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The Effects of Complete Bed Baths Using Towels with Different Surface Properties - Comparison of Gauze and Synthetic Towels

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Abstract

Aim: We aimed to compare the effects of complete bed baths using towels with different surface properties (such as gauze/synthetic).

Methods: Nineteen healthy male students who consented were treated with complete bed baths using 2 types of towels on different days, and the effects were evaluated using the following indices: core body temperature, skin temperature, blood pressure, heart rate variability, skin moisture and oil contents, skin surface pH and cleanliness levels, short-version POMS-J, levels of wakefulness and relaxation, and texture rated on a Likert scale.

Results: Both types of towel led to a decrease in the score for 1 subscale of the short-version POMS ($P<0.05$), decrease in the level of wakefulness, and increase in the level of relaxation ($P<0.01$) after the bed bath. Additionally, increases in the core and skin temperatures ($P<0.01$) and a decrease in the heart rate ($P<0.05$) until the final point, decrease in the systolic blood pressure level ($P<0.01$) at 15 minutes after the bed bath, decrease in the oil content ($P<0.01$) until the final point, and a marked decrease in the rate of change in the skin cleanliness level ($P<0.01$) were commonly observed. Thus, the results were almost the same, but the synthetic towels were more positively evaluated in terms of <Favorable texture> ($P<0.05$), and led to a gradual increase in the skin surface pH level ($P<0.01$) until the final point. The pH level showed little change when using the gauze towels.

Conclusion: While the results were almost the same when using the gauze and synthetic towels, the subjective evaluation supported the latter's superiority in texture, and the former lacked subjective comfort.

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Introduction

With the advancement of sophisticated medical technology, new treatments and tests are increasingly being introduced in Japan's medical services, increasing overall workload, and keeping nurses extremely busy. The consequent simplification and labor-saving in care procedures are making it difficult to ensure the quality of care. As a prime example of such a situation, complete bed baths for long-term bedridden or severely ill patients, which is an advanced nursing technique, are performed with only a few steamed cotton towels [1]. Regarding this, our interview survey found patients are also dissatisfied because their hygiene needs are not fulfilled [2], and our national survey involving ward nurses revealed that complete bed baths for patients are performed with only a few steamed cotton towels, and that these nurses have difficulty achieving a sense of accomplishment [1].

On the other hand, there are problems related to infection with cotton towels. Currently, when reusing cotton towels used in medical settings, it is mandatory to perform sterilization treatments, such as high-temperature heating or disinfection with disinfectants, as prescribed by medical law. It has been believed that cotton towels, when processed through appropriate procedures, do not contain a large amount of bacteria that can cause infection, and, therefore, do not increase the risk of infection. However, some previous studies focusing on bed bath materials noted an increased risk of infection by cotton towels reused after cleaning and disinfection [3, 4], while others reported hospital-acquired infection by *Bacillus cereus* growing in towels [5], although these studies only examined the current status. In order to address this issue, we entrusted a specialized institution to culture bacteria growing on reused cotton towels, and obtained a high general bacterial count of 2,360 ± 252 cfu/100 cm^2, which cannot be ignored in terms of infection prevention [6]. The results confirmed that these towels are not safe materials for bed baths, but reused cotton towels continue to be used in nursing practice settings. In Western countries, the effects of bed baths using cotton and single-use synthetic towels were compared from the perspectives of cleanliness, comfort, and cost-effectiveness, and synthetic towels were superior in all aspects [7, 8]. However, these studies simply compared healthcare professionals' impressions of bed bath effects, and the evidence remained poor. The traditional hygiene processes are also a barrier to the establishment of sufficient evidence.

Under these circumstances, we first focused on single-use synthetic towels as materials that replace cotton towels. We compared 3 types of single-use synthetic towels with markedly different surface properties and thickness levels, and found the thin, nonwoven type subjectively and physiologically superior to the others [9]. Subsequently, we conducted experiments to compare the effects of partial bed baths using cotton and synthetic towels [10]. The results supported the advantage of cotton towels in comfort, but their heat-retaining property was unsatisfactory. In contrast, synthetic towels were

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excellent in heat retention, but their flat surface did not create comfortable feelings. Furthermore, when performing complete bed bath using cotton and synthetic towels [11], the former was superior in texture. Both were similarly effective to retain heat, but synthetic towels, due to their nature of not leaking heat compared with cotton towels, exhibited superior heat retention even as time passed. Thus, both types of towel had advantages and disadvantages due to the physical properties of their surfaces, but it was found that the most excellent types of synthetic towel have a similar bed bath effect to cotton towels. However, we could not obtain sufficient evidence regarding appropriate surface unevenness levels for synthetic towels to create comfortable feelings when used as an alternative material to cotton towels in nursing practice settings. Evidence to theorize their moisturizing and cleaning effects also remained insufficient. The results indicated the necessity of continuously examining appropriate materials and surface properties, focusing on surface unevenness, to find synthetic towels that enhance physiological and subjective comfort.

Therefore, as the first step, we compared the effects of complete bed baths using coarse and fine synthetic towels in a simulated clinical setting. Subjective evaluation revealed the superiority of the coarse to fine towels in creating comfortable feelings with a favorable texture when used as a bed bath material. The moisturizing and cleaning effects were similar between the 2 types, but the coarse towels stably retained moisture over time [12]. On the other hand, the sense of comfort was enhanced only temporarily, and it did not last until the final point in either case. Subsequently, we compared complete bed baths using coarse and gauze towels [13]. The results revealed that coarse towels were superior in the moisturizing effect and softness based on the subjective evaluation of texture, but their effect of removing dirt from the skin was poor, provided too little tactile and pressure stimulation, and led to little change in autonomic activity. Gauze towels were not subjectively evaluated as comfortable, but they provided stronger tactile and pressure stimulation, led to favorable changes in autonomic activity, and showed a greater effect of removing dirt from the skin. The results demonstrated that, while both types of towel have advantages and disadvantages due to the physical properties of their surfaces, they are not subjectively and objectively comfortable materials yet. Thus, there is an urgent need to establish evidence regarding appropriate materials and surface properties of towels.

In the present study, we performed complete bed baths using gauze towels [13] and synthetic towels made of embossed non-woven fabric to compare comfort and skin cleanliness between different towel materials and surface properties.

Methods

Study design: This study used a quasi-experimental design in which two types of interventions, complete bed baths using gauze/embossed synthetic towels, were provided at random for the same participants on different days.

Participants and sample size: We initially set the sample size to 15 students in consideration of the burden on participants. Based on the results of a preliminary experiment, we calculated the standard deviation of the difference in heart rate at each point between the gauze and synthetic towels. Conducting a test with the set number of cases, the maximum value of 6.9 as the standard deviation, the significance level set at 0.05, and the power set at 0.8, we obtained a difference of 5.4 in detection and a range of 95% confidence interval of ±3.8 in interval estimation [14]. As for the participants, we eventually included a total of 19 students, excluding 1 with many missing values related to autonomic activity and 1 who withdrew from the experiment, and adding 4 in anticipation of further withdrawals in the following processes. All the participants were healthy, normal build (BMI 21.8 ± 0.2) male students (aged 23.4 ± 3.9) who had no skin wounds or allergies.

Outline and characteristics of the towels

Figure 1 outlines the 2 types of towels used in this study: gauze and synthetic. The gauze towels were made by physically integrating gauze and nonfat cotton without using adhesives (100 meshes/cm^2; Ryugu Co., Ltd.) [12]. In contrast, the synthetic towels were nonwoven fabric-type. They are made of rayon, polyester, and polypropylene fiber materials, cut into small pieces, compressed, and surrounded by the same fiber materials (4 reliefs/cm^2 embossed; Unicharm Corporation).

Preparation of towels for the bed baths

Towel materials: We used 2 types of towel with different surface properties (gauze: 17×26.5 cm and 100 meshes/cm^2; and synthetic: 17×26.5 cm and 4 reliefs/cm^2 embossed), unifying their size, weight, and water content. Thus, we prepared 8 dry towels of both types, and applied a bed bath solution to all towels at the maximum possible volume applicable without dripping even when the towels were grasped (gauze: 240 mL; and synthetic: 280 mL) to make them similarly weigh 310 g. Subsequently, both types of towel were folded to palm size, 9×17 cm. After these processes, the 2 types of towel became equal in their size and weight, and prepared for comparison of bed bath effects based only on the surface properties. The gauze and synthetic towels were stored in a bed bath container at a constant temperature (86.2±3.2°C) to keep the former at 54.7±1.5°C and the latter at 57.9±0.6°C.

Bed bath environment

We prepared 2 beds for the bed baths, and alternately used them to prevent the warmth of the last participant's body from remaining on the bed sheet until the next session. For each participant, we measured the room temperature, humidity, illumination, and noise level, which might influence the measurement data. During each bed bath, a room temperature of 23.7±0.3°C and a humidity of 40.7±0.2% were maintained, with the intensity of illumination at 78.4±5.2 Lux and noise level at 47.7±0.5 dB.

Method of bed bath

To unify the quality of the bed bath, the same practitioner performed the procedure for all participants. The towels were folded to palm size (9×17 cm). The length and force of each wipe was approximately 23 to 25 cm and 0.57±0.04 kgf/cm^2, respectively. The practitionerinitially placed the participants in the left lateral recumbent position,

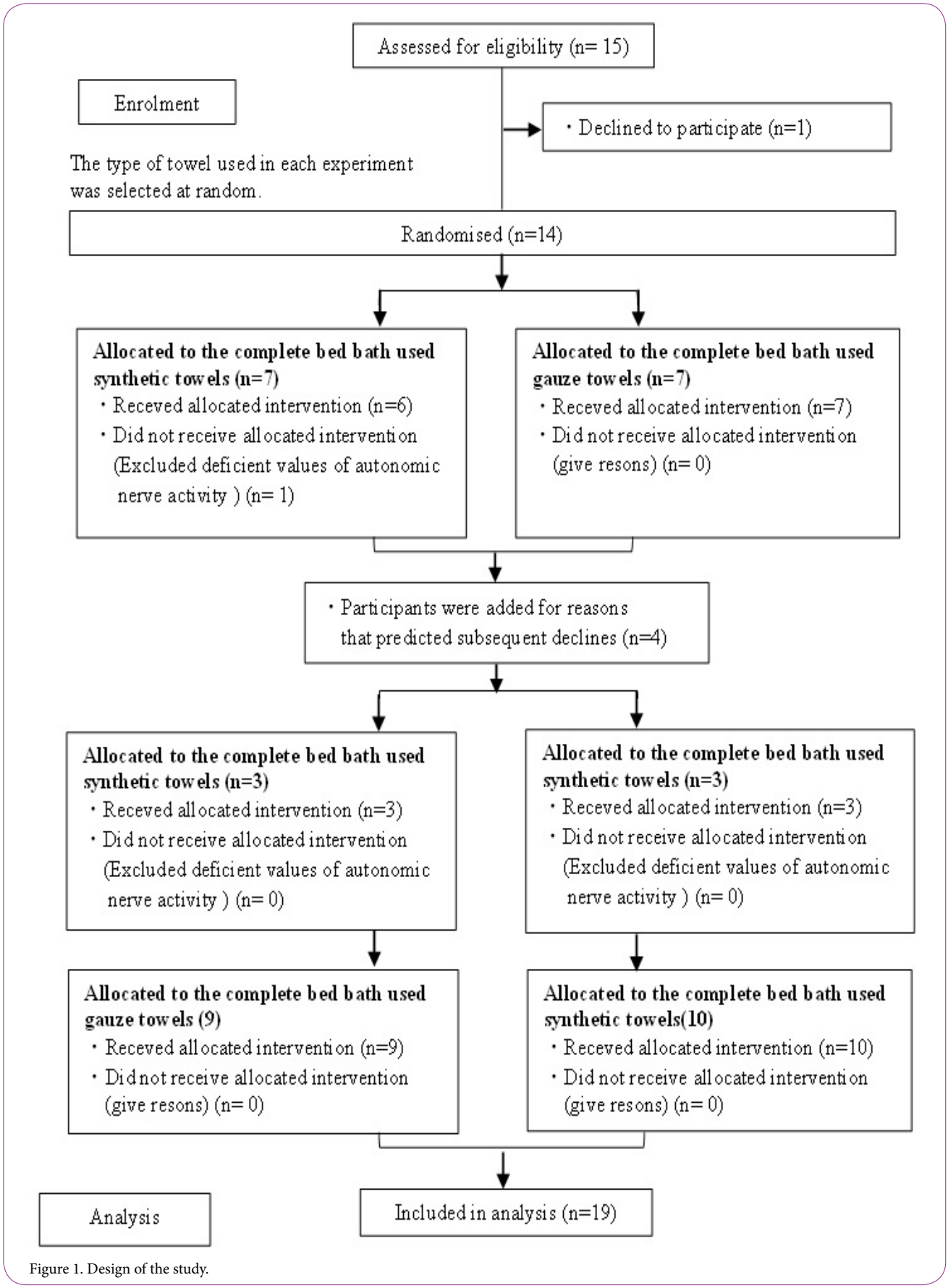


Figure 1. Design of the study.

and applied a hot towel sheet to their back for 30 seconds. After removing that towel, she took a new one, and performed 2 sets of 5 repetitions of upward and downward wipes along the spine from the posterior region of the neck to lower back on the left and right sides. Subsequently, placing the participants in a supine position, she performed 3 repetitions of upward and downward wipes along their both arms, neck, chest, abdomen, and both legs, in this order. This unified bed bath procedure was performed for all participants. Towels were changed whenever shifting the region. The facial, genital, and gluteal areas were excluded in all cases.

Data Collection

Measurement using subjective indices

To subjectively compare the texture and heat-retaining property between gauze and synthetic towels, we used a short Japanese version of the Profile of Mood States (short-version POMS-J) [15] and a visual analogue scale (VAS) [16, 17]. We examined the participants' psychological conditions before and after the bed baths using the former, and their levels of wakefulness and relaxation using the latter. POMS-J, consisting of 6 subscales: <tension-anxiety>, <depression>, <anger-hostility>, <vigor>, <fatigue>, and <confusion>, enabled us to measure rapidly changing moods and emotions before and after the bed baths. There are 30 questions to be answered on a 5-point scale (0-4 points). We used the following formula to standardize the POMS-J scores as T-scores, based on the raw scores for each question: [T-score=50+10×(raw score–mean/standard deviation)]. Similarly, we assessed the levels of wakefulness and relaxation using VAS. One of us presented a 100-mm horizontal line to each participant, with the descriptions of "Definitely no" (0) and "Definitely yes" (100) at the left and the right ends, respectively, traced the line with our finger, and drew a vertical line at the point indicated by the participant. Furthermore, at 30 minutes after the bed bath, we asked the participants about their impressions of the texture of each type of towel. We examined 7 aspects of texture based on the findings of a previous study [7]: <Soft>, <Warm>, <Favorable texture>, <Feeling comfortable when being wiped>, <Feeling refreshed>, <A sense of fitness> (skin contact and thickness), and <Feeling that the body has been cleaned>. Each aspect was rated on a 3-point Likert scale from "Definitely no" (1) to "Definitely yes" (3).

Measurement using objective indices

To objectively compare the effects of bed baths using 2 types of towel with different surface properties, we measured the skin temperature, core temperature, heart rate, skin moisture and oil contents, skin surface pH and cleanliness levels, and blood pressure. For these measurements, we used the following devices: skin temperature: a digital clinical thermometer for continuous measurement Terumo Finer CTM-303 (Terumo Corporation); core temperature: a zero-heat-flow clinical thermometer Coretemp CM-210 (Terumo Corporation); heart rate: an electrocardiogram MemCalc/Tarawa (GMS Co., Ltd.); skin moisture content: Corneometer® CM825 (Courage + Khazaka electronic GmbH); skin oil content: Sebu-meter®SM810 (Courage + Khazaka electronic GmbH); skin surface pH level: Skin pH Meter® PH900 (Courage + Khazaka electronic GmbH); skin cleanliness level: Lumitester PD-30 (Kikkoman Biochemifa Company); and blood pressure: a digital sphygmomanometer HEM-737 Fuzzy (Omron Corporation).

We attached surface probes for skin temperature measurement to 4 regions: the anterior chest (midpoint between both papillae), right forearm (midpoint between the elbow and wrist joints), right fourth finger pulp, and hallux of the left foot. When measuring the core temperature, we covered the probe (Core Temperature Probe PD1, Terumo Corporation) with a piece of gauze folded in four to avoid direct contact between the sensor and skin, and attached it to the point right under the navel with tape with a width of 2.5 cm. We performed electrocardiography, adopting the 3-lead methods.

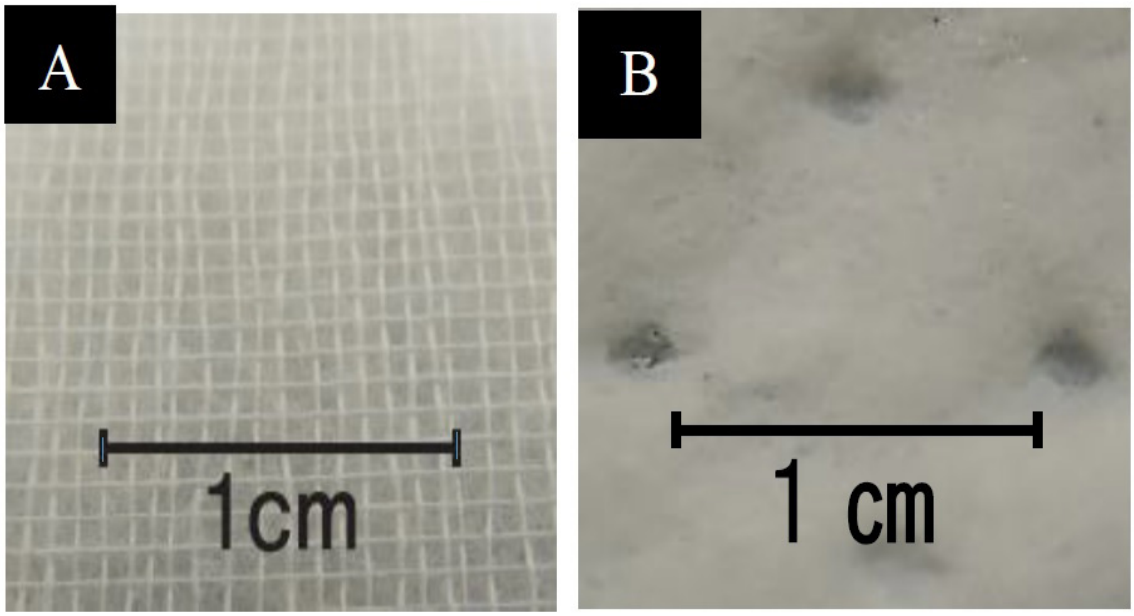
We measured the skin moisture and oil contents, surface pH level, and cleanliness in the left cervical region. For skin cleanliness evaluation, we measured the ATP activity level. ATP is a chemical substance that exists in all living bodies, such as animals, plants, and microorganisms. We used this index to count microorganisms such as bacteria. We chose the left cervical region for these measurements, as it does not require positioning or removing blankets, and consequently influences autonomic activity less. For the same reason, we examined the skin in the following order: skin moisture content, oil content, surface pH level, and cleanliness level. The site of measurement in the left cervical region was a section with a width of 40×40 mm with its center at 50 mm above a fourth of the clavicle from the sternal end. We measured the skin moisture content and surface pH level three times to adopt a mean at each point. We measured the skin oil content and cleanliness level once, and adopted a mean at each point. For each measurement of the skin moisture/oil content or surface pH level, we slightly shifted the site of measurement within the left cervical region. We measured the skin cleanliness level using a cotton swab contained in the attached cleaning kit. We moistened the cotton swab with sterile distilled water, and rubbed the skin surface forwards and backwards 5 times with it.

We collected data, as shown in Figure 2. First, we continuously recorded the skin temperature, core temperature, and electrocardiographic value for 50 minutes from the initiation of bed rest to another rest after the bed bath. Among these values, we adopted those obtained at 4 points for the skin and core temperatures: immediately before the bed bath, immediately before the completion of the bed bath, and 15 and 30 minutes after the bed bath. For the left brachial artery blood pressure, skin moisture and oil contents, and skin surface pH level, we adopted the values obtained at the following 4 points: immediately before, immediately after, and 15 and 30 minutes after the bed bath. Lastly, for the skin cleanliness level, we adopted the values obtained at 2 points: immediately before and immediately after the bed bath.

Procedures

We instructed the participants to stop eating and drinking 2 hours before the initiation of the experiment. Prior to the experiment, the participants changed into a patient gown and short pants over their underwear in a dressing room, and moved with slippers on their feet. Subsequently, in another room, we provided them with an outline of the experiment, and confirmed their current health condition.

We guided each participant to a private room for the bed baths, and instructed him to lie on the bed. We covered him from his toes to shoulders with 2 blankets, and pulled the hems of his short pants up to his upper thigh. We attached probes for the core and skin temperature measurements and electrodes for the electrocardiography to his body.



Gauze towel: 100mesh/ cm^2

Synthetic towel : 4 reliefs/ cm^2 embossed

Figure 2: Surface of towel fabric.

We conducted the experiment, as shown in Figure 2. After a 12-minute bed rest period with probes attached, the practitioner performed the bed bath procedure for 8 minutes. After the bed bath, a 30-minute bed rest period was inserted. Thus, the duration of the entire process was 50 minutes. During the initial bed rest period, we conducted evaluation using the short-version POMS-J and VAS (wakefulness/relaxation).

Immediately before the bed bath, we measured the blood pressure, skin moisture and oil contents, and skin surface pH and cleanliness levels. The participants closed their eyes during the bed baths. We measured the blood pressure, skin moisture and oil contents, and skin surface pH level immediately after and 15 and 30 minutes after the bed bath, and the skin cleanliness level immediately after the bed bath. At 30 minutes after the bed bath, we conducted evaluation using the POMS-J and VAS (wakefulness/relaxation) again, and examined the participants' impressions of the texture of each type of towel. We continuously measured the electrocardiographic value and core and skin temperatures throughout the experiment.

Verbal communication with the participants during the experiment was limited to the following occasions: immediately before pulling the blanket off, immediately before covering their body with a towel, when confirming the temperature of the towel, and immediately before each measurement.

All the participants participated in the experiment twice; they received a bed bath during the same time zone (9:00 to 16:00) on 2 different days when the gauze and synthetic towels were used, respectively. The order in which the 2 types of towel were used for the 2 sessions was determined at random (Figure 3).

Data analysis

We analyzed all the data collected using the statistical software SPSS Ver. 24.0 for Windows. We calculated the autonomic activity level by analyzing the electrocardiographic data, adopting the maximum entropy method (MemCalc/Tarawa, GMS Co., Ltd.). Through frequency analysis, we set the low (LF) and high (HF) frequency components of heart rate variability at 0.04-0.15 and 0.15-0.40 Hz, respectively, and regarded the LF/HF ratio and HF as representing sympathetic and parasympathetic activities, respectively. Additionally, we analyzed the data representing the heart rate (HR) and parasympathetic (HF) and sympathetic (LF/HF) activities during each of the following stable 2-minute-periods: before the bed bath (from 3 minutes after the initiation of rest), immediately before the completion of the bed bath (from 6 minutes after the initiation of the bed bath), 15 minutes after the bed bath (from 11 minutes after the bed bath), and 30 minutes after the bed bath (from 23 minutes after the bed bath). We chronologically compared the data obtained immediately before the completion of the bed bath, 15 minutes after, and 30 minutes after the bed bath with those obtained before it as baseline values. At the same time, we compared the amounts of change in each value at each point when using the gauze and synthetic towels. The heart rate varied between the 2 types of towel at 15 minutes after the bed bath, but the difference was slight. Therefore, we used the values before the bed bath as baseline values (0) to compare the amount of change between them.

Similarly, we examined chronological changes in the core and skin temperatures immediately before the completion of the bed bath, and 15 and 30 minutes after the bed bath, with those before the bed bath as baseline values. In both cases, we compared the amount of change at each point between the 2 types of towel. We also examined chronological changes in the skin moisture/oil contents and surface pH level immediately before the completion of the bed bath, immediately after, and 15 and 30 minutes after the bed bath, with those before the bed bath as baseline values, and compared the amount of change in each index at each point between the 2 types of towel. As for ATP activity as an index of skin cleanliness, we calculated the change rate immediately after the bed bath, with the values before the bed bath as baseline values (0) for comparison. We also compared moods before and after the bed bath based on the POMS-J and VAS scores, and examined the impression of texture of each type of towel

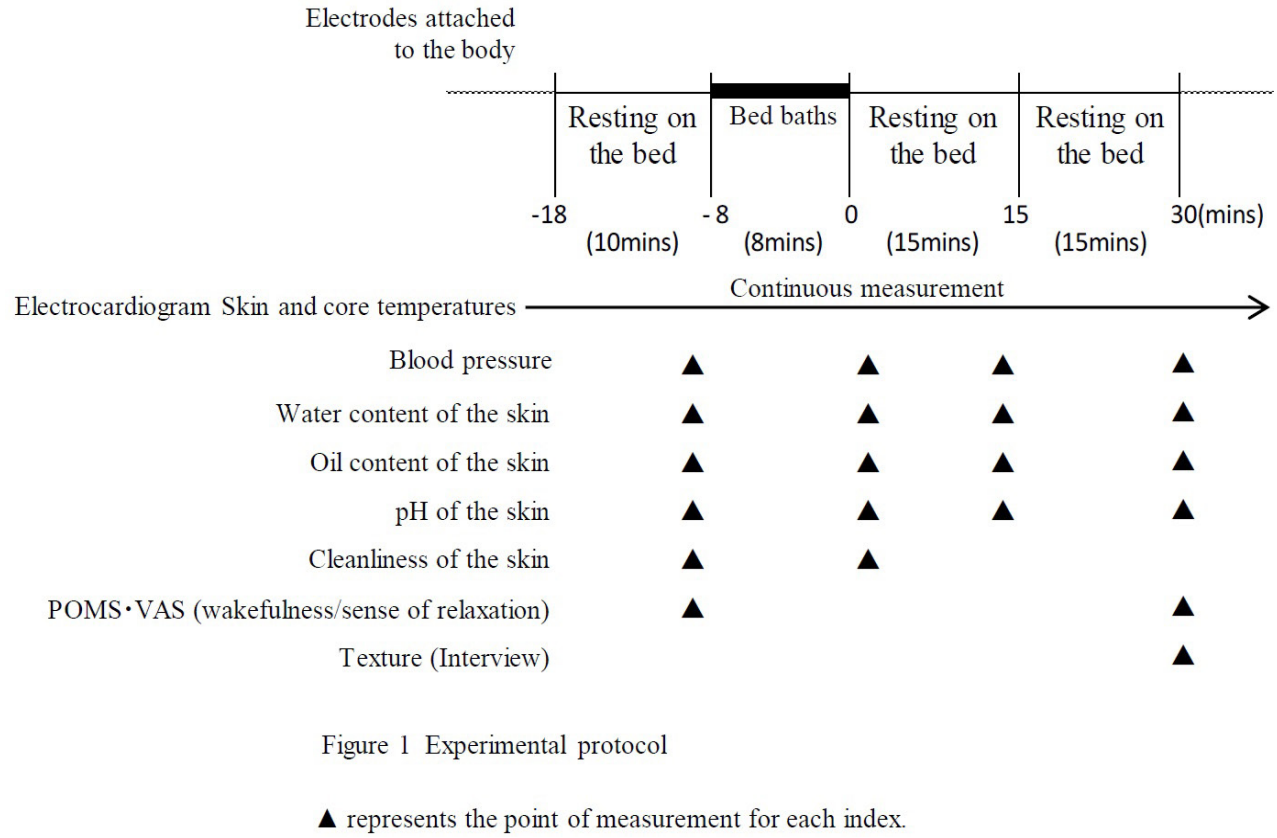


Figure 3: Experimental protocol.
▲ represents the point of measurement for each

after the bed bath. For statistical analysis, we used the non-parametric test. For intra-group comparison of measurement values, we conducted the Friedman test, and for inter-group comparison using the amounts of change based on the values during the rest period before the bed bath, we used the Wilcoxon signed-rank sum test. To compare the impression of texture after the bed bath between the 2 types of towel, we conducted the chi-square test. In all cases, we set the significance level at lower than 5%.

Ethical Considerations

We provided all the participants with an explanation of the purpose of the study, guarantee of free decision-making, protection of privacy, preservation of confidentiality, a guarantee of withdrawal at any time with no disadvantage and publication of the results, in writing and orally, to obtain their signed informed consent. The study was conducted with the approval of the Research Ethics Committee of the affiliated institution, and there were no conflicts of interest to declare.

Results

We performed complete bed baths (excluding the facial and genital areas) on 19 healthy male students through a unified procedure using 2 types of towel (gauze/synthetic) differing only in the surface properties. Although repeated measures ANOVA should have been performed, we used the Wilcoxon signed-rank sum test, because the aim of this study was exploratory.

Comparison of the bed bath effects based on the subjective indices

In terms of texture, both the gauze and synthetic towels were positively evaluated, as 50 to 80% of the participants answered "Definitely yes" for 3 aspects: <Warm>, <Feeling refreshed>, and <Feeling that the body has been cleaned>. On the other hand, the rate of answering "Possibly" or "Definitely no" for <A sense of fitness> reached 60%, revealing a negative rating in both cases. In other aspects, the synthetic towels were more positively evaluated than the gauze towels, as about 50% of the participants regarded the former as <Soft> and <Feeling comfortable when being wiped>. The only aspect in which the synthetic towels were rated significantly higher than the gauze towels was <Favorable texture> (P=0.029) (Table 1). Comparison of the participants' VAS scores, representing their levels of wakefulness and relaxation before and after the bed baths using the gauze and synthetic towels, revealed a significant increase after the bed bath in both cases (wakefulness: gauze: P=0.001 and synthetic: P=0.000; and relaxation: P=0.003 and P=0.008) (Table 2).

Similarly, comparison of the participants' POMS-J scores, representing their moods before and after the bed baths using the gauze and synthetic towels, revealed a significant decrease only in <tension-anxiety> after the bed bath in both cases (P=0.003 and P=0.021, respectively). As for other subscales, <depression>, <anger-hostility>, <fatigue>, and <confusion> revealed little pre-post change, while the score for <vigor> slightly decreased after the bed bath in both cases (Table 3).

Items	Responses	Gauze towels n = 19	Synthetic towels n = 19	*P* value
Soft	Yes	3	9	0.112
	Neutral	8	5	
	No	8	5	
Warm	Yes	15	16	0.328
	Neutral	2	3	
	No	2	0	
Favorable texture	Yes	5	13	0.029*
	Neutral	5	3	
	No	9	3	
Feeling comfortable when being wiped	Yes	6	11	0.252
	Neutral	9	5	
	No	4	3	
Feeling refreshed	Yes	13	10	0.609
	Neutral	4	6	
	No	2	3	
Feeling a sense of fitness	Yes	7	6	0.802
	Neutral	8	10	
	No	4	3	
Feeling that the body has been cleaned	Yes	12	10	0.078
	Neutral	4	9	
	No	3	0	

Table 1: Texture of the materials of towels.

Note 1) χ^2 test*. P < 0.05
Note 2) The results of inter-group comparisons were not significant.

Item	Materials	Before bed baths	After bad baths	*P* Value
Wakefilness	Gauze towels (n=19)	56.5(4.5)	35.8(3.8)	0.000 **
	Synthetic towels (n=19)	49.6(4.1)	28.2(2.7)	0.001 **
Sense of erlaxation	Gauze towels (n=19)	64.8(3.1)	75.6(3.0)	0.008 **
	Synthetic towels (n=19)	65.7(2.9)	74.2(4.4)	0.003 **

Table 2: Changes in VAS for wakefulness and the sense of relaxation following bed.

Note 1) Wilcoxon signed-rank tests were used to compare values prior to and following the intervention. ** P<0.01
Numerical values are expressed as Mean (SD).
Note 2) The results of inter-group comparisons were not significant.

Comparison of the bed bath effects based on the objective indices

To clarify the effects of complete bed baths using 2 types of towel (gauze/synthetic) with different surface properties on the human body, we examined the results of analysis based on each physiological index. Table 4 shows the core and skin temperatures, Table 5 shows the blood pressure as a hemodynamic index, Table 6 shows the heart rate and autonomic activity, and Table 7 shows the skin moisture/oil contents and surface pH level.

When using the gauze and synthetic towels, there was a marked increase of approximately 1.4°C (P=0.001 and *P*=0.001, respectively) in the core temperature from immediately before to 30 minutes after the bed bath. The skin temperatures of the anterior chest (approximately 1.2°C), the right forearm (approximately 1.4°C), and tips of the hallux of the left foot (approximately 3.3°C), also markedly increased (*P*=0.001 and *P* =0.001, respectively). Furthermore, in both cases, the skin temperature of the fingertip (the fourth finger pulp of the right hand) decreased by 0.3°C from immediately before to during the bed bath, but exceeded the pre-interventional value at the final

Item	Materials	Before bed baths	After bad baths	*P* Value
Tension-Anxiety	Gauze towels (n=19)	14.9 (5.1)	2.3 (2.2)	0.003 **
	Synthetic towels (n=19)	16.6 (5.0)	2.3 (3.5)	0.021 *
Depression-Dejection	Gauze towels (n=19)	6.2 (0.0)	7.0 (0.0)	0.715
	Synthetic towels (n=19)	1.1 (0.0)	2.3 (0.0)	0.317
Anger-Hostility	Gauze towels (n=19)	2.3 (0.0)	0 (0.0)	0.285
	Synthetic towels (n=19)	0 (0.0)	0 (0.0)	1.000
Vigor	Gauze towels (n=19)	24.7 (0.0)	15.7 (5.0)	0.061
	Synthetic towels (n=19)	22.3 (0.0)	16.3 (6.6)	0.074
Fatigue	Gauze towels (n=19)	17.4 (4.8)	13.9 (5.8)	0.069
	Synthetic towels (n=19)	18.7 (5.3)	15.2 (4.3)	0.069
Confusion	Gauze towels (n=19)	16.6 (2.4)	15.1 (3.0)	0.330
	Synthetic towels (n=19)	16.6 (2.4)	16.1 (2.2)	0.466

Table 3: Comparison of gauze and synthetic towels prior to and following bed baths using the short version of POMS-J.

Note 1) Numerical values are T scores calculated using the following formula:
[50+10 (raw score - mean/SD)]. Numerical values are expressed as Mean (SD).
Note 2) Values obtained before and after the intervention were compared using the Wilcoxon signed-rank test.
* $P< 0.005$, ** $P< 0.001$
Note 3) The results of inter-group comparisons were not significant.

point, revealing a significant increase of 1.7°C (P=0.001 and P=0.001, respectively). Thus, the changes in the core and skin temperatures were similar between the gauze and synthetic towels.

Concerning the effects of complete bed baths using the 2 types of towel on blood pressure (Table 5), a significant decrease in the systolic blood pressure level (approximately -4.4 mmHg) was observed at 15 minutes after the bed bath in both cases (P=0.002 and P=0.015, respectively). However, when using the gauze towels, the value decreased (approximately -5.5 mmHg) at 15 minutes after the bed bath, and did not recover until the final point, remaining low. In contrast, when using the synthetic towels, the value, after showing a decrease (approximately -3.2 mmHg) at 15 minutes after the bed bath, increased and finally exceeded the pre-interventional value (approximately 0.4 mmHg). As for the diastolic blood pressure level, it decreased (approximately -3.2 mmHg) at 15 minutes after the bed bath, and remined unrecovered until the final point in both cases.

Variability analysis using the electrocardiographic records (Table 6) revealed that when using the gauze towels, the heart rate continued to decrease from immediately before the completion of the bed bath to the final point, revealing significant differences immediately before the completion (approximately -3.7 bpm) (P=0.041), at 15 minutes after (approximately -4.8 bpm) (P=0.001), and 30 minutes after (approximately -5.5 bpm) (P=0.041) the bed bath. When using the synthetic towels, the heart rate also decreased from immediately before the completion of the bed bath to the final point, revealing a significant difference at 15 minutes after (approximately -3.7 bpm) (P=0.012) and 30 minutes after (approximately -5.4 bpm) (P=0.001) the bed bath. With regard to the parasympathetic activity level (HF), it increased at 15 minutes after the bed bath, and then tended to decrease at the final point when using the gauze towels, whereas it decreased at 15 minutes after the bed bath, and then tended to slightly increase at the final point, remaining high when using the synthetic towels. Furthermore, the sympathetic activity level (LF/HF) tended to increase immediately before the completion of the bed bath in both cases; however, the level at the final point was lower than the pre-interventional value when using the gauze towels, whereas it tended to decrease, but recovered to the pre-interventional value when using the synthetic towels. Comparison of the amount of change at each measurement point between the 2 types of towel revealed no significant differences in the heart rate, HF, or LF/HF.

Table 7 shows the skin moisture/oil contents and surface pH levels. When using the gauze towels, the skin moisture content increased (approximately 5.0%) immediately after the bed bath, then tended to decrease, and recovered to the pre-interventional value at the final point. When using the synthetic towels, the skin moisture content slightly increased (approximately 2.1%) immediately after the bed bath, and there were decreases at 15 and 30 minutes after the bed bath (approximately -0.9% and -2.1%, respectively). Comparison of the amount of change in the skin moisture content at each measurement point between the 2 types of towel revealed no significant differences. When using the gauze towels, there were significant decreases in the skin oil content at 15 minutes after (approximately -10.0 μg/cm^2) (P=0.001) and 30 minutes after (approximately -11.1 μg/cm2) (P=0.004) the bed bath. When using the synthetic towels, the skin oil content significantly decreased immediately before the completion (approximately -15.9 μg/cm^2) (P=0.034), at 15 minutes after (approximately -15.4 μg/cm^2) (P=0.001), and 30 minutes after (approximately -15.3 μg/cm^2) (P=0.005) the bed bath. Comparison of the amount of change in the skin oil content at each measurement point between the gauze and synthetic towels revealed that the decreases immediately after (approximately -15.9 vs. -7.5 μg/cm^2) (P=0.024) and at 15 minutes after (approximately -16.0 vs. -10.0 μg/cm^2) (P=0.045) the bed bath were more significant in the latter.

Item	Materials	Before use	Immediately after use	15 minutes after the completion	30 minutes after the completion
Core temperature	Gauze towels (n=19)	34.6 (0.3)	35.6 (0.2)	36.0(0.1)	36.1 (0.1)
	Synthetic towels (n=19)	34.9 (0.2)	35.7 (0.2)	36.0 (0.1)	36.1 (0.1)
Anterior chest	Gauze towels (n=19)	34.4 (0.2)	34.9 (0.2)	35.3 (0.1)	35.5 (0.1)
	Synthetic towels (n=19)	34.3 (0.1)	34.9 (0.1)	35.4 (0.1)	35.5 (0.1)
Right arm	Gauze towels (n=19)	33.7 (0.2)	34.0 (0.2)	34.8 (0.2)	35.1 (0.1)
	Synthetic towels (n=19)	33.8 (0.2)	34.0 (0.2)	34.8 (0.2)	35.1 (0.1)
4th finger pulp of the right hand	Gauze towels (n=19)	33.8 (0.7)	33.5 (0.4)	35.4 (0.2)	35.4 (0.2)
	Synthetic towels (n=19)	33.3 (0.8)	33.1 (0.6)	35.0 (0.3)	35.3 (0.2)
1st toe of the left foot	Gauze towels (n=19)	25.0 (1.2)	25.7 (1.2)	27.4 (1.3)	28.1 (1.2)
	Synthetic towels (n=19)	23.6 (1.2)	24.4 (1.1)	25.9 (1.3)	27.0 (1.3)

Table 4: Changes in core and skin temperatures after bed baths using gauze and synthetic towels.

Note 1) Following Friedman's test, values obtained before and after the intervention were compared using the Wilcoxon signed-rank test. * P <.05, **P <.01
Numerical values are expressed as Mean (SE).

Note 2) The results of inter-group comparisons were not significant.

Materials	Blood pressure (mmHg)	Before use	Immediately after use	15 minutes after the completion	30 minutes after the completion
Gauze towels (n=19)	SBP	117.6 (2.0)	116.0 (2.3)	112.1 (2.0)	116.4 (2.0)
	DBP	71.6 (1.6)	71.4 (1.6)	68.8 (1.5)	70.8 (1.2)
Synthetic towels (n=19)	SBP	117.1 (2.2)	116.3 (2.0)	113.9 (1.7)	117.5 (1.8)
	DBP	72.7 (1.2)	70.9 (1.6)	69.2 (1.4)	71.3 (1.3)

Table 5: Change in blood pressure after bed baths using gauze and synthetic towels.

Note 1) Following Friedman's test, values obtained before and after the intervention were compared using the Wilcoxon signed-rank test. * *P* <.05, **P<.01
Numerical values are expressed as Mean (SE).

Note 2) The results of inter-group comparisons were not significant.

Item	Materials	Before use	Immediately after use	15 minutes after the completion	30 minutes after the completion
HR (bpm)	Gauze towels (n=19)	67.7 (2.0)	64.0 (1.9)	64.0 (1.9)	62.2 (1.7)
	Synthetic towels (n=19)	65.6 (1.9)	62.4 (1.7)	61.9 (1.6)	60.2 (1.5)
HF ($msec^2$)	Gauze towels (n=19)	733.6 (286.8)	676.7 (234.5)	794.9 (217.3)	744.7 (161.4)
	Synthetic towels (n=19)	956.6 (342.3)	935.7 (317.4)	806.6 (158.1)	906.6 (211.7)
LF/HF	Gauze towels (n=19)	2.1 (0.5)	2.8 (0.6)	1.5 (0.3)	1.5 (0.3)
	Synthetic towels (n=19)	1.8 (0.3)	2.5 (0.6)	2.1 (0.4)	1.9 (0.5)

Table 6: Changes in HR, HF and LF/HF after bed baths using gauze and synthetic towels.

Note 1) Following Friedman's test, values obtained before and after the intervention were compared using the Wilcoxon signed-rank test. * P <.05, ** P <.01 Numerical values are expressed as Mean (SE).
Note 2) The results of inter-group comparisons were not significant.

		Mean (SE)			
Item	Materials	Before use	Immediately after use	15 minutes after the completion	30 minutes after the completion
Skin moisture content (%)	Gauze towels (n=19)	47.8 (2.3)	35.6 (0.2)	36.0(0.1)	36.1 (0.1)
	Synthetic towels (n=19)	48.4 (3.1)	50.5 (2.7)	47.5 (2.6)	46.3 (2.8)
Oil content (μ g/cm^2)	Gauze towels (n=19)	14.6 (2.4)	7.1 (1.5)	4.6 (1.0)	4.5 (08)
	Synthetic towels (n=19)	19.1 (3.2)	3.2 (0.6)	3.7 (1.3)	3.8 (0.8)
pH	Gauze towels (n=19)	5.9 (0.2)	6.0 (0.1)	6.1 (0.1)	6.0 (0.1)
	Synthetic towels (n=19)	5.5 (0.2)	5.7 (0.2)	5.9 (0.2)	5.9 (0.2)

Table 7: Change in skin moisture content, oil content, pH after bed baths using gauze and synthetic towels.

Note 1) Following Friedman's test, values obtained before and after the intervention were compared using the Wilcoxon signed-rank test. ** P <.01 Numerical values are expressed as Mean (SE).
Note 2) The results of inter-group comparisons were not significant.

In addition, the skin surface pH level increased immediately before the completion in both cases (approximately 0.1 and 0.2, respectively). Specifically, an almost constant value was maintained from 15 minutes after the bed bath to the final point when using the gauze towels, whereas there was an increase at 15 minutes after the bed bath (approximately 0.4), and then a constant value was maintained until the final point when using the synthetic towels. Comparison of the amount of change in the skin surface pH level at each measurement point between the 2 types of towel revealed no significant differences.

The rate of change in the skin cleanliness level between before and after the bed bath was -25.8% for the gauze towels and -34.2% for the synthetic towels, revealing significant differences (P=0.033 and P=0.004, respectively).

Discussion

This study compared the effects of complete bed baths using 2 types of towel (gauze/synthetic) with different surface properties on the human body, involving healthy male students, and clarified the relationship between the surface unevenness of towels and the effects of complete bed baths. This section discusses the results regarding texture (comfort), moisturizing effects, and skin cleanliness.

Comparison of texture based on surface unevenness

Our previous studies demonstrated that when used as an alternative material to cotton towels in nursing practice settings, various types of disposable towel are not subjectively and objectively comfortable materials yet, although they have advantages and disadvantages due to the physical properties of their surfaces [9-13].

Among the subjective evaluation results in the present study, particular attention should be paid to the absence of significant changes in the short-version POMS-J scores after the bed bath, decrease in the score for 1 subscale, decrease in the level of wakefulness, and increase in the level of relaxation, as well as the decrease in the systolic blood pressure level at 15 minutes after the bed bath, which were similarly observed when using the gauze and synthetic towels. However, in terms of <Favorable texture>, the synthetic towels were more positively evaluated than the gauze towels after the bed bath (P=0.029), and also excellent in terms of softness and wiping comfort. The gauze towels were rated low in terms of softness and wiping comfort, suggesting that excessive tactile and pressure stimulation due to the uneven surface of the fabric integrating the gauze and non-fat cotton and having 100 meshes/cm^2 resulted in a rough texture, and did not lead to a comfortable feeling. In contrast, the synthetic towels were found <Soft>, with moderate wiping comfort, as they were made of non-woven fabric embossed with 4 reliefs/cm^2, and provided milder tactile and pressure stimulation.

When focusing on autonomic activity among the objective indices, although the decrease in the heart rate (HR) until the final point significantly varied between the gauze and synthetic towels, parasympathetic activity (HF) showed little change, and sympathetic activity (LF/HF) tended to decrease until the final point after increasing immediately before the completion in both cases, suggesting the influence of factors other than tactile and pressure stimulation to the skin due to surface unevenness [18, 19, 20].

Based on this, the changes in the core and skin temperatures can be explained as follows: It is possible that the skin temperature decreased immediately after the bed bath due to vaporization heat from evaporation, and then the blood flow at the body surface transiently decreased to maintain the core temperature. Consequently, the evaporation immediately after the bed bath ended soon, and the skin temperature increased due to the increase in blood flow [21]. This also indicates that the increases in the core and skin temperatures from during the bed bath to the final point, which were commonly observed, and the decrease in the heart rate (HR) until the final point were associated to achieve heat retention in both cases. Moreover, the gauze towels were made by integrating a dense structure of cotton without using any adhesive, and the synthetic towels were made of embossed non-woven fabric. Both structures may have contributed to the heat-retaining effect that continued until the final point by preventing heat loss from the interfilament spaces.

Thus, the 2 types of towel were shown to have a similar heat-retaining effect, because the rate of heat loss from the interfilament spaces was similarly low due to their fabric structures. However, the synthetic towels were highly rated in the subjective evaluation of texture, whereas the gauze towels were poorly evaluated in terms of softness, texture, and wiping comfort due to the high unevenness of the entire fabric and surface, revealing an inconsistency with the results related to autonomic activity as an objective index to compare tactile and pressure stimulation caused by the surface of the fabric [13]. In short, the synthetic towels were also superior to gauze towels in fabric surface texture, in addition to heat retention.

Comparison of moisturizing effects based on surface unevenness

The skin consists of 3 layers: the epidermis that is the outermost layer, dermis, and subcutaneous. The most superficial layer of the epidermis is the stratum corneum, followed by the stratum granulosum, stratum spinosum, and stratum basale. Sebum in the stratum corneum functions as a barrier on the skin to prevent the evaporation of accumulated moisture [22].

Comparison of the skin moisture content revealed that the value remained high from during the bed bath to the final point when using the gauze towels, whereas it markedly decreased from 15 minutes after the bed bath to the final point when using the synthetic towels. In the former made by physically integrating gauze with 100 meshes/cm^2 and nonfat cotton, a larger number of interfilament spaces in the skin contact area allowed significant evaporation of water from the surface of the skin, but water may have been absorbed by the absorbent cotton wool integrated with the gauze, and then adhered to the surface of the skin. As a result, the stratum corneum swelled, and the amount of moisture increased, achieving a greater moisturizing effect [22]. In the latter made of embossed non-woven fabric with 4 reliefs/cm^2, there may have evaporation of moisture from the interfilament spaces in areas in close contact with the skin, resulting in a decrease in moisture content during the bed bath.

In general, sebaceous glands secreting sebum are concentrated in the face and scalp, chest, back, and neck [23]. With fatty acids and lactate in sweat covering the skin surface, normal skin pH levels are maintained on the slightly acidic side, at 4.2-6.4, and increased pH levels negatively affect the skin barrier function [24]. Furthermore, in the case of dry skin, the skin surface pH level gradually increases due to poor control of water vapor loss from the inside, making the skin tend to be dry [25]. From the perspective of fiber structure, the marked decrease in the skin oil content with a slight increase in the skin surface pH level after the bed bath using the synthetic towels also indicates that the larger area of the surface in direct contact with the skin even led to the removal of sebum, natural moisturizing factors in the epidermis, and intercellular lipids in the stratum corneum [22]. This explains why the skin tended to drier with the synthetic towels. However, after the bed bath, while the skin moisture content gradually decreased in both cases, the skin cleanliness level was slightly higher for the synthetic towels than the gauze towels (-34.2 and -25.8%, respectively), supporting the former's effectiveness to remove dirt from the skin. On the other hand, the gauze towels were suggested to be effective to retain moisture in the material itself, and contribute to the maintenance of normal skin barrier function.

In summary, the gauge towels were highly , moisturizing, but their effect of removing dirt from the skin was poor, whereas the synthetic towels excessively removed sebum and moisture from the skin, but they were effective to remove dirt from it.

Conclusions

In this study, we compared the effects of complete bed baths using gauze and synthetic towels in a simulated clinical setting. Although the fabric surface structure and unevenness varied between the 2 types

of towel, the results related to autonomic activity were the same, the rate of heat loss from the interfilament spaces was commonly low, and, therefore, the heat-retaining effect was also almost the same. However, the subjective evaluation showed the synthetic towels' superiority in texture. In addition, the gauge towels were highly moisturizing, but their effect of removing dirt from the skin was poor, where as the synthetic towels excessively removed sebum and moisture from the skin, but they were effective to remove dirt from it.

To find synthetic towels that enhance physiological and subjective comfort, we have examined appropriate materials and surface properties focusing on the surface unevenness, involving healthy individuals. Our next plan is to conduct clinical trials using synthetic towels introduced as an alternative material to cotton towels on severaly ill patients in medical facilities or those receiving long-term care.

Competing Interests

The authors declare that they have no competing interests.

Author Contributions

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