

# Comparison of Effects of Complete Bed Baths Using Different Towel Materials: Cotton and Synthetic

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## Abstract

**Aim:** To compare the effects of complete bed baths using cotton and synthetic towels.

**Methods:** Complete bed baths were performed on 15 healthy male students, cotton and synthetic towels were of the same size, weight, and moisturizing amount, and on different days using towels made of different materials. The indices to assess bed bath effects included the core body temperature, skin temperature, blood pressure, electrocardiograms (heart rate variability), Profile of Mood States (short version; POMS-J) scores, levels of wakefulness and relaxation (Visual Analogue Scale), and texture (Likert scale scores).

**Results:** Heart rate decreased ( $P<.05$ ), while skin and core body temperatures increased in the precordial and antibrachial regions and in the tips of the left toes (all  $P<.05$ ) until the end of bed baths using both materials, but in the comparison between the groups of the amount of change in each measurement time of both materials. In contrast, a greater sense of texture ( $P<.05$ ), decreased POMS-J scores ( $P<.05$ ), and increased parasympathetic (high frequency component) and suppressed sympathetic (low frequency/high frequency index) nerve activities were observed only after a complete bed bath using cotton towels (respectively  $P<.05$ ). Although skin temperature increased in all target regions until the end of the procedure when synthetic towels were used ( $P<.05$ ), no marked changes were observed in subjective evaluation results or autonomic nerve activity.

**Conclusions:** Cotton and synthetic towels both increased skin temperature to the same extent during bed baths; however, cotton towels were more comfortable than synthetic towels in terms of subjective evaluations and autonomic nerve activity.

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## Introduction

Complete bed baths for severely ill and long-term inpatients are conducted by nurses who have been well-informed of their clinical conditions. Previous studies investigated the effects of complete bed baths, including cleaning the body, heating the body [1,2], and sedation/analgesia [3].

Previous studies investigated the effects of complete bed baths, with a focus on the towel material [6]. Infection prevention studies identified *Bacillus cereus* in reused cotton in healthcare institutions [3,7], and cases of hospital-acquired infections due to *B. cereus* in reused cotton towels and mortality [6] have been reported deaths by *Bacillus cereus* present in cotton towels. We previously cultivated bacteria from cotton towels reused in healthcare institutions using the petrifilm analysis method (Falco Life Science Ltd.). The findings revealed the presence of significant numbers of common bacteria ( $2,360\pm 252$  cfu/100 cm<sup>2</sup>) in reused cotton towels [5]. In the 2000's, studies comparing cleaning methods with traditional (cotton) and new (synthetic) towels, in terms of cleanliness, comfort, and economic efficiency, were conducted in Western countries. The findings suggested greater cleanliness, comfort, and economic efficiency of complete bed baths using synthetic towels [8,9]. However, these studies only compared the effects of complete bed baths based on impressions submitted by healthcare professionals, and these findings were not supported by experimental evidence. This lack of evidence has been left untouched, partly because hygiene care techniques are classic. However, if we aim to advance and develop evidence-based efficient and effective care techniques, we should hurry to develop and introduce new cleaning materials to replace cotton towels based on Japan's unique cleanliness culture.

## Purpose of Research

As a part of research on complete bed baths, we examined whether synthetic towels could really used as an alternative to cotton towels. Because of their absorbency, physical/chemical characteristics, and weaving methods, after heating the towel, it is known that the temperature of the cotton towels decreases rapidly than the synthetic towels [5]. However, the texture of cotton towels, with many small loops, is thought to be softer than synthetic towels. Then, we conducted a preliminary experiment on cleaning parts of the body using three types of synthetic towels of different shapes and thicknesses. Our previous findings suggested that thin non-woven fabric was the most comfortable material of those tested [10]. Subsequent experiments investigated the cleaning effects of cotton and the most comfortable synthetic towels: subjects were healthy female students and two types of towels were used to clean parts of their bodies [5]. In comparing this cotton and synthetic towel, the size, weight, thickness, moisture content, and temperature of both materials were made the same, but the textures of the materials and the surface of the fabric were carefully arranged so that they were different. The Subjects felt more comfortable

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when cotton towels were used because contact and pressure stimuli influenced autonomic nervous system activity, although the texture of synthetic towels was softer and their heat-retaining effects were better. These findings suggested that cotton and synthetic towels had various advantages and disadvantages because of differences in their forms or physical characteristics. However, the experimental findings were not supported by requisite evidence and could not examine adequately the cleaning effects of the two types of towels because the body areas cleaned were limited to the back, arms, and legs.

Therefore, the purpose of this study is to perform complete bed bath for healthy male students using both materials under conditions closer to the clinical method, and compare the feeling of touch and the effect of heat retention.

### Definition of terms

**Complete bed bath:** Defined as complete bed bath that takes 8 minutes excluding the face and genital area.

**Partial bed bath:** For ethical reasons, it is defined as a 6-minute bed bath of the limbs and back, excluding the face, pubic area, chest, and abdomen.

### Methods

#### Study design

This study was conducted with a quasi-experimental design, in which two types of interventions were provided at random for each group.

#### Study subjects and sample sizes

The sample size was set at 15 students considering the load on the participants. The difference detected by the test with the set number of cases is 5.4 and the width of the 95% confidence interval in the interval estimation is  $\pm 3.8$ , when the significance level is 0.05, the power is 0.8 and the standard deviation is 6.9, which is maximum value of standard deviation of difference between gauze towels use and synthetic towels use for heart rate difference between time points in preliminary experiments. [5,11]. The subjects were assessed as eligible for male students of standard physique who had no skin wounds or allergic constitution and had no problem with their health condition. As a result, one of the 16 male students who had high blood pressure was excluded, and the subjects of this study were 15 male students of standard physical constitution ( $BMI 21.3 \pm 0.6$ ) ( $20.7 \pm 1.0$  years old) who had no problem with their health condition (Figure 1).

#### Experimental methods

##### Characteristics of the towel materials

The study used common cotton (OmiKenshi Co., Ltd.) and synthetic towels widely used in medical settings.

The cotton towels were made of 100% cotton and had loops of thin threads (referred to as wana) on the surface. Therefore, their air permeability and moisture absorbency were high because water vapor was transmitted through the gaps between the threads and fibers.

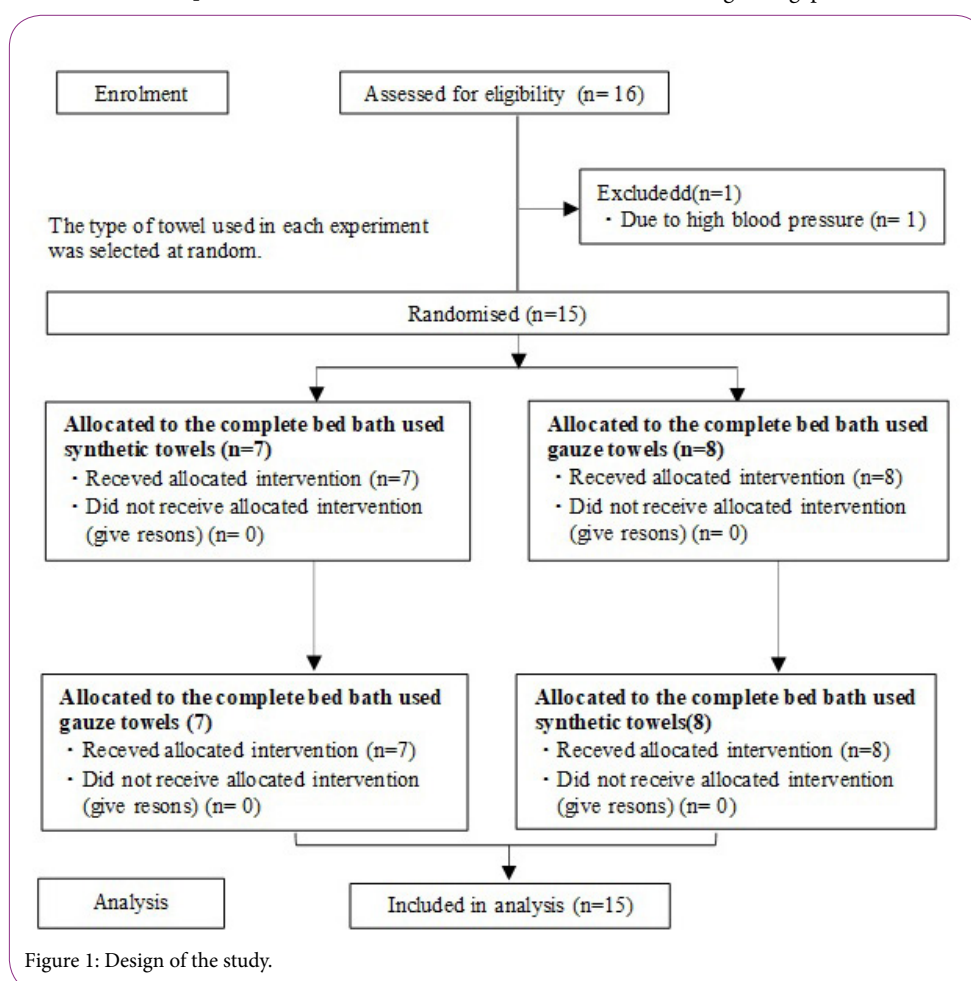
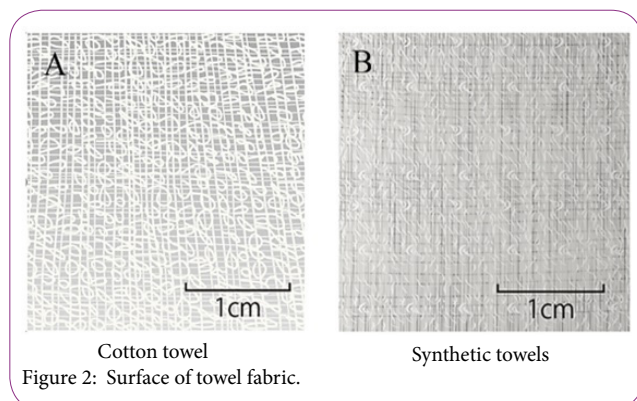


Figure 1: Design of the study.

The synthetic towels were a thin type of non-woven towel (SPC®) selected because it was considered to be the most appropriate cleaning material both subjectively and objectively among commercially available towels [6]. Non-woven synthetic towels are produced by laying fibers on a sheet and solidifying them using flexible glue, rather than weaving or knitting. Although non-woven synthetic fabric has poor air permeability, its absorbency and heat-retaining effects are high. Synthetic towels used in this study were made from rayon and polyester, to which purified water and a solution with small volumes of propylene glycol (moisturizing, lubricating, emulsifying, and preservative ingredients), fermented alcohol, phenoxyethanol (preservative and sterilizing ingredients), methyl parahydroxybenzoate (preservative and sterilizing ingredients), and ethyl parahydroxybenzoate (preservative and sterilizing ingredients) were added.

### Preparation of towels

The findings from a previous study suggested that the heat-retaining effects of towels are significantly higher when the constituents contained in the towels are removed [5]; therefore, towels without constituents except for their raw materials were used in the experiments (Figure 2). Cotton towels were dried in an oven at 90°C for 60 minutes to reduce the water content to <0.1%. Synthetic towels were heated with a clothes iron and then dried in an oven. In addition, we confirmed that the synthetic towels contained no dermal irritants through outsourced testing (Falco Life Science Ltd.) [5].



Because the forms of cotton and synthetic towels before absorbing hot water needed to be the same in order to compare their cleaning effects, we standardized the size, weight, and water content of the two types of towels; both towel types were cut to the same size: 40×17 cm. The weight of one synthetic towel (5 g) was one-third that of a cotton towel (15 g), eight sets of three-layered synthetic towels and eight cotton towels were prepared for each subject.

When the two types of towels contained the same volume of water, their weights were equal. The maximum volume of water contained in both types of towels was calculated from the mean weight differences before and after soaking in water (the towels were not dripping); the maximum volume of water was 270 mL. These procedures ensured that the sizes and weights of the towels were equal in order to examine variations in their cleaning effects due to differences in their materials.

Towels were stored in a temperature-controlled cleaning unit maintained at 79.4±0.7°C. The towel users removed them from the cleaning unit and confirmed, using the inner side of their arm, that the temperatures of the synthetic and cotton towels were 55.6±0.1°C and 55.3±0.2°C, respectively, immediately before using them.

### Methods for complete bed baths

Two beds were used alternately because the temperatures of the sheets were higher immediately after use. Bed baths were conducted by one person to ensure the same technique was used. The person is a woman in her fifties with a nurse license. The towels were folded to a size of 13×8 cm in order to be easily held by the hand. Each stroke cleaned approximately 23-25 cm of the body, and the cleaning intensity was 0.57±0.04 kgf/cm<sup>2</sup> [5]. Subjects lay in a left lateral decubitus position on the bed, and a hot towel was placed on their back for 30 seconds. After removing the hot towel, the area between the posterior neck and lower back was cleaned using another towel; bed baths involved two sets of ten strokes by one hand parallel to the spine (five left to right and right to left movements each). Subjects then lay in the supine position and their arms, chest, abdominal area, and legs were cleaned using the towels (three sets of left to right and right to left movements for each body region). The towels were exchanged for each body area.

### Data collection

#### Measurements using subjective indices

Subjective assessment of the psychological effects of bed baths using cotton and synthetic towels used the short version of the Profile of Mood States [12] in Japanese (POMS-J) and the Visual Analogue Scale (VAS) [13] [14], a scale designed to assess wakefulness and sense of relaxation. The short version of POMS-J, consisting of six subscales: (1) Tension-Anxiety, (2) Depression-Dejection, (3) Anger-Hostility, (4) Vigor, (5) Fatigue, and (6) Confusion, assesses changes after bed baths in the feelings and emotions of subjects over a short period of time. The short version of POMS-J involved 30 questions, and five-point scale scores (0 to 4 points) were given. In the short version of POMS-J, the Total score is calculated based on the raw score for each question item:

$$[\text{Total score} = 50 + 10 \times (\text{raw score} - \text{mean score} / \text{standard deviation})].$$

VAS was used to assess wakefulness and the sense of relaxation. Two straight horizontal lines were prepared: the left and right ends represented “Definitely no” (0) and “Definitely yes” (100), respectively. The researcher moved their finger along the VAS line from the left to right end, was told by the subject when to stop the movement, and then drew a vertical line at that point. Furthermore, subjects were asked about the textures of the two types of towels 30 minutes after bed baths. When the body is being cleaned seven assessment items were adopted from a previous study [9]: appropriate softness, warmth, comfortable texture, sense of comfort experienced, feeling refreshed, fit to the body (tightness of the materials and thickness), and removal of dirt. A three-point Likert scale (from “Definitely no” (1) to “Definitely yes” (3)) was used for assessment.

#### Measurements using subjective indices

Physiological indices of core and skin temperatures, heart rate variability, and blood pressure were measured to subjectively assess the cleaning effects of the towels, including texture and heat-retaining properties. Thermometers using zero-heat-flow (Core Temp CM-210, Terumo Corporation), continuous measurement-type electronic thermometers (Terumo Finer CTM-303, Terumo Corporation), electrocardiographic equipment (memory heart rate meter LRR-03, GMS Co., Ltd.), and an electronic manometer (HEM-737 Fuzzy, Omron Corporation) were used to measure core and skin

temperatures, hear rate variability, and blood pressure, respectively. To measure core temperature, a probe (Core Temperature Probe PD1, Terumo Corporation) was wrapped with quarto gauze (7×7 cm) to prevent the sensor from directly contacting the skin and attached to the area below the navel using 2.5-cm width tape. Body-surface probes to measure skin temperature were attached to the anterior chest (between the nipples), right arm (between the elbow and hand joints), fourth finger pulp of the right hand, and first toe of the left foot. Electrocardiography was conducted using the 3-induction method.

Data were collected as shown in Figure 3. Core/skin temperatures and electrocardiograms were recorded continuously for 48 minutes between the initiation of complete rest and the completion of bed baths at complete rest. Core/skin temperatures and arterial blood pressure in the left arm were measured four times: immediately before bed baths and then immediately and 15 and 30 minutes after its completion.

### Procedures

Subjects were asked to refrain from eating and drinking 2 hours before the initiation of the experiment. Subjects were taken individually to an air-conditioned room (room temperature: 23.7±0.2°C, humidity: 43.8±0.7%) with a noise level of 100.4±1.1 dB and an illumination intensity of 40.6±5.6 Lux. Probes to measure core/skin temperatures and electrodes for electrocardiography were attached while the subject lay on the bed. Subjects lying on the bed in the supine position wore shorts (with the hems folded to 20 cm above the knees), and two cotton blankets on their shoulders.

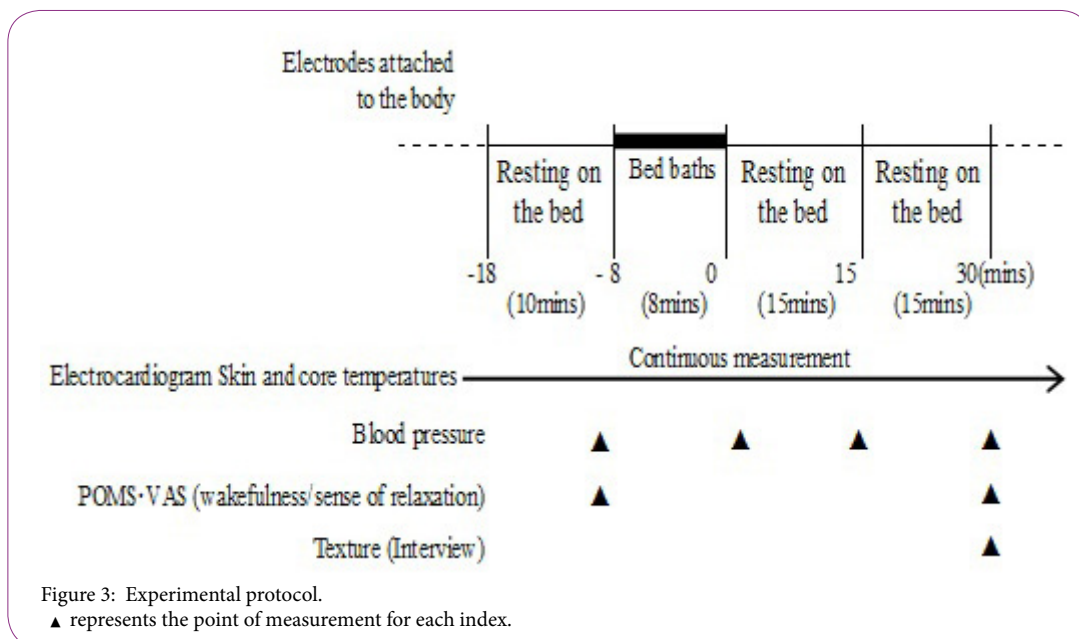
Complete bed baths were conducted in accordance with the procedure shown in Figure 1. After 10 minutes of complete rest on the bed, subjects received bed baths for 8 minutes, and then rested on the bed for 30 minutes (48 minutes total). During the 10 minutes prior to bed baths, subjects answered questions from the short version of POMS-J and VAS, and their blood pressure was measured immediately before bed baths. During bed baths, the subjects closed their eyes. Blood pressure was measured immediately before bed baths and 15 and 30 minutes after bed baths. Subjects answered questions from the short version of POMS-J and VAS to describe

their subjective assessments of the textures of the towels 30 minutes after bed baths. Electrocardiogram data and core/skin temperatures were measured continuously during the experiment. The same cleaning procedure was implemented twice for each subject using the cotton and synthetic towels, respectively. Subjects received complete bed baths twice between 9:30 and 11:30 or between 13:00 and 16:00 on different 2 days. The type of towel used in each experiment was selected at random.

### Data analysis

All collected data were analyzed using SPSS Ver. 21.0 C (SPSS) statistical analysis software. In order to assess autonomic activation in subjects, electrocardiographic waveforms were input into a computer, and a frequency analysis of heart rate variability was conducted using the maximum entropy method (MemCalc/Tarawa, CMS Co., Ltd.). Based on the results of the frequency analysis, heart rate variability was classified into low-frequency (LF; 0.04–0.15 Hz) and high-frequency (HF; 0.15–0.40 Hz) components. The LF/HF ratio (LF/HF) was used as an index of sympathetic activity, and HF as an index of parasympathetic activity. Heart rate, parasympathetic activity (HF), and sympathetic activity (LF/HF) were analyzed for 2 minutes from 4 minutes after the initiation of complete rest (prior to bed baths), 6 minutes after the initiation (immediately before the completion) of bed baths, 13–15 minutes after the completion of bed baths, and 24 (or approximately 30) minutes after the completion of bed baths because the heart rate, HF, and LF/HF were stable during these 2 minutes. Data obtained prior to bed baths were compared with those obtained immediately after 15 and 30 minutes after bed baths, and changes in heart rate, HF, and LF/HF at these points were compared between the cotton and synthetic towel groups. For these frequency analyzes, the analysis period and analysis time duration at which the most rest was maintained were selected.

Core and skin temperatures prior to bed baths were compared with temperatures prior to, immediately after and 15 and 30 minutes after the completion of bed baths. Blood pressure measured prior to bed baths was compared with that measured prior to, immediately after and 15 and 30 minutes after the completion of bed baths, and blood





pressure changes were compared between the cotton and synthetic towel groups. Furthermore, the feelings of subjects prior to and after bed baths were compared using the short version of POMS-J and VAS.

A non-parametric test was used for statistical analyses. For intragroup comparison, the Friedman test was performed on the measured values immediately, 15 minutes, and 30 minutes after the resting time before complete bed bath was used as the reference value. Wilcoxon signed rank test was used for comparison between groups, using the resting time before complete bed bath as a reference value and the amount of change immediately after, 15 minutes, and 30 minutes after complete bed bath. Differences in the textures of the two towels after bed baths were compared using the  $\chi^2$  test. Significance levels in all tests were <5%.

### Ethical considerations

Subjects received an explanation of the purpose of the research, protection of privacy, preservation of confidentiality, and a guarantee of withdrawal at any time with no disadvantage, and signed informed consent was obtained. The study was conducted with the approval of the research Ethics Committee of the Graduate School of Health Sciences, Department of Nursing (No. D06-0006).

### Results

The effects of cotton and synthetic towels were described using subjective and objective indices prior to and after bed baths.

### Comparison of complete bed bath effect cotton towels and synthetic towels by subjective assessment indices

For the textures of the cotton and synthetic towels, > 50% of subjects answered “Definitely yes” to three questions (“warmth”, “sense of comfort experienced when the body is being cleaned”, and “feeling refreshed”) regardless of the type of towel. The rate of subjects who stated that “cotton towels removed dirt from the body” was significantly higher ( $P=0.029$ ), whereas the rates of those who felt that “the texture of synthetic towels was comfortable” and “synthetic towels were appropriately soft” were significantly higher ( $P=0.017$ ) (Table 1).

Wakefulness and the sense of relaxation were assessed using VAS prior to and after bed baths. Although the sense of relaxation after bed baths was significantly higher for both cotton and synthetic towels (respectively  $P=0.018$ ,  $P=0.002$ ), significant decreases were observed in wakefulness and the sense of relaxation after bed baths with synthetic towels ( $P=0.047$ ) (Figures 4a, b). No significant difference was observed between the groups in the amount of change in each measurement time of both materials (Figure 4). The feelings of subjects prior to and after bed baths were compared using the short version of POMS-J. Although significant decreases were noted in “Tension-Anxiety” and “Fatigue” for cotton towels (respectively  $P=0.018$ ,  $P=0.002$ ) (Figures 5a, e), significant decreases were not observed in any assessment item when synthetic towels were used. No significant difference was observed between the groups in the amount of change in each measurement time of both materials (Figure 5).

Table 1: Comparison of the texture of towels during complete bed baths.

Items	Responses	Cotton towels n = 15	Synthetic towels n = 15	$\chi^2$
Appropriate softness	Yes	1	8	8.13 *
	Neutral	6	2	
	No	8	5	
Warmth	Yes	11	11	2.67 n.s.
	Neutral	2	4	
	No	2	0	
Comfortable texture	Yes	3	8	3.63 n.s.
	Neutral	8	5	
	No	4	2	
Sense of comfort	Yes	8	8	1.17 n.s.
	Neutral	3	5	
	No	4	2	
Feeling refreshed	Yes	11	8	1.47 n.s.
	Neutral	3	6	
	No	1	1	
Fit to the body	Yes	6	6	0.28 n.s.
	Neutral	6	7	
	No	3	2	
Removal of dirt	Yes	10	3	7.05 *
	Neutral	2	7	
	No	3	5	

Note 1) Numerical values in the table represent the number of subjects [cotton towels (n=15), synthetic towels (n=15)].

Note 2)  $\chi^2$  test. \*  $P < .05$

Note 3) The results of inter-group comparisons were not significant.

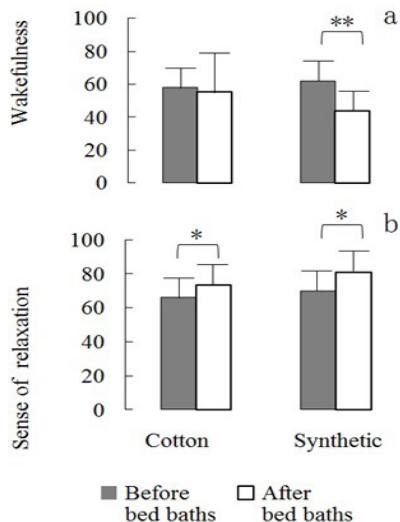


Figure 4: Changes in VAS for wakefulness and the sense of relaxation following bed baths.

Note 1) Cotton towels (n = 15), synthetic towels (n = 15).

Numerical values are expressed as “Mean ± SE”

Note 2) Wilcoxon signed-rank tests were used to compare values prior to and following the intervention.

\*  $P < .05$ , \*\*  $P < .01$

Note 3) No significant difference was observed between the groups in the amount of change in each measurement time of both materials.

### Comparison of complete bed bath effect cotton towels and synthetic towels by objective assessment indices

The biological effects of complete bed baths using cotton and synthetic towels were analyzed, with a focus on each physiological index. Their effects on core and skin temperatures are shown in Figure 6. Their effects on blood pressure, an index of circulatory dynamics, are shown in Table 2, and on the heart rate and autonomic activation in Figure 7.

The skin temperatures at three points, excluding the fingertip (fourth finger pulp of the right hand), increased significantly until 30 minutes after the completion of bed baths with cotton towels, whereas the temperatures at all four points increased significantly until 30 minutes after completion of bed baths with synthetic towels (Figures 6b, c, d, e). The skin temperature of the toe (first toe of the left foot) before bed baths was approximately 26.9°C, and then increased significantly between 15 and 30 minutes after bed baths (by 4.3°C and 2.6°C when cotton and synthetic towels were used, respectively) (Figure 6e). The right arm was observed immediately before the completion of bed baths using cotton towels, and a significant increase was noted between 15 and 30 minutes after the completion of bed baths (by 1.1°C). Although no increase in the skin temperature of the right arm was observed immediately before the completion of bed baths using synthetic towels, it increased between 15 and 30 minutes after the completion of bed baths (by 1.1°C) (Figure 6c). The temperature of the fingertip (fourth finger pulp of the right arm) decreased significantly immediately before the completion of bed baths using cotton (-1.4°C) or synthetic (-1.0°C) towels, and then increased significantly between

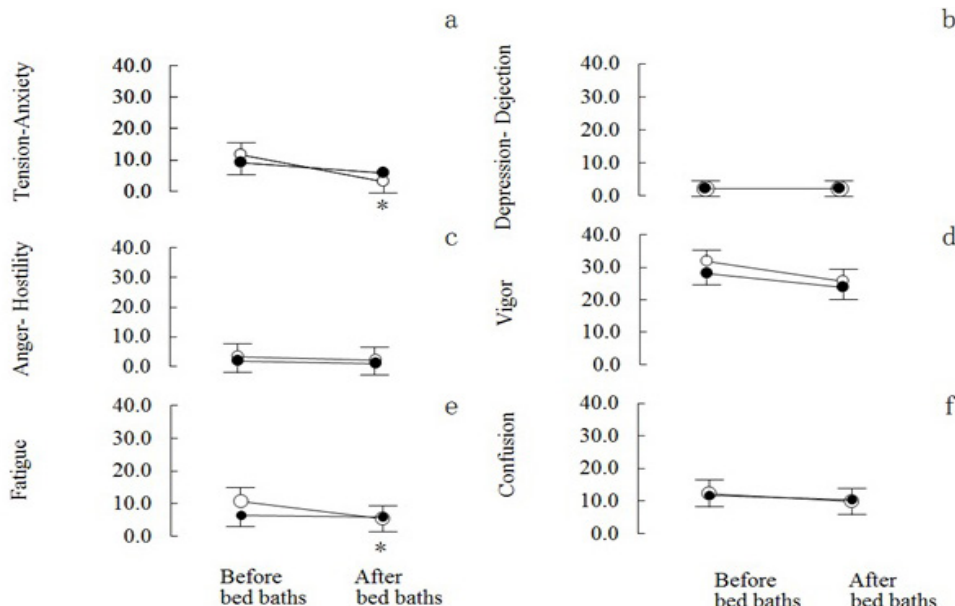


Figure 5: Comparison of cotton and synthetic towels prior to and following bed baths using the short version of POMS-J

Note 1) ○ Cotton towels (n = 15), ● Synthetic towels (n = 15)

Numerical values are T scores calculated using the following formula:  $[50 + 10 \text{ (raw score - mean/SD)}]$ . Numerical values are expressed as “Mean ± SD”

Note 2) Values obtained before and after the intervention were compared using the Wilcoxon signed-rank test.

\*  $P < .05$

Note 3) “Tension-Anxiety” and “Fatigue” for cotton towels were noted Significant decreases after complete bed baths.

Note 4) No significant difference was observed between the groups in the amount of change in each measurement time of both materials.

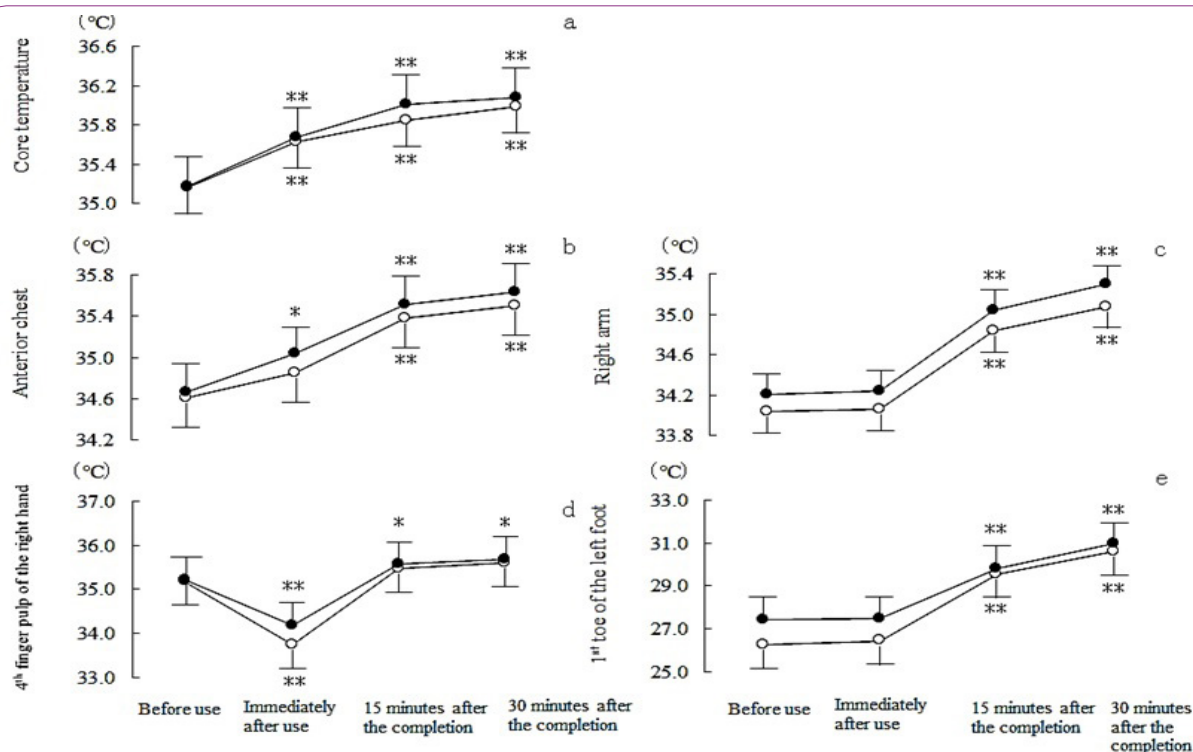


Figure 6 Changes in core and skin temperatures after bed baths using cotton and synthetic towels

Note 1) o Cotton towels (n=15), • Synthetic towels (n=15). Numerical values are expressed as “Mean ± SE”

Note 2) Following Friedman’s test, values obtained before and after the intervention were compared using the Wilcoxon signed-rank test. \*  $P < .05$ , \*\*  $P < .01$

Note 3) No significant difference was observed between the groups in the amount of change in each measurement time of both materials.

Materials	Blood pressure (mmHg)	Mean (SE)			
		Before use	Immediately after use	15 minutes after the completion	30 minutes after the completion
Cotton towels (n=15)	SBP	112.8 (1.8)	105.9 (6.6)	111.1 (2.0)	110.4 (1.2)
	DBP	66.2 (1.5)	68.3 (1.4)	67.8 (1.4)	66.0 (1.6)
Synthetic towels (n=15)	SBP	114.9 (1.8)	114.3 (2.1)	114.1 (2.0)	112.2 (1.6)
	DBP	67.1 (1.3)	68.9 (1.3)	66.3 (1.6)	66.6 (1.5)

Table 2: Changes in blood pressure after complete bed baths using cotton and synthetic towels.

Note 1) Numerical values in the table are expressed as “Mean (SE)”.

Note 2) Following Friedman’s test, values obtained before and after the intervention were compared using the Wilcoxon signed-rank test. \*  $P < .05$

Note 3) The results of inter-group comparisons were not significant.

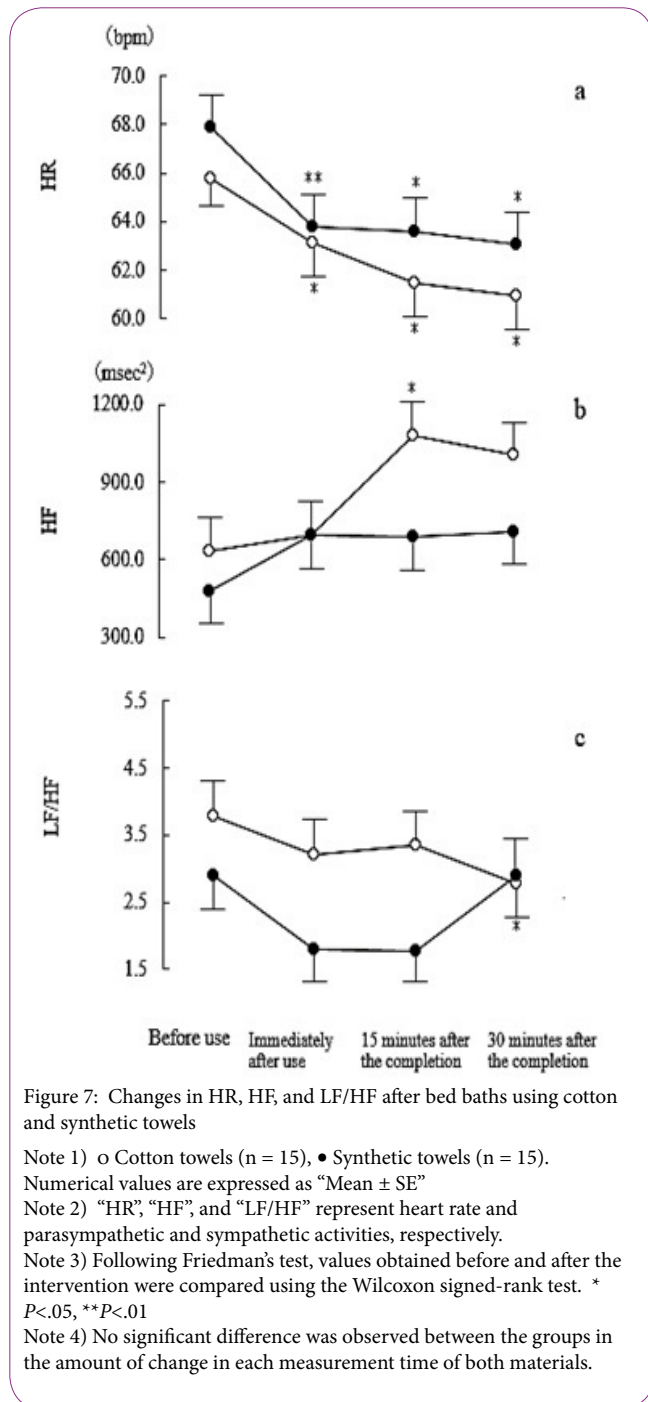
Note 4) No significant difference was observed between the groups in the amount of change in each measurement time of both materials.

15 and 30 minutes after the completion of bed baths using synthetic towels, and the temperature of the fingertip with cotton towels use was not significant (Figure 6d). No significant difference was observed between the groups in the amount of change in each measurement site and each measurement time of both materials (Figure 6).

Blood pressure fluctuated by approximately -0.2 to 2 mmHg when cotton or synthetic towels were used. However, a decrease of 2.7 mmHg in systolic blood pressure occurred 30 minutes after bed baths using synthetic towels ( $P=0.014$ ). No significant difference was observed between the groups in the amount of change in each measurement time of both materials (Table 2).

Figure 7 shows the analysis of heart rate variability based on electrocardiography. Heart rate decreased significantly between immediately and 30 minutes after bed baths using cotton or synthetic towels (4.8 times/minute) (Figure 7a). With cotton towels, parasympathetic activity (HF) increased significantly at 15 minutes after bed baths ( $P=0.015$ ), and HF was maintained at that level. Sympathetic activity (LF/HF) started to decrease gradually immediately before bed baths and declined significantly 30 minutes after the completion of bed baths ( $P=0.015$ ). Parasympathetic activity (HF) increased slightly immediately before the completion of bed baths using synthetic towels, but no significant change was observed between 15 and 30 minutes after bed baths (Figure 7b).

When synthetic towels were used, sympathetic activity (LF/HF) was low between immediately before and 15 minutes after the completion of bed baths, and then started to increase (Figure 7c). No significant difference was observed between the groups in the amount of change in each measurement time of both materials (Figure 7).



## Discussion

This comparative study examined the biological effects of complete bed baths on the bodies of healthy male students, focusing on differences between cotton and synthetic towels. The results of subjective and objective assessments suggested differences in bed baths using cotton and synthetic towels due to their surfaces.

The effects of complete bed baths in the present study reflected the characteristics of the two types of towels, and differed markedly from those of partial bed baths [5]. Below, we will discuss the comparison of the whole body cleaning effect of different towel materials in the order of touch and heat retention effect in this research result. In addition, a comparison between the results of this study and the results of partial cleaning will be discussed.

### Comparison of the textures of towels with concavities and convexities on their surface

The results suggested that subjects who took complete bed baths using cotton towels felt comfortable or were pleased with their texture with loops. Subjective assessments reported significant difference in "the removal of dirt", which differed markedly from partial bed baths using cotton towels, and J-POMS scores for "Tension-Anxiety" and "Fatigue" decreased with complete bed baths using cotton towels. For synthetic towels, the score for "appropriate softness" was high, but no significant changes were noted J-POMS scores after bed baths (Table 1, Figure 5). After complete bed baths using cotton towels with loops, subjects felt cleaner and more refreshed because wider areas of their bodies were cleaned than in partial bed baths. Although synthetic towels, used in either complete or partial bed baths, were soft and had a comfortable texture, they did not apply strong stimuli or change subject feelings because their surface was flat. It can be inferred that when the researcher wiped a wide area of the subject's body, the spatial facilitation effect was obtained by giving a decompression stimulus [15].

Among objective indices, decreases in heart rate occurred between immediately and 30 minutes after the completion of bed baths using cotton or synthetic towels, suggesting that tension was alleviated. When cotton towels were used, parasympathetic activity (HF) increased slightly immediately before the completion of bed baths, and a significant increase was observed 15 minutes after; parasympathetic activity (HF) did not decrease, suggesting that the sense of comfort had been maintained. Sympathetic activity (LF/HF) decreased immediately before the completion of bed baths, increased slightly, and then decreased significantly; Similar to the experimental results of Araki et al. and Fredrickson et al., It can be said that the tactile and pressure stimuli received on the skin were moderately felt and the excitement of the sympathetic nerve was suppressed [16,17]. Therefore, it can be said that with cotton towels, the touch and pressure stimuli on the skin due to the unevenness of the fabric surface acted in response to the autonomic nervous system. However, synthetic towels did not apply strong contact/pressure stimuli to the skin or significantly influence the function of the autonomic nervous system; parasympathetic activity (HF) increased slightly and was maintained at the same level after that. Therefore, when comparing the feel of the materials, the cotton towel seemed more comfortable than the synthetic towel because it was the result of the objective data also provided results that support the subjective results of relaxing the tension with synthetic towels. Texture was more comfortable in complete than in partial bed baths [5], particularly when cotton towels were used.

### Comparison of heat-retaining effects with a focus on differences in the inter-fiber space of the materials

Wet cotton towels rapidly become cold because the large volume of water contained in their inter-fiber space evaporates and their temperature decreases; the temperature of wet cotton towels was



reported previously to decrease from 80°C to 30°C or lower within 20 minutes [5]. Furthermore, mesh-type synthetic towels with large inter-fiber spaces exhibited less heat loss than cotton towels, although their heat-retaining effects more rapidly disappeared than with nonwoven towels because of more heat loss due to evaporation of moisture upon wetting [2]. Conversely, non-woven towels consisting of layers of dense sheets, as used in the present study, had high heat-retaining effects [18,19]. Heat-retaining effects are closely associated with aeration properties, which are influenced by the size of the inter-fiber space on the surface of towels, and the water absorption rate. According to the results of subjective assessments including texture, subjects felt the same level of warmth after they were cleaned using cotton or synthetic towels; however, they felt a significant difference in the sense of relaxation after bed baths. Synthetic towels produced a significant decrease in wakefulness after bed baths, suggesting that their heat-retaining effects were high.

Complete bed baths using cotton and synthetic towels increased core and skin temperatures in three regions of the body [anterior chest, right arm, and toe (first toe of the left foot)] until their completion because heat and massage stimuli during bed baths expanded arteriovenous anastomoses and warm blood was distributed to the superficial venous layer [20], which suggested that their heat-retaining effects were similar. During bed baths using cotton or synthetic towels, the skin temperature of the fingertip (fourth finger pulp of the right hand) decreased (by approximately -1.2°C) and then increased significantly until the completion of bed baths (by 1.5°C), which suggested that the heat-retaining effects of synthetic towels were higher. Because the heat-retaining effects of synthetic towels expanded the peripheral vascular system to increase the blood volume and decrease peripheral vascular resistance [20], a decrease occurred in systolic blood pressure after the completion of bed baths.

Ten minutes or less of hot fomentation did not necessarily increase parasympathetic activity (HF) even though subjects experienced a subjective sense of comfort [21]. Complete bed baths in the present study did not markedly influence the autonomic nervous system, presumably because the total cleaning time was <10 minutes; however, the heat-retaining effects of synthetic towels were maintained for longer than cotton towels.

On the other hand, the skin temperature after bed bath using both materials was compared by gender. Comparing the complete bed bath performed on the male students this time with the partial bed bath (limbs and back) performed on the female students in the previous study [5], the male students are especially the fingertips of the hands compared to the female students. Peripheral circulatory failure or excessive sensitivity to cold was noted in the toes (first toe of the left foot) of female students [22,23], and the skin temperature of their toes did not increase [5]. In complete and partial bed baths using synthetic towels, core and skin temperatures increased significantly until the completion of in three regions of the body [anterior chest, right arm, and fingertip (fourth finger pulp of the right hand)], but not in the toe (first toe of the left foot). This result suggested that heat-retaining effects are maintained regardless of the body region. In other words, when comparing the heat retention properties due to the difference in fiber gaps between the materials, both materials had the same heat retention effect, but the synthetic fiber towels have fewer gaps between the fibers than cotton towels and do not leak heat, so time has passed.

However, in complete bed baths using cotton towels or when larger areas of the body were cleaned than in partial bed baths, a dilation of

the peripheral vascular system, an increase in the blood flow, and a decrease in peripheral vascular resistance were observed as the effects of contact/pressure and massage stimuli applied to the surface of the skin even though the temperature of cotton towels decreased rapidly [20].

## Conclusion

The present study compared the effects of cotton and synthetic towels used for complete bed baths, which are often conducted in clinical settings. In a subjective assessment of texture, subjects felt more comfortable when cotton towels were used. Although the heat-retaining properties of synthetic and cotton towels were high, the temperature of synthetic towels, with larger inter-fiber spaces, decreased more slowly, and their heat-retaining effects over time were higher. Although the texture of synthetic towels was less comfortable and their surface did not apply as strong a stimulus, they were assessed as an alternative to cotton towels both subjectively and objectively.

We are planning to examine appropriate materials and forms used for the surface of synthetic towels, including the levels of concavities and convexities, in order to increase physiological and subjective comfort.

## Author Contributions

All authors have approved the final article and acknowledge that all those entitled to authorship are listed as authors. All authors met the criteria of authorship, substantial contributions to (1) conception and design, acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content; and (3) approval of the final manuscript. Chizuru Matsumura (CM), Kiyoko Fukai (KF) especially contributed to the study design, coordinated the study, interpreted the data, and drafted and reviewed the manuscript. CM especially contributed to the collection of data and the performance of statistical analyses. KF especially contributed to the program development and the supervision of program implementation.

## Approval code issued by the Institutional Review Board (IRB) and the Name of the Institution(s) that Approved

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the Okayama University Graduate School Nursing Science Ethics Committee (approval number D06-006, February 2007). This study was enrolled in the UMIN as an intervention study and as a prospective randomized crossover trial. The trial registration number is UMIN 000058203.

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## Competing Interests

The authors declare that they have no competing interests.

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