater than the cut-off were classified as the skin barrier dysfunction group; a, Student's t-test (*t*-statistics); b, Mann–Whitney U test (*z*-statistics); c, Pearson's chi-squared test (χ^2-statistics). * Missing data, n = 3.

6.4.2. Development of nomogram

Multivariate logistic regression analysis included five predictors, indicating an overall predictive performance (Brier score = 0.152). The final selected predictors were chronic kidney disease, purpura, dry skin, ADL, and BMI; the detailed results are shown in Table 2. Based on these results, we developed a nomogram to predict skin barrier dysfunction during bed baths in older patients (Figure 1). Moreover, we created a web-based dynamic nomogram that can be conveniently accessed at https://konya2023.shinyapps.io/launch (Figure 2).

Table 2. Predictors of skin barrier dysfunction during bed baths by multivariate logistic regression analysis

Variables	*B*	SE	Wald	*P*-value	OR	OR (95% CI) Lower	Upper
CKD	1.21	0.46	6.81	.009	3.34	1.35	8.36
Purpura	0.98	0.46	4.41	.036	2.66	1.06	6.66
Dry skin	0.75	0.51	2.16	.142	2.12	0.80	6.06
BMI: Underweight [a]	0.68	0.57	1.42	.233	1.97	0.63	5.99
BMI: Overweight [b]	1.13	0.54	4.45	.035	3.11	1.08	9.07
ADL	-0.02	0.01	3.65	.056	0.98	0.97	1.00
Intercept	-1.94	0.64	9.12	.003	-	-	-

Notes: ADL, activities of daily living (Barthel index); *B*, regression coefficient; BMI, body mass index; CI, confidence interval; CKD, chronic kidney disease; OR, odds ratio; SE, standard error; a, BMI < 18.5 kg/m^2 (ref: normal weight), b, BMI ≥ 25.0 kg/m^2 (ref: normal weight).

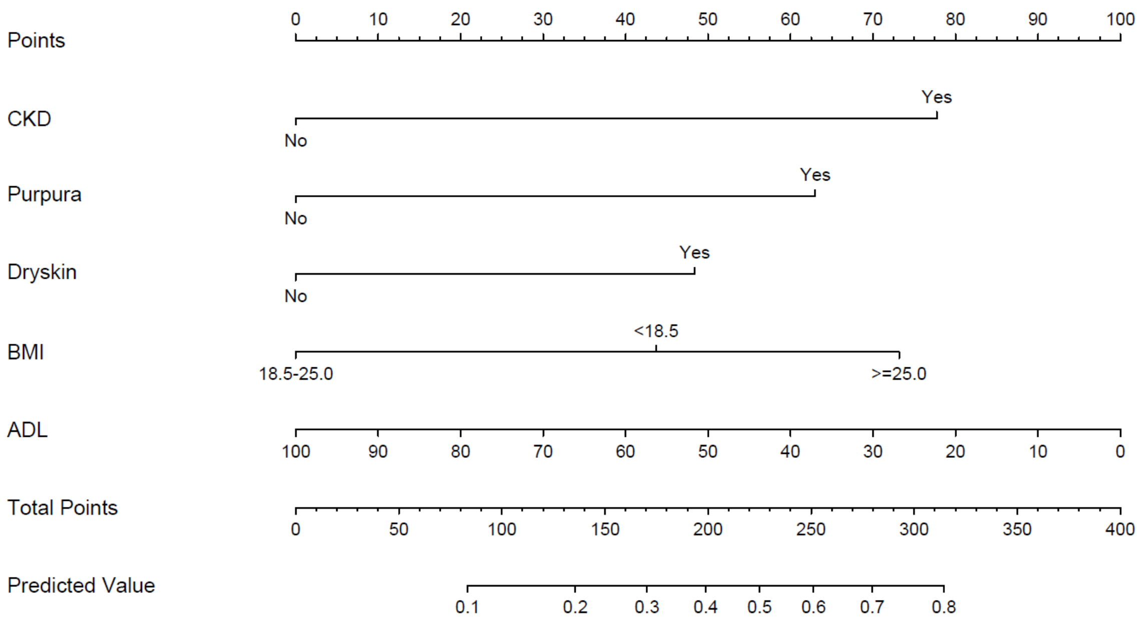

Figure 1. A nomogram predicting skin barrier dysfunction during bed baths

Notes: ADL, activities of daily living (Barthel index); BMI, body mass index; CKD, chronic kidney disease. The user draws a vertical line upward from each variable to the "Points" bar. The sum of the points is transformed into a "Predicted Value" by drawing a vertical line downward from the "Total Points" bar.

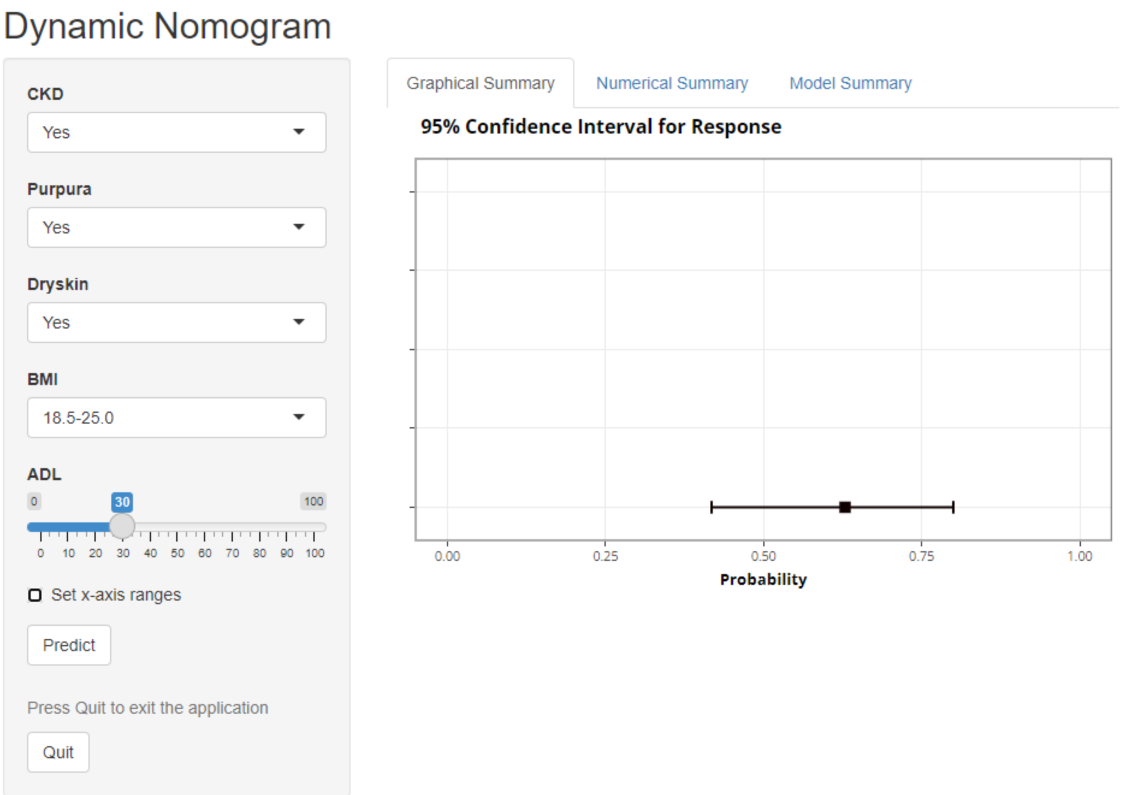

Figure 2. A dynamic nomogram predicting skin barrier dysfunction during bed baths

Notes: Predicted values can be conveniently calculated online at https://konya2023.shinyapps.io/launch/. For example, the predicted value for one patient (CKD = yes, Purpura = yes, Dry skin = yes, ADL = 30 points, and BMI = 22.0) was 0.63.

6.4.3. Model performance: discrimination

The AUCs before and after bootstrapping were 0.800 (95% CI: 0.725–0.876) and 0.760 (95% CI: 0.689–0.839). The Youden index was 0.468, and the corresponding cut-off value was 0.155. The sensitivity and specificity of the model were 0.923 and 0.545, respectively. The model showed good discrimination even after optimism was corrected.

6.4.4. Model performance: calibration

The calibration plot corrected by bootstrapping (Figure 3) showed good agreement between the observed and predicted probabilities (Hosmer-Lemeshow test, $P = .230$). The calibration slope was 0.812, with an acceptable slope. The calibration plots tended to slightly underestimate risk with anticipated probability in the 20% range.

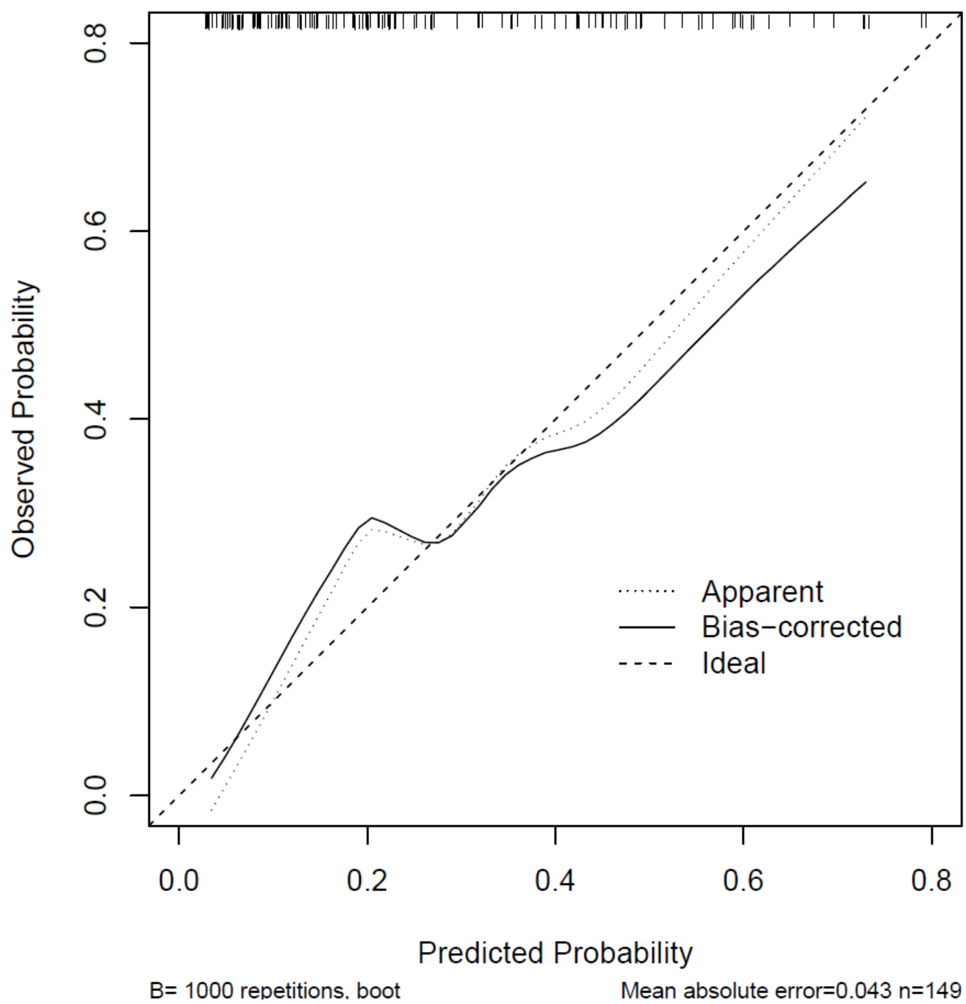

Figure 3. Calibration plot for nomogram predicting skin barrier dysfunction during bed baths

Notes: The calibration plot presents the relationship between the predicted risk (x-axis) and the observed proportion of the actual outcome (y-axis). A perfect prediction coincides with the 45-degree line (slope = 1).

6.4.5. Model performance: clinical usefulness

The DCA showed that the nomogram has a higher net benefit than default strategies of "treat all" or "treat none" for reasonable threshold probability (Figure 4). The nomogram has potential clinical utility across a wide range of threshold probabilities, ranging from 5% to 75%.

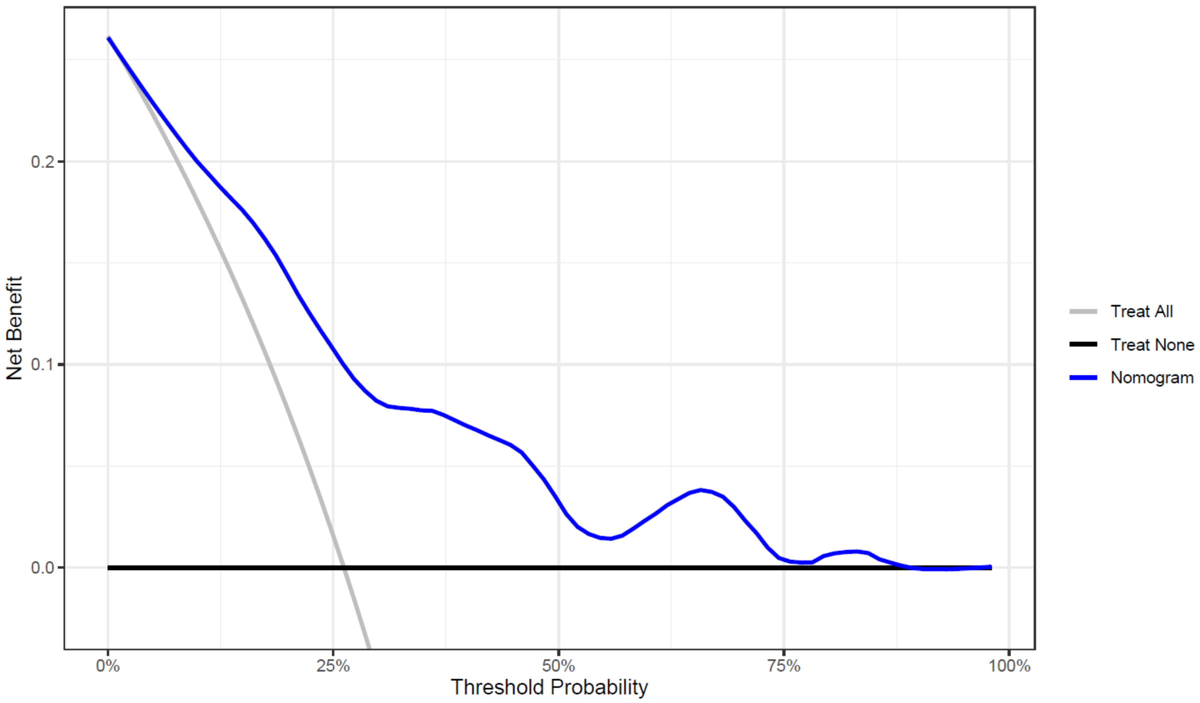

Figure 4. Decision curve analysis for nomogram predicting skin barrier dysfunction during bed baths

Notes: The threshold probability on the x-axis shows the relative weight of the benefit of a true positive and the harm of a false positive (odds ratio of harm to benefit). The threshold probability differs among patients and clinical settings. For example, in the case of a threshold probability of 10% (odds ratio 1:9), "missing skin barrier dysfunction by bed baths is weighted nine times worse than unnecessary intervention." With a threshold probability of 20% (odds ratio 1:4), "missing skin barrier dysfunction by bed baths is weighted as four times worse than unnecessary intervention." The net benefit on the y-axis shows the proportion of true-positive patients receiving net benefits after weighing the harms and benefits.

6.5. Discussion

6.5.1. Predictors for skin barrier dysfunction during bed baths in older patients

Nurses should adequately assess the risk of skin barrier dysfunction before selecting bed bath methods incorporating patient preferences. Our study revealed that 26.2% of older patients experienced skin barrier dysfunction due to ordinary pressure, with 73.8% experiencing only minor effects within the measurement error. This finding highlights the importance of using a risk-stratified approach for selecting optimal bed bath techniques for patients who have different risks. Hence, we developed a nomogram to predict skin barrier dysfunction during bed baths in older patients. A nomogram consisting of chronic kidney disease, purpura, dryness, BMI, and ADL showed good discrimination, calibration, and clinical usefulness.

Interestingly, the nomogram indicated the need for a systemic assessment encompassing disease, skin health, physical function, and nutritional status. The association between chronic kidney disease and skin barrier dysfunction is widely known [31]. Chronic kidney disease has been reported as a risk factor for skin barrier dysfunction due to bed bathing [6], consistent with our findings. Although the complete pathological mechanism remains unclear, possible causes of the vulnerability of the skin barrier caused by chronic kidney disease include metabolic imbalances, endocrine disorders, and peripheral neuropathy [31].

Senile purpura are purpuric macules on the extremities involving decreased vessels and dermal thickness, which are related to skin fragility in older adults [32]. Dry skin pertains to persistent barrier dysfunction characterized by insufficient moisture retention within the stratum corneum [28]. These two skin symptoms predict skin tears in the forearms of older Japanese patients [32], supporting our results.

Our findings indicate that maintaining an appropriate BMI is essential for maintaining skin integrity in bed baths. Obesity is linked to elevated TEWL and delayed barrier recovery, increasing the risk of skin diseases and impaired wound healing [33]. Being underweight is associated with dry skin and reduced elasticity [19]. Although there was no correlation between BMI and skin barrier function in earlier studies [13], these results support our finding of a non-linear relationship between BMI and skin barrier function.

Previous studies detected no difference in TEWL in the forearm between bedridden and healthy older adults [34]. They reported no connection between care dependency and skin barrier function [28]. However, Aisen et al [35] showed that bedridden older patients had lower skin hydration levels than healthy older adults. Furthermore, low ADL predicts dry skin [36], skin tears, and pressure ulcers [2]. Our findings seem reasonable, as aging is associated with low ADL and skin barrier dysfunction.

6.5.2. Prediction model for the risk of skin barrier dysfunction during bed baths

The new predictive model consisted of logically selected predictors based on literature review, data distribution, and expert opinion. This process was particularly appropriate for studies with relatively small sample sizes, resulting in model stability and less overfitting [25].

Our nomogram showed good discriminative ability, with an AUC of 0.800 and an optimism-corrected AUC of 0.760. The model had a higher sensitivity (92.3 %) than a specificity (54.5%). Given that high sensitivity over specificity is desired in safety management [37], this result is consistent with the envisioned use of nomograms. Calibration plots tended to slightly underestimate risk with anticipated probability in the

20% range, but the degree would not greatly affect clinical judgment [38]. The Hosmer–Lemeshow test showed good agreement between the predicted risk and observed proportion of the actual outcome. Discriminative ability is the primary requirement in model performances when the objective is to identify "high-risk" cohorts [25]. Overall, this nomogram suggests good internal validity. DCA showed a higher net benefit of our nomogram than the default strategies in a spectrum of practical thresholds ranging from 5% to 75%, indicating its clinical utility. "Treat" refers to diverse interventions, including additional or specialized care [30]. In our context, skin care prioritizes skin integrity through weak pressure application or moisturizer use. Our nomogram may assist nurses in assessing patients' need to receive such skin care and improving clinical outcomes according to various preferences influenced by discussions between nurses and patients.

6.5.3. Limitations

This study has several limitations. First, the nomogram could not be applied to patients with skin diseases because they were excluded. However, most skin care studies exclude patients with skin diseases, such as atopic diseases. This is because these patients require special treatment. Moreover, our study is inherently limited by its finite generalizability because of the small sample size at a single hospital in Japan. Ethnic and regional differences can influence skin barrier function [39]. Therefore, external validation studies are needed in multicenter settings with different patient demographics, magnitudes, and countries.

6.5.4. Clinical implications

The new nomogram provides nurses and caregivers with predictive value for the risk of skin barrier dysfunction in bed baths. This information provides objective evidence of "skin vulnerability" to assist in the skin assessment of users and allow risk stratification of older patients. Given that even the risk factors useful for skin assessment in skin care are unclear [5], this nomogram can potentially trigger innovations in skin care, including bed baths.

Based on the risk stratification of skin vulnerability, users can select appropriate care considering the prioritization of the three primary objectives of skin care (skin integrity, skin cleanliness, and comfort enhancement). As a precondition, bed bathing with weak pressure is recommended for older patients based on accumulated evidence [6]. For high-risk patients, users can plan care that pays particular attention to skin vulnerability, not only in terms of wiping pressure but also the type and frequency of skin care and the products used. It would be desirable to prioritize evidence-based, “low-irritating” skin care [5,40] and add comfort care such as a hot towel [23]. Low-risk patients can receive standard care that prioritizes the maximum patient preferences and requests.

Owing to the current healthcare systems and staff shortages, there is concern that the value of fundamental care, including skin care, can be overlooked [11]. Our nomogram-based risk stratification of skin vulnerability could lead to optimization of the effort required for care while preserving the quality of skin care. Low-risk patients require less effort for skin care than high-risk patients. Therefore, nurses can focus on other nursing care. This may motivate busy nurses to recognize the importance of skin assessment in skin care. In addition, the predicted risk values calculated by the nomogram provide a basis for care that can be shared by nurses and patients, allowing informed consent for skin care. For patients with independent ADL, the nomogram could also be used for skin self-care. Skin self-care education may also be useful for high-risk patients. Therefore, the nomogram is beneficial to both nurses and patients. To expand usability, we developed an interactive nomogram (https://konya2023.shinyapps.io/launch/), which can be conveniently accessed in clinical settings. Further improvements based on feedback from users in the clinical field will enable tailored skin care with higher quality.

6.6. Conclusions

Using data prospectively collected from Japanese patients aged 65 years or more at a public hospital, we developed a dynamic nomogram to predict skin barrier dysfunction during bed baths. The five predictors were chronic kidney disease, purpura, dry skin, BMI, and ADL, all readily accessible to nurses and caregivers. The nomogram demonstrated satisfactory discrimination, calibration, and clinical usefulness. The novel nomogram can facilitate nurses' selection of tailored bed bath methods to prevent skin disorders and incorporate patient preferences. The results of this study could guide the development of strategies to enhance the quality of skin care for a growing number of older adults. Additional external validations are required in multicenter settings with different patients, magnitudes, and countries.

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Supplementary Table 1. Exploratory model evaluation included the current model and variables that were significant in the univariate analysis

Model	AIC	AUC
Model 1	**151.569**	**0.800**
Model 1 + heart disease	153.934	0.801
Model 1 + steroid use	153.412	0.802
Model 1 + edema	151.715	0.802
Model 1 + heart disease + steroid use	155.668	0.803
Model 1 + heart disease + edema	153.788	0.801
Model 1 + edema + steroid use	153.720	0.802
Model 1 + heart disease + steroid use + edema	155.978	0.802

Model 1, Final model, including chronic kidney disease, purpura, dry skin, activities of daily living, and body mass index.
AIC, Akaike Information Criterion; AUC (c-statistic), area under the receiver operating characteristic curve.

Supplementary Table 2. Exploratory model evaluation for exploring the influence of body mass index

Model	AIC	AUC
Model 2	152.251	0.772
Model 2 + heart disease	154.350	0.774
Model 2 + steroid use	153.682	0.774
Model 2 + edema	151.769	0.776
Model 2 + heart disease + steroid use	155.827	0.776
Model 2 + heart disease + edema	153.804	0.780
Model 2 + edema + steroid use	153.737	0.776
Model 2 + heart disease + steroid use + edema	155.820	0.778

Model 2, exploratory model, after excluding body mass index from the final model.
AIC, Akaike Information Criterion; AUC (c-statistic), area under the receiver operating characteristic curve.

Chapter 7

Conclusions

7.1. Conclusions

This dissertation aimed to verify the effectiveness of weak wiping pressure during bed baths and develop a prediction model for skin barrier dysfunction in hospitalized older adults. In conclusion, four main findings were demonstrated: 1) using disposable towels during bed baths, nurses do not need to excessively wipe but can adequately remove dirt by wiping three times under weak pressure (10–20 mmHg), regardless of the towel material; 2) impaired skin barrier function in older patients caused by ordinary pressure on the first day did not recover to baseline values the next day, whereas weak pressure presented no adverse effects, suggesting the safety of weak pressure; 3) the ODS-J showed good reliability and validity and can be used by Japanese clinical nurses and caregivers for dry skin assessment; and 4) the dynamic nomogram to predict skin barrier dysfunction during bed baths in older patients, consisting of five predictors (chronic kidney disease, purpura, dry skin, ADL, and BMI), showed good discrimination, calibration, and clinical usefulness. These findings can guide the development of safe and effective bed bath care for older patients in the clinical setting. As a precondition, bed bathing with weak pressure is recommended for older patients based on accumulated evidence. The novel nomogram can facilitate nurses' selection of tailored skin care methods to prevent skin disorders and incorporate patient preferences. For high-risk patients, users can plan care that pays particular attention to skin vulnerability, not only in terms of wiping pressure but also the type and frequency of skin care and the products used. Low-risk patients can receive standard care that prioritizes the maximum patient preferences and requests. Further research is expected to program these findings and implement them in clinical settings and through fundamental nursing education.

7.2. Implications for clinical practice

Bed bathing with weak pressure is recommended for older patients based on accumulated evidence. This method would be considered an "optimal wiping pressure" because it sufficiently removes skin dirt regardless of the towel material, does not cause discomfort, and maintains the skin barrier function, even if conducted on consecutive days.

Nurses and caregivers can quickly assess the risk of skin barrier dysfunction in older patients using a dynamic nomogram before bed bathing. The presence or absence of chronic kidney disease, ADL, and BMI can be ascertained early during hospitalization, and purpura is easily assessed visually. In addition, the ODS-J is useful in dry skin assessment. For high-risk patients, users can plan care that pays particular attention to skin vulnerability, not only in terms of wiping pressure but also the type and frequency of skin care and the products used. It would be desirable to prioritize evidence-based, "low-irritating" skin care and add comfort care such as a hot towel. Low-risk patients can receive standard care that prioritizes the maximum patient preferences and requests.

Therefore, tailored bed baths according to the skin assessment using the prediction model may improve the quality of bed bath care for a growing number of older patients and residents. Our results would serve as guidelines for developing safe and effective skin care, and future implementation research in clinical practice is desirable.

7.3. Implications for future research

Further research is required to implement the results of this study in the clinical setting. First, external validation of the dynamic nomogram is required in multicenter settings including larger sample sizes, different patients, and countries. Moreover, we need to verify whether bed bath programs using the updated nomogram can lead to the prevention of skin disorders and improved comfort and satisfaction in older patients. Finally, an educational program on optimal wiping pressure should be developed. Specifically, there is a need to develop training equipment for acquiring skills on weak pressure implementation through collaboration between industry and academia, and to introduce the outcome in fundamental nursing education.

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Young Scientists (DC2) and JST, and the Establishment of University Fellowships towards the Creation of Science Technology Innovation (grant number JPMJFS2101).

Special thanks go to my family, particularly my parents, for their positive support in my decision to undertake the doctoral course. Finally, my heartfelt appreciation goes to my wife, who has supported my efforts and dreams since I was an undergraduate.

List of research achievements

- **Full publications**

1. **Konya I**, Nishiya K, Shishido I, Hino M, Watanabe K, Yano R. Minimum wiping pressure and number of wipes that can remove dirt during bed baths using disposable towels: a multi-study approach. BMC Nursing. 2023;22:18. https://doi.org/10.1186/s12912-022-01162-z
2. **Konya I**, Watanabe K, Shishido I, Sugimura N, Matsushita Y, Yamaguchi S, Yano R. Post-Work Recovery from Fatigue and Sleep Episodes among Nurses Who Are Engaged in 16-Hour Night Shifts: A Prospective Observational Study. Healthcare. 2022; 10(6):1089. https://doi.org/10.3390/healthcare10061089
3. **Konya I**, Iwata H, Hayashi M, Akita T, Homma Y, Yoshida H, Yano R. Reliability and validity of the Japanese version of the overall dry skin score in older patients. Skin Research and Technology. 2022; 28(1):28-34. https://doi.org/10.1111/srt.13085
4. **Konya I**, Iwata H, Hayashi M, Akita T, Homma Y, Yoshida H, Yano R. Effectiveness of weak wiping pressure during bed baths in hospitalized older adults: A single-blind randomized crossover trial. Geriatric Nursing. 2021;42(6):1379-1387. https://doi.org/10.1016/j.gerinurse.2021.09.008
5. **Konya I**, Nishiya K, Yano R. Effectiveness of bed bath methods for skin integrity, skin cleanliness and comfort enhancement in adults: A systematic review. Nursing Open. 2021;8(5):2284–2300. https://doi.org/10.1002/nop2.836
6. **Konya I**, Shishido I, Ito YM, Yano R. Combination of minimum wiping pressure and number of wipings that can remove pseudo-skin dirt: A digital image color analysis. Skin Research and Technology. 2020;26(5):639-647. https://doi.org/10.1111/srt.12844
7. **Konya I**, Yamaguchi S, Sugimura N, Matsuno C, Yano R. Effects of differences in wiping pressure applied by nurses during daily bed baths on skin barrier function, cleanliness, and subjective evaluations. Japan Journal of Nursing Science. 2020;17(3):e12316. https://doi.org/10.1111/jjns.12316
8. Shishido I, **Konya I**, Yano R. Effect on autonomic nervous activity of applying hot towels for 10 s to the back during bed baths. Journal of Physiological Anthropology. 2020;39(1):35. https://doi.org:10.1186/s40101-020-00245-7

9. Watanabe K, Sugimura N, Shishido I, **<u>Konya I</u>**, Yamaguchi S, Yano R. Effects of 90 Min Napping on Fatigue and Associated Environmental Factors among Nurses Working Long Night Shifts: A Longitudinal Observational Study. International Journal of Environmental Research and Public Health. 2022; 19(15):9429. https://doi.org/10.3390/ijerph19159429
10. Yamaguchi S, Watanabe K, Sugimura N, Shishido I, **<u>Konya I</u>**, Fujita T, Yoshimitsu Y, Kato S, Ito YM, Yano R. Salivary biomarker profiles and chronic fatigue among nurses working rotation shifts: An exploratory pilot study. Healthcare, 2022;10(8):1416. https://doi.org/10.3390/healthcare10081416
11. 西谷琴音，**<u>紺谷一生</u>**，宍戸穂，杉村直孝，渡部一拓，矢野理香．清拭タオルの面替え操作の有無における汚れの除去率, 皮膚温および主観的評価の比較. 日本看護技術学会誌，2021;20:40-46．https://doi.org/10.18892/jsnas.20.0_40
12. 宍戸穂，杉村直孝，安田佳永，渡部一拓，**<u>紺谷一生</u>**，三浦苑華，矢野理香．背部への清拭時に温タオルを 10 秒間貼用する効果の予備的研究．日本看護技術学会誌，2020;19:54–62．https://doi.org/10.18892/jsnas.19.0_54

- **Unpublished articles** (2/15/2024)

✓ Risk factors of skin barrier dysfunction in older adults: A systematic review
(Chapter 2, *Revision submission*)

✓ Effects of consecutive bed bathing with weak versus ordinary pressure on skin barrier recovery of hospitalized older adults: A within-person randomized controlled trial
(Chapter 5: *Under review*)

✓ A dynamic nomogram to predict skin barrier dysfunction during bed baths in hospitalized older adults: A prospective study
(Chapter 6: *Under review*)

- **International conference presentations**

1. **<u>Konya I</u>**, Yano R. Factors Associated with Skin Barrier Dysfunction during Bed Baths in Hospitalized Older Adults. The 6th FHS International Conference, 2-12, Japan, October 2023. (Poster)
2. **<u>Konya I</u>**, Nishiya K, Shishido I, Hino M, Watanabe K, Yano R. Comparisons of Wiping Pressure and Number of Wipings Between Disposable and Cotton Towels Used by Clinical Nurses: A Cross-Sectional Study. The 7th International Nursing Research Conference of World Academy of Nursing Science, EP6-34, Taipei, Taiwan, October 2022. (Poster)
3. **<u>Konya I</u>**, Watanabe K, Shishido I, Sugimura N, Matsushita Y, Yamaguchi S, Yano R. Post-work Recovery from Fatigue and Sleep Episodes among Nurses Who Are Engaged in 16-hour Night Shifts: A Longitudinal Study. The 25th East Asian Forum of Nursing Scholars, OA-06, Taipei, Taiwan, April 2022. (Oral)
4. **<u>Konya I</u>**, Sugimura N, Matsushita Y, Shishido I, Watanabe K, Yano R. Age-specific characteristics of fatigue and sleep among nurses who work 16-hour night shifts: A prospective study. The 5th FHS International Conference, 1-34, Japan, September 2021. (Poster)
5. **<u>Konya I</u>**, Iwata H, Hayashi M, Akita T, Homma Y, Yoshida H, Yano R. Optimal Wiping Pressure during Bed Baths for Older Patients: A Single-blind Randomized Crossover Study. The 24th East Asian Forum of Nursing Scholars, 245, Philippines, April 2021. (Oral)
6. **<u>Konya I</u>**, Iwata H, Hayashi M, Akita T, Homma Y, Yoshida H, Yano R. Reliability and validity of Japanese version of the overall dry skin score in older patients. The 24th East Asian Forum of Nursing Scholars, 246, Philippines, April 2021. (Poster)
7. **<u>Konya I</u>**, Yano R. Factors related to the effects of different wiping pressure applied by nurses during daily bed baths on skin barrier function and subjective evaluations. The 23rd East Asian Forum of Nursing Scholars, A00569, Thailand. January 2020. (Oral)
8. **<u>Konya I</u>**, Yano R. Relationship between wiping pressure and dirt removal rate among clinical nurses. The 23rd East Asian Forum of Nursing Scholars, A00570, Thailand. January 2020. (Oral)

9. **Konya I**, Yano R. Effects of weak wiping on skin barrier function of subjects with sensitive skin sensation, The 4th FHS International Conference, 1–19, Japan. July 2019. (Poster)
10. **Konya I**, Yamaguchi S, Sugimura N, Kawahata I, Matsuno C, Yano R. Relationship between pressure of bed bath provided by nurses and their experience of skin trouble. The 22rd East Asian Forum of Nursing Scholars, 1B07, Singapore. January 2019. (Poster)
11. Nishiya K, **Konya I**, Shishido I, Yano R. An integrative review of subjective evaluations in hygiene care. The 5th FHS International Conference, 2-13, Japan, September 2021. (Poster)
12. Yamaguchi S, Watanabe K, Sugimura N, Shishido I, **Konya I**, Fujita T, Yoshimitsu Y, Kato S, Ito M. Y, Yano R. The characteristics of longitudinal changes in salivary biomarkers and fatigue of nurses working rotation shifts: An exploratory pilot study. The 5th FHS International Conference, 1-38, Japan, September 2021. (Poster)
13. Watanabe K, Sugimura N, Shishido I, Hiramori Y, **Konya I**, Yamaguchi S, Nishiya K, Hino M, Yano R. What is the indicator of nurses' busyness during night shift? The 5th FHS International Conference, 2-9, Japan, September 2021. (Poster)
14. Nishiya K, **Konya I**, Yano R. An integrative review of comfort in hygienic care. The 24th East Asian Forum of Nursing Scholars, 242, Philippines, April 2021. (Oral)
15. Yamaguchi S, Watanabe K, Sugimura N, Shishido I, **Konya I**, Fujita T, Yoshimitsu Y, Kato S, Yano R. Test-retest reliability of salivary cortisol in nurses working rotation shifts in an acute care hospital. The 24th East Asian Forum of Nursing Scholars, 228, Philippines, April 2021. (Poster)
16. Kagamiyama H, Sugimura N, Shishido I, **Konya I**, Watanabe K, Yano, R. Sleep patterns, work engagements, and mental health statuses of nurses working 16-hour night shifts in Japan. The 24th East Asian Forum of Nursing Scholars, 283, Philippines, April 2021. (Poster)
17. Nishiya K, Arano S, **Konya I**, Sugimura N, Watanabe K, Yano R. Effects of different towel wiping methods on patients' skin surface temperature and subjective evaluations: A crossover study, The 23rd East Asian Forum of Nursing Scholars, A00638, Thailand. January 2020. (Poster)

- **Japanese conference presentations**

1. **紺谷一生**，吉田真由美，渡邊千亜紀，守田明美，矢野理香．連日の弱圧清拭がドライスキンを有する高齢患者の皮膚バリア機能回復に及ぼす影響．第43回日本看護科学学会学術集会，JS3-4，山口，2023年12月（口演）
2. **紺谷一生**，吉田真由美，渡邊千亜紀，守田明美，矢野理香．連日の弱圧清拭と通常圧清拭が高齢患者の皮膚バリア機能回復に及ぼす影響：A within-person randomized controlled trial．日本看護技術学会第21回学術集会，O5-4，熊本，2023年10月（口演）
3. **紺谷一生**，矢野理香．ディスポーザブルタオル清拭における皮膚汚れが除去できる最小限の清拭圧と拭き取り回数. 第42回日本看護科学学会学術集会，O43-6，広島，2022年12月．（口演）
4. **紺谷一生**，西谷琴音，日野真莉絵，渡部一拓，矢野理香．臨床看護師を対象としたタオル素材別の清拭圧調節に関する実態調査：2施設横断研究．日本看護研究学会第48回学術集会，O7-2，愛媛，2022年8月．（口演）
5. **紺谷一生**，西谷琴音，矢野理香．清拭方法に関するエビデンスの現状：システマティックレビュー．第40回日本看護科学学会学術集会，O24-04，東京，2020年12月．（口演）
6. **紺谷一生**，杉村直孝，宍戸穂，渡部一拓，山口真弥，鷲見尚己，鏡山浩美，吉田祐子，矢野理香．看護職のための快適な仮眠環境の構築（第1報）－夜勤後仮眠環境システム使用における疲労軽減効果－．第24回日本看護管理学会学術集会，P28-6，石川，2020年8月．（示説）

7. **紺谷一生**，山口真弥，矢野理香．清拭圧の差異による皮膚バリア機能，清浄度および主観評価への影響. 第 18 回日本看護技術学会学術集会, O-5, 福井, 2019 年 9 月．（口演）

8. 矢野理香，**紺谷一生**，山口真弥，渡部一拓，安田佳永，宍戸穂，出塚望，井部俊子．看護職の夜勤に関わる睡眠・疲労研究の到達点．第 43 回日本看護科学学会学術集会，K-23，山口，2023 年 12 月．（交流集会）

9. 宇高由莉，樋口直，**紺谷一生**，渡部一拓，宍戸穂，矢野理香．背部への温タオル貼用における清拭タオルの枚数別にみた皮膚表面温度の経時的変化. 日本看護技術学会第 19 回学術集会，O-5，愛知，2021 年 10 月．（口演）

10. 樋口直，宇高由莉，**紺谷一生**，宍戸穂，矢野理香．無撚糸温タオルの効果的な背部貼用時間の検討．日本看護技術学会第 19 回学術集会，O-6，愛知，2021 年 10 月．（口演）

11. 杉村直孝，**紺谷一生**，宍戸穂，山口真弥，渡部一拓，吉田祐子，鷲見尚己，鏡山浩美，矢野理香．看護職のための快適な仮眠環境の構築（第 3 報）－夜勤後仮眠環境システム使用における睡眠覚醒と今後の使用のニーズ－．第 24 回日本看護管理学会学術集会，P28-7，石川，2020 年 8 月．（示説）

12. 渡部一拓，杉村直孝，**紺谷一生**，宍戸穂，山口真弥，矢野理香．16 時間夜勤を行う看護師の夜勤中仮眠取得に関連する環境要因．第 24 回日本看護管理学会学術集会，P30-6，石川，2020 年 8 月．（示説）

13. 矢野理香，宍戸穂，杉村直孝，**紺谷一生**，山口真弥，渡部一拓，鏡山浩美，吉田祐子，鷲見尚己．看護職のための快適な仮眠環境の構築（第 2 報）－夜勤後仮眠環境システム使用における睡眠満足度－．第 24 回日本看護管理学

会学術集会，P28-5，石川，2020 年 8 月．（示説）

14. 渡部一拓，山口真弥，杉村直孝，宍戸穂，**紺谷一生**，矢野理香．16 時間夜勤を行う看護師の夜勤中仮眠と疲労感の関連．第 24 回日本看護管理学会学術集会，P30-4，石川，2020 年 8 月．（示説）
15. 山口真弥，**紺谷一生**，矢野理香．経表皮水分蒸散量と角質水分量の再テスト信頼性と変化の臨床的有意性の基準の検討．第 39 回日本看護科学学会学術集会，PC-32-11，石川，2019 年 12 月．（示説）
16. 山口紗希，**紺谷一生**，三浦苑華，山口真弥，矢野理香．清拭方向と皮膚バリア機能，清浄度および主観的評価との関連．第 18 回日本看護技術学会学術集会，O-11，福井，2019 年 9 月．（口演）
17. 三浦苑華，山口紗希，**紺谷一生**，安田佳永，矢野理香．末梢静脈留置針挿入時に効果的に血管怒張を促す温タオルによる前腕温罨法の検討．第 18 回日本看護技術学会学術集会，P-24，福井，2019 年 9 月．（示説）

- **Awards**

1. **若手最優秀演題口頭発表賞**

   第 43 回日本看護科学学会学術集会

   「連日の弱圧清拭がドライスキンを有する高齢患者の皮膚バリア機能回復に及ぼす影響」

   2023 年 12 月 10 日

2. **DATE AWARD (Best Poster Award)**

   The 6th FHS International Conference

   "Factors Associated with Skin Barrier Dysfunction during Bed Baths in Hospitalized Older Adults"

   October 2023

3. **Top Downloaded Article 2021**

   NURSING OPEN

   "Effectiveness of bed bath methods for skin integrity, skin cleanliness and comfort enhancement in adults: A systematic review"

   March 2023

4. **Top Cited Article 2020-2021**

   JAPAN JOURNAL OF NURSING SCIENCE

   "Effects of differences in wiping pressure applied by nurses during daily bed baths on skin barrier function, cleanliness, and subjective evaluations"

   April 2022

5. **Best Oral Presenter Award**

   The 24th East Asian Forum of Nursing Scholars

   "Optimal wiping pressure during bed baths for older patients: A single-blind randomized crossover study"

   April 2021

6. **北海道大学大学院保健科学院長賞**

   2021 年 3 月

7. **北海道大学大学院保健科学院修士課程研究発表賞 (Best Presentation Award)**,

   2021 年 3 月

8. **北海道大学クラーク賞**

   2019 年 3 月

9. **北海道大学医学部保健学科卒業研究優秀賞**

   2019 年 3 月

10. **北海道大学医学部保健学科長賞**

    2018 年 10 月

11. **北海道大学新渡戸賞**

    2016 年 7 月

- **Fundings/Fellowship**

1. **日本学術振興会特別研究員（DC2）**

   Acceptance rate: 18.8% (149/797)

   2022 年 4 月－2024 年 3 月

2. **日本学術振興会科学研究費助成事業特別研究員奨励費（特別枠採択）**

   研究課題名：「糖尿病・慢性腎臓病患者の清潔ケアにおける皮膚バリア機能変動予測モデルの開発」

   Grant number: JP22J11419/JP22KJ0068 (2,300,000 JPY)

   2022 年 4 月－2024 年 3 月

3. **北海道大学アンビシャス博士人材フェローシップ制度（SDGs）**

   Grant number: JPMJFS2101 (400,000 JPY)

   2021 年 4 月－2022 年 3 月

- **Research information**

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