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

Abstract

Aim: Wiping pressure (WP [mmHg]) 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 hospitalised older adults.

Methods: This within-person, randomised, 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 ($10 \leq WP < 20$) and ordinary pressure ($20 \leq WP < 30$) 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 WP during bed baths. Weak pressure is particularly desirable for patients with dry skin.

Trial registration: UMIN000048838

Keywords: Aged; Bed bath; Hygiene; Nursing care; Skin care; Skin barrier function

Abbreviations: ODS, Overall dry skin score; RCT, Randomised controlled trial; SC, Stratum corneum; SCH, Stratum corneum hydration; SDC, Smallest detectable change; TEWL, Transepidermal water loss; WP, Wiping pressure; SD, Standard deviation.

Highlights

- Skin barrier recovery of older adults differs with weak and ordinary pressure use.
- Consecutive bed bathing with weak pressure has no adverse effects on skin barrier.
- Skin barrier impairment due to ordinary pressure did not recover the next day.
- Ordinary pressure especially impaired the skin barrier of patients with dry skin.
- Skin barrier recovery over a few days indicated that weak pressure is safe.

1. Introduction

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 [mmHg]), 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]. Previous studies have defined ordinary pressure ($20 \leq WP < 30$) as WP routinely applied by clinical nurses and weak pressure ($10 \leq WP < 20$) as WP applied for patients with vulnerable skin [12,13,15]. Single bed bathing with ordinary pressure significantly reduced the skin barrier function of older hospitalised adults compared with that with weak pressure [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 normalisation occurs slowly [18,20]. This condition may cause 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 hospitalised older adults. We hypothesised that ordinary pressure for 2 consecutive days would decrease skin barrier function over time compared with weak pressure.

2. Materials and Methods

2.1. Trial design

This single-blind, within-person, randomised, controlled trial (RCT) included participants who received two interventions; each intervention was applied to one of the randomised 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 randomised trials [21]

(Supplementary Table S1) after trial registration on the University hospital Medical Information Network Clinical Trials Registry (UMIN-CTR) (ID: UMIN000048838).

2.2. Participants

This study was conducted from October 2022 to March 2023 (autumn and winter). It involved older adults hospitalised 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 haemodialysis shunt of both forearms; application of moisturiser 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).

2.3. Interventions

This study defined WP (mmHg) as the force applied vertically to skin surfaces during bed baths [13]. Based on this definition, frictional force was approximated as a force proportional to WP. [13]. By controlling for factors other than WP, confounding by other friction-related factors were avoided as much as possible. Figure 1 shows the reliability, validity, and detailed study procedures for interventions.

Two types of bed baths using a cotton towel were sequentially administered to the volar forearm and randomised 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 with 10≤WP<20 (gently stroking the skin surface), and intervention with ordinary pressure was defined as wiping three times with 20≤WP<30 (pressing until the skin surface sank slightly) [15]. To control WP within our definition, the interventionist was trained well in advance. In addition, each WP was monitored using a Palm Q® (portable interface pressure sensor; CAPE Co., Ltd., Yokosuka, Japan).

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. Our study hospital had a fixed day for bathing and bed baths. Follow-up was scheduled to avoid other clinical skin care treatments. Furthermore, all ward staff and participants were asked not to provide or receive any other skin care treatments as much as possible.

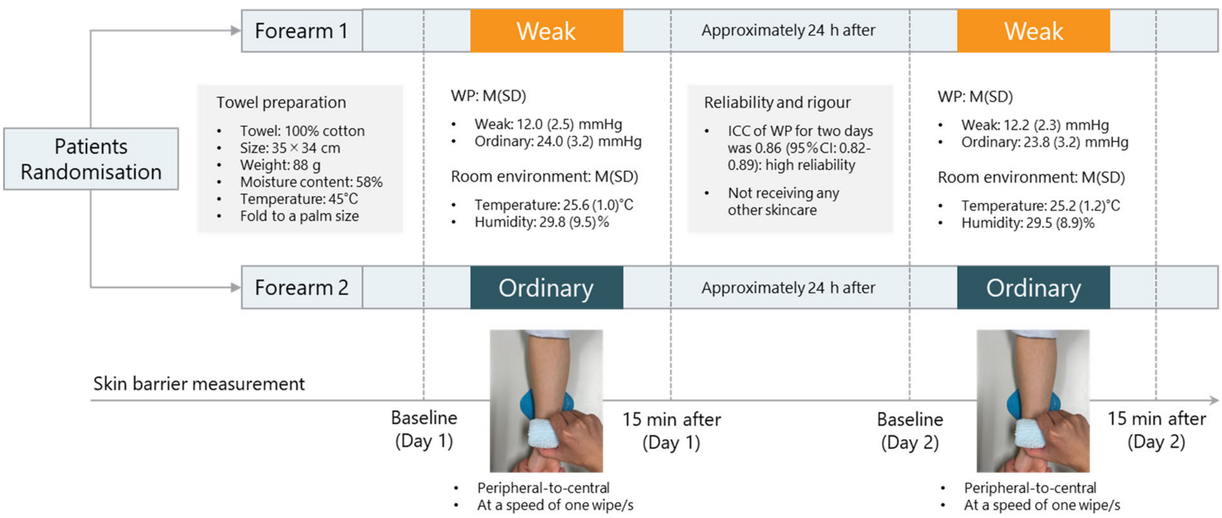

Figure 1. Study procedures

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) of WP during intervention for all patients; Ordinary, bed bathing with 20≤WP<30; Weak, bed bathing with

10≤WP<20; WP, wiping pressure.

2.4. Randomisation

A person without involvement in this study generated the allocation sequence using computer-generated random numbers and then performed simple randomisation (1:1 ratio) of the body sites and interventions. The intervention was conducted by a researcher who was not involved in the randomisation and who was a part-time registered nurse with 3 years of clinical experience specialising 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 randomisation and allocation processes were concealed from the nursing managers who performed patient enrolment and were blinded to the patients.

2.5. Outcomes

2.5.1. 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 minimise influences of related factors (e.g., acclimatisation 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 S2).

2.5.2. 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].

2.5.3. 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, hospitalisation 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].

2.6. 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 characterised 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.

3. Results

3.1. 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 analysed. 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.

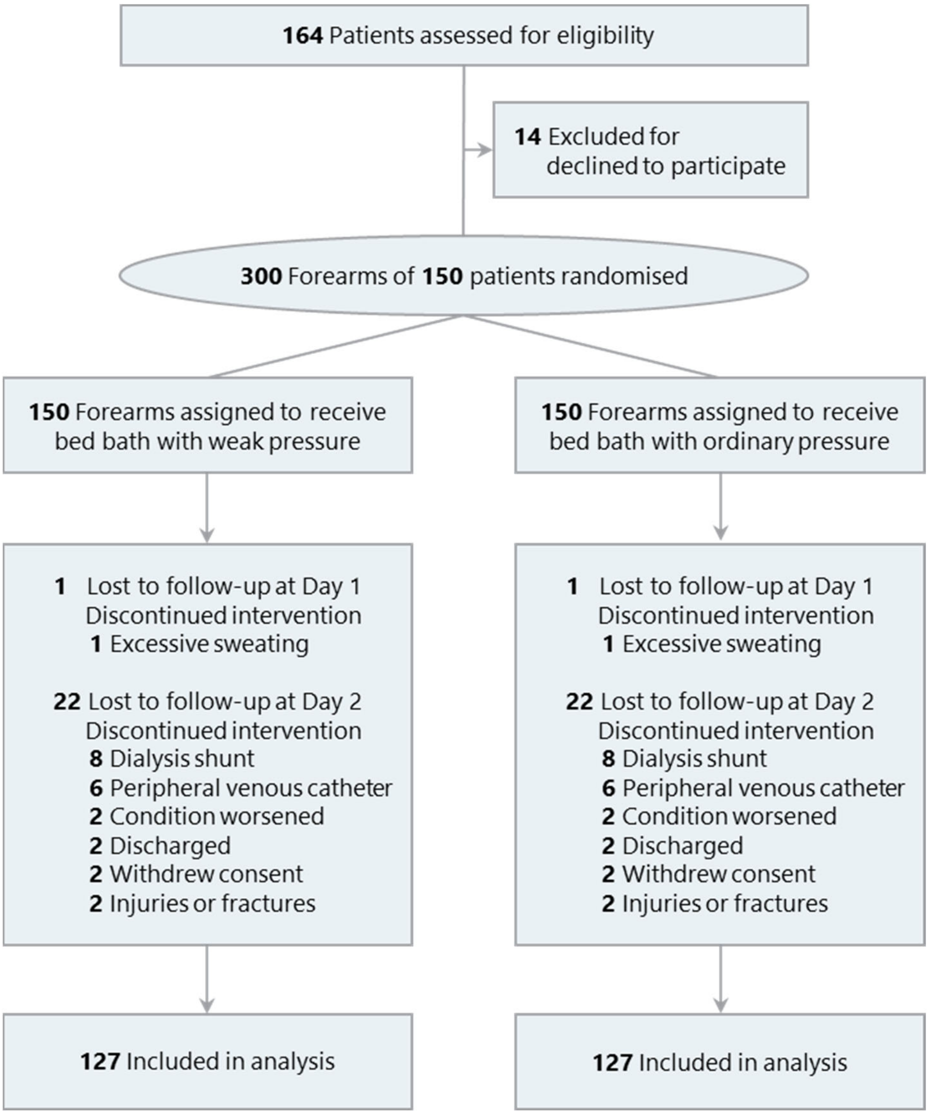

Figure 2. Study flow diagram

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)	
Hospitalisation 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%)	
Dyslipidaemia [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%)

3.2. 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]). The results for the interaction variable indicated that the time courses of TEWL for 2 days significantly differed between the two groups. 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 S2 and S3). 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 $_{\text{group level}}$.

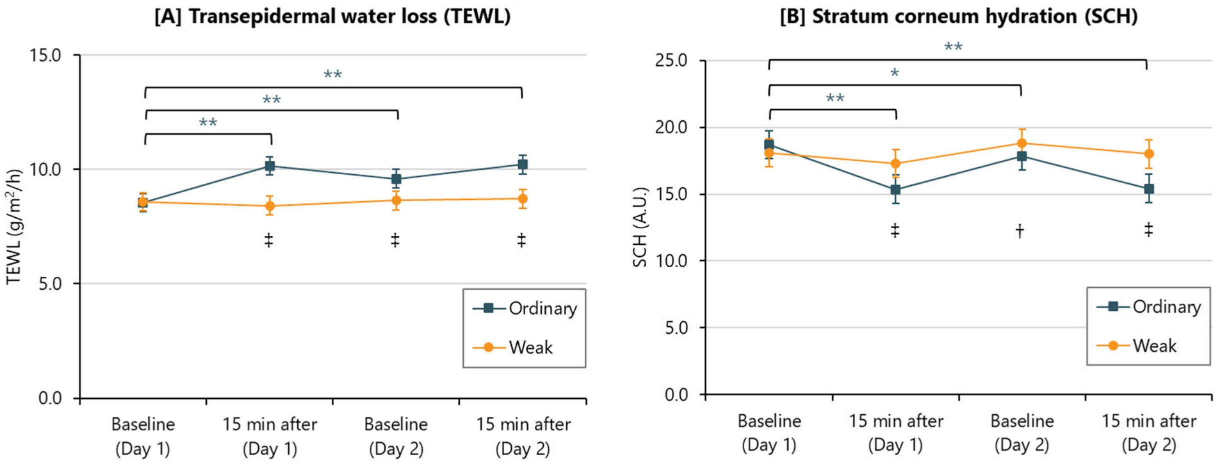

Figure 3. Comparisons of the effects of weak and ordinary pressure on skin barrier recovery (n = 127)

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

3.3. 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]). The results for the interaction variable indicated that the time courses of SCH for 2 days significantly differed between the two groups. 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 S2 and S3). 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 $_{\text{group level}}$.

3.4. Exploratory subgroup analysis

Subgroup analyses were used to examine the heterogeneity of the primary results with and without dry skin (Supplementary Table S4). 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.

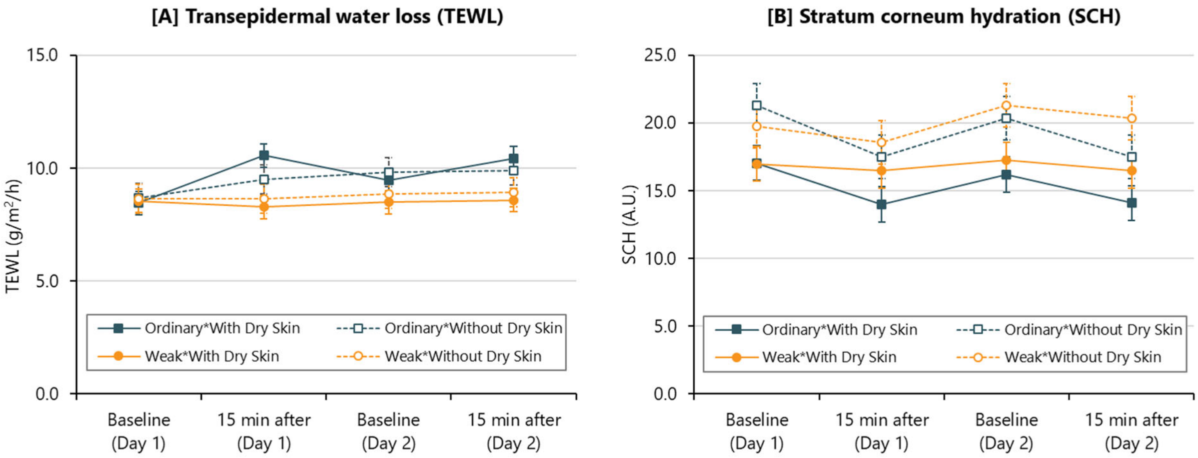

Figure 4. Comparisons of the effects of weak and ordinary pressure on skin barrier recovery according to dry skin (n = 127)

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

4. 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, compared with weak pressure, ordinary pressure on day 1 significantly reduced the skin barrier function in older patients [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 moisturising factors in the SC were altered for 3 days [34]. These results support the findings of the present study. Considering that frictional force was proportional to WP, the frictional force of ordinary pressure was greater than that of weak pressure. Frictional irritation caused by ordinary pressure may have affected traumatic deformation of keratinocytes in the SC [35], leading to delayed skin barrier recovery among older adults [18, 35]. Our findings appear to be well supported by this mechanism.

Disruption of the skin barrier results in dry skin, pruritus, cutaneous infections, inflammatory dermatoses, and possible systemic inflammation [36–38]. Thus, consecutive bed bathing with ordinary pressure may chronically decrease skin barrier function and increase the risk of various skin disorders. 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 [30,39,40]. 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.

4.1. 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 [41]. 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 criticised [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].

4.2. 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 analyse 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 [42]; therefore, multicentre, international studies are required to expand the generalizability of our findings.

5. 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.

Supplementary tables

Table S1. CONSORT checklist for reporting within-person randomised trials

Table S2. Reliability and agreement among skin barrier measurements at a hospital

Table S3. Details of statistical information in Figure 3

Table S4. Details of statistical information in Figure 4

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Declarations of interest

The authors declare no conflict of interest.

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