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Research Article

Development of A Relaxation Effect Evaluation System by Measuring Human Skin Comfort

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Abstract

This study aimed to examine the actual state of stimulation on the human skin by five wipe samples, including somatic sensations expressed in brain waves, skin moisture content measured by near-infrared spectroscopy, and skin surface roughness measured by biosensing, considering the degree of friction, skin surface temperature, humidity, and subjective image. This study provides a comprehensive review by referring to the results of previously reported biosensing measurements, brain waves, and near-infrared measurements.

A total of 20 university students (10 men and 10 women), with an average age of 22.4±0.94 years, were included in the study. No deviations were observed in the participants vital signs, and the participants were in good physical condition. There were five types of wipe samples: loop-woven drying towel, the steam cloth, the steam-generating cleaning tool, loop-woven squeezed towel, and shirring squeezed towel.

Regarding the comfort felt by wiping, the skin reaction and relaxation effect differed depending on the material. Moreover, samples that can provide steam to the skin surface may wipe the sebum from the skin; however, compared with conventional hot water squeezing, they give a sense of warmth and peace and can provide high-quality cleansing to the frail. It is necessary to appropriately select a wipe sample depending on the health condition of the subject. In addition to psychological evaluation, the latest medical engineering evaluation is a new system that can evaluate the relaxation effect on the human skin.

Keywords: Skin moisture content; Wiping; Steam cloth; Biosensing measurement; Near-infrared measurement; Brain wave

Introduction

The physical hygiene behaviour of an individual differs by country. While Westerners take showers more often, Japanese people prefer taking baths and often use public baths with other people. Bathing uses a lot of hot water, so it is also affected by the abundance of resources. Japanese people often take a bath at home to recover from fatigue; however, if they are hospitalized, they lose that opportunity. Nurses often perform wiping to frail patients and should provide a refreshing and skin-cleansing alternative to bathing. A wrung towel soaked in warm water is often used for cleaning, but it is necessary to finish by wiping off the moisture. If the moisture is not wiped off, the skin temperature will decrease by 0.5°C [1], making vulnerable patients feel cold and causing extra energy consumption. In hospitals, steamed towels made with cleaning trucks are used (Kawashima, 1985); however, if the steaming time is long, they contain too much steam and have the same drawbacks as wrung towels.

Therefore, the authors developed a steam-generating cleaning tool that does not leave moisture on the skin after cleaning and verified its effectiveness. In determining the effectiveness of wiping, many studies have conventionally relied on patients' subjective evaluations, such as "comfort," but the authors used brain waves. Electroencephalography (EEG) was used to measure skin sensation [2] and to evaluate bathing along with physiological indicators, such as heart rate and blood pressure and subjective evaluation [3]. Brain waves are electronically converted somatic sensations, and their types and corresponding brain activity states are classified as follows [4]: δ is a frequency component of 2-4 Hz, which may occur during sleep and brain trauma. θ is a frequency component of 4-8 Hz that is generated from the center of the head when performing calculations or mental activities. α is a frequency component of 8–13 Hz, which often appears mainly in the back of the head when the person is at rest with eyes closed and in a relaxed state. β is a frequency component of 13-30 Hz and a brain wave that often appears during an awake state. δ (delta) waves (0.5-< 4 Hz) and θ (theta) waves (4-< 8 Hz) have lower frequencies than alpha waves; therefore, they are considered slow waves and are noted during sleep. Other types include fast, thorny, and sharp waves [5,6].

Furthermore, subjective evaluation indicators include images that have been confirmed to have a certain degree of correspondence with brain activity states [7]. The measurement can be performed using the Semantic Differential Method (SD method). In fact, when the authors examined the relationship between a person's "comfortable" sensations in brain waves and imagery, they found that they were synchronized. Moreover, they measured the temperature, humidity, and moisture content of the skin surface environment and confirmed that these factors influence brain waves. From this measurement, it was explained that the cleaning material using steam a relaxing effect [8]. However, these measurements showed that differences in materials (shirred-cut towels, loop-woven towels, nonwoven towels, etc.) caused differences in types of skin irritation, had different effects on brain waves, and affected comfort. Therefore, the difference between the materials became an issue. Thus, the quality of the material is also related to the feeling of "comfort," so a comprehensive texture evaluation is necessary. Additionally, in our study (2021), a moisture sensor (Shinei KK's thin-walled THP-728 and a network-type thermo-hygrometer TRH-7X) was used to measure the amount of moisture on the skin surface after wiping. This was performed by inferring moisture from the amount of spatial transpiration rather than directly measuring the amount of moisture remaining on the skin surface after wiping. Therefore, to accurately measure the amount of water on the skin surface, it was necessary to identify the amount of water using near-infrared spectroscopic imaging.

Near-infrared spectroscopy, which has a characteristic water absorption peak, is suitable for direct moisture measurement. Morimoto et al. (2022) [9] used near-infrared imaging and two-dimensional Fourier spectroscopy to quantitatively identify the amount of water on the skin surface before and after wiping.

This method uses absorbance, which is a dimensionless quantity that indicates how much the intensity of light decreases when it passes through a certain object. It also indicates the amount of light absorbed and estimates the actual water content from the absorbance. The absorbance was measured using an imaging-type dimensional Fourier spectrometer IRS-N0917Q [10] (Ishimaru I., 2005, manufactured by Nisshin Kikai, Kagawa Prefecture) and near-infrared spectroscopy developed by Ishimaru et al. A tungsten halogen light was used as the near-infrared light source. Near-infrared light from this near-infrared light source can be safe for living organisms because even when it is continuously irradiated onto human skin at a constant irradiance, the temperature of the skin does not decrease [11].

Morimoto et al. (2022) [9] measured the amount of skin moisture of nine men after wiping with three types of materials: steam cloth, loop-woven towel, and shirring squeezed towel. The intervention method involved swab testing the inside of the forearm. The relative change in the absorbance of the skin surface before and after wiping and the absorbance of the wiping material were measured using an imaging-type dimensional Fourier spectrometer with near-infrared rays for 40 s. The results showed that the absorbance of the cleaning materials increased in the following order: the steam cloth, shirring squeezed towel, and loop-woven squeezed towel. Moreover, in terms of absorbance on the skin surface, 8 of 9 people confirmed that moisture increased in the order of the steam cloth, loop-woven squeezed towel, and shirring squeezed towel. This indicates that the amount of water contained within each wiped sample and the amount of water smeared on the skin surface are different.

Furthermore, when moisture is smeared onto the skin surface by wiping, a friction sensation occurs in addition to a warm and wet sensation. A person's sense of "comfort" may also be influenced by the sensation that occurs when moisture changes the skin surface. Biosensing technology can capture such changes in a person's biological body; tactile sensors have been developed as one of these technologies. Previous skin texture evaluation indicators have measured surface roughness, slippage, and static friction, but it was unknown.

Therefore, Hisayasu et al. (2023) [12] developed a nontactile device that can measure unevenness and abrasion phenomena on the skin surface side and the surface side of the cleaning material during wiping and conducted skin measurements before and after wiping. The fine undulations of the skin surface and the sharp waveform at the top that had been observed before wiping disappeared immediately after wiping, and a smooth, large-amplitude waveform due to swelling was obtained. Two minutes after wiping, the skin becomes dry and the fine undulating waveforms begin to appear again. The surface irregularities peaks, and bottoms of the frictional force waveform were determined in a visualization diagram that numerically analyzed the temporal changes in the skin surface condition for each wiping method. Using the difference in unevenness, the numerical difference between the average value and SD before and after wiping was investigated. For all materials, it was confirmed that the average value and SD increased immediately after wiping and decreased 2 min after wiping [12].

Therefore, it is necessary to re-examine whether there is a difference in the objective index of comfort depending on the cleaning material.

Purpose

This study investigated the actual state of human skin stimulation caused by five wipe samples using somatic sensations expressed in brain waves, skin moisture measured by near infrared spectroscopy, skin surface temperature, humidity, and images. This study aimed to consider the roughness of the skin surface and the degree of friction detected by sensing. This study comprehensively reviews reported biosensing, brain waves, and near infrared measurement. The explanatory power of the objective evaluation index of “feeling comfortable on human skin” is expected to be improved.

Methods

Study Design

Intervention observational study.

Participants

A total of 20 university students (10 men and 10 women), with an average age of 22.4±0.94 years, were included in the study. The average vital signs of the participants were systolic blood pressure of 121.5±11.99 mmHg and 74.3±5.19 mmHg, body temperature of 36.6°C±0.27°C, pulse rate of 81.7±11.34 times/min, and respiratory rate of 15.0±3.07 times/min. They did not have pathological deviations.

The participants had a clear level of consciousness, did not have metabolic diseases such as diabetes, and did not apply oil to the measurement site. They got enough sleep, had no subjective symptoms of dry mouth, were in good physical condition, were not taking oral medications daily, did not have difficulty maintaining the same position, and had no mental symptoms due to tension. Immediately before the measurement, we confirmed that they were suitable participants.

Wipe Samples

Five types of wipe samples were used: loop-woven drying towel, the steam cloth, the steam-generating cleaning tool, loop-woven squeezed towel, and shirring squeezed towel. The tests were performed in the order listed above.

1. Loop-woven Drying Towel

A water-free 100% cotton loop-woven towel was used.

2. The Steam Cloth

The steam cloth was created based on Published Patent No. 6734013 [13]. The method for making the steam cloth is shown in the figure. (1) Prepare two loop-woven cotton towels; fold the first towel in eight, and fold the second in four. (2) Open the first towel, and pour 20 cc of boiling water at 80°C–90℃ into the center. (3) Squeeze the first towel dripped with hot water with your hands to remove the hot water. (4) Tap the first towel containing steam with your palm to instantly cool it to approximately 50°C–55°C. (5) Place the first towel between the second four-folded towel. (6) The steam-filled towel is now wrapped in a drying towel. However, in the measurement, considering the reactivity to the data, only the first towel containing steam was used for wiping.

3. Steam-Generating Cleaning Tool

The steam-generating cleaning tool was created based on registered patent No. 6705081 [14], (Figure 1). This wiping tool is characterized by a structure consisting of a heating element and nonwoven fabric coated with hydrophilic jelly. The heating element is a hand warmer type and generates heat between 60℃ and 80°C with air. A hand warmer-type heating element is wrapped in a nonwoven fabric coated with hydrophilic jelly, and the water inside the jelly moves outside due to the heat of the heating element. It can also be used to clean the skin and as a pack with a protective cloth. The effects of wiping include cleaning the skin, relaxing the skin by warming it, and promoting circulation from the periphery of the limbs to the central region.

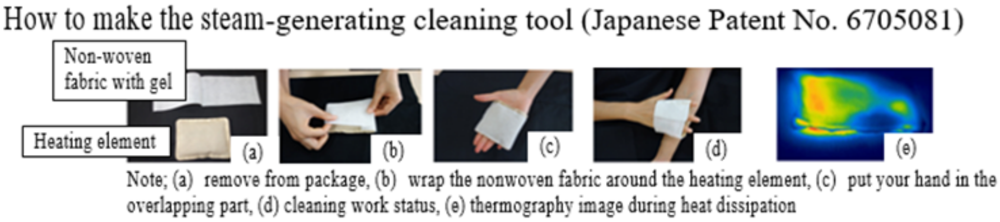

Figure 1: How to make the steam-generating cleaning tool.

4. Loop-woven Squeezed Towel

It is a wet towel made by soaking a 100% cotton loop-woven towel in 50°C hot water and then squeezing it by hand. It is used daily at home and in medical settings. The surface has a protruding loop-shaped thread, and the loop-shaped structure can retain moisture.

5. Shirring Squeezed Towel

It is made of 100% cotton, and the ends of the loops of a loop-woven cotton towel are cut off to make it more comfortable for the skin. Therefore, it is not possible to retain moisture after wiping, and the amount of moisture smeared onto the skin surface will increase compared with the loop-woven towel. The method for making it is the same as that for a hand-squeezed wet towel.

Measuring Method

In addition to the loop-woven drying towel used under controlled conditions, the measurement order was a loop-woven towel (water temperature, 50 °C), shirring squeezed towel (water temperature, 50°C), the steam cloth, and the steam-generating cleaning tool. The wiping method involved the participant sitting on a chair and wiping the inside of the forearm twice from the wrist toward the elbow while at rest. To standardize the technique, cleaning was performed by a specific person under the guidance of an experienced nurse. The participants also wiped the same area on the same day and identified the measurement area.

Measuring Tools

Temperature and Humidity Measurement Tools

A moisture sensor (Shinei KK's THP-728 and network-type thermo-hygrometer TRH-7X) was used to measure the temperature and humidity of the skin surface. Data collection was performed using an independently developed app (by Nisshin Kikai, Kagawa Prefecture, Japan).

Moisture Measuring Device Using Near-infrared Spectroscopy

Skin surface moisture content measurement was performed using an imaging-type dimensional Fourier spectrometer IRS-N0917Q (Patent No. 4474535, 19 registered Japanese patents, 14 patent applications in Japan, 20 registered international patents, 18 international patent applications) [10] using near-infrared spectroscopy (Nisshin Kikai, Kagawa Prefecture, Japan). The measurement band was 900–1,700 nm, and the number of pixels was 320 × 256 pixels.

Image Measuring Questionnaire

We created a questionnaire to measure images using Kawachi et al.'s (2008) [15] 5-factor 20 adjective pairs and Nishikawa et al.'s (1997) [16] 4-factor 57 items (1997) as item pools. The items were extracted statistically. The rating scale of the questionnaire was 1-10. Nineteen women with an average age of 23.18 ± 7.87 years were surveyed, and after a swab test of their left or right forearm with two different samples, they completed a questionnaire survey. The analysis was performed using IBM SPSS version 24 (IBM Company, USA) and the Ward's method cluster analysis based on Euclidean distance. The extracted question items were thermal sensation (warm - cool, comfortably warm - cool, poka poka – buru buru), luck / misery (like - dislikes, comfortable - uncomfortable, gentle feeling - thorny feeling, happy - unhappy, healthy - unhealthy, feeling laid back - feeling not busy, feeling graceful - feeling vulgar), and feeling of openness (progressive feeling - conservative feeling, simple feeling - sophisticated feeling, feeling refresh - feeling moist), softness (feeling hungry - feeling relaxed, nervous - relaxed, feeling soft - feeling hard, dry - moist), and cold sensation(be cool- stuffy, cool down - sloppy, slightly cold - warm, chilly - sweaty).

Brain Waves

The participants were seated in a reclining chair, at rest, and with their eyes closed, and the inside of their left forearm was wiped using the wipe tools. EEG measurements were performed using the international 10-20 system, and silver chloride electrodes were attached on the scalp to record brain waves at the following nine locations, F3, F4, Fz, C3, C4, Cz, O3, O4, and Oz [17]. First the control EEG was recorded for 2 minutes before wiping. Subsequently a, test EEG was recorded for 2 minutes from the start of wiping for 10 seconds. After a 3-minute break, the test EEG recordings were repeated five times using each wiping tool. The order the five wiping tools was randomly changed in each subject. Measurements of the SD method were performed. before and after all EEG recordings.

Biological Sensing Equipment

It is thought that the stimulation of wiping the skin surface also affects the friction caused by the unevenness of the skin surface. Therefore, we installed a high-resolution tactile sensor (nanotactile sensor) developed by Takao et al. (2023) [12] that achieves a maximum displacement resolution of ≤42 nm and an input resolution of ≤ 12 µN. A scanner-type tactile measurement device that can measure unevenness changes was used [12].

Measurement Environment

The laboratory environment had a temperature of 24.4℃±0.85℃ and humidity of 63.9% ± 3.10%, and the experiment was conducted in a laboratory on the second floor of a reinforced concrete building at University A.

Measurement Period

Measurement data for cleaning materials were collected from September 11-23, 2022.

Analysis Method

Temperature and humidity were examined descriptively, and images were examined based on cross-correlation between wipe samples. Near-infrared spectroscopy measurements of moisture were performed by comparing the average absorbance of the water absorption peak (1450 nm) on the skin surface before and after each wipe. We analyzed the recorded EEGs as follows. After we excluded raw EEG data obtained up to 10 seconds from the start of wiping, we sampled the subsequent noise-free raw EEG data four times for 10 seconds each. For power spectrum (PS) analysis, epochs sampled for 10 seconds were transformed by fast Fourier transformation with 8.4 sampling points/Hz using EFRP-RT version 3.1.0 (Melon Technos Co, Japan), and four transformed data in an electrode were averaged in each channel. We manually measured the peak value ((µV)*2) and the area (µV)*2xHz) of each frequency band as Θ (4-8 Hz), slow α (8-11 Hz), fast α (11-14 Hz), and β (14-30 Hz). A statistical comparison using repeated - measures analysis of variance and paired Student's t-test was performed among the conditions [17]. In biosensing measurements, skin surface and frictional irregularities were compared between the wipe samples. Finally, we descriptively examined the relationship between the objective indicators.

Results

No participants who provided consent to participate in the measurements dropped out.

Temperature and Humidity (Figure 2, 3)

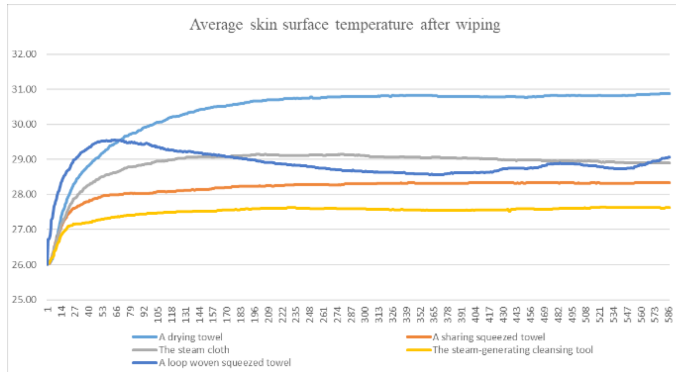

Figure 2: Skin surface temperature change after wiping: standardization (N=20).

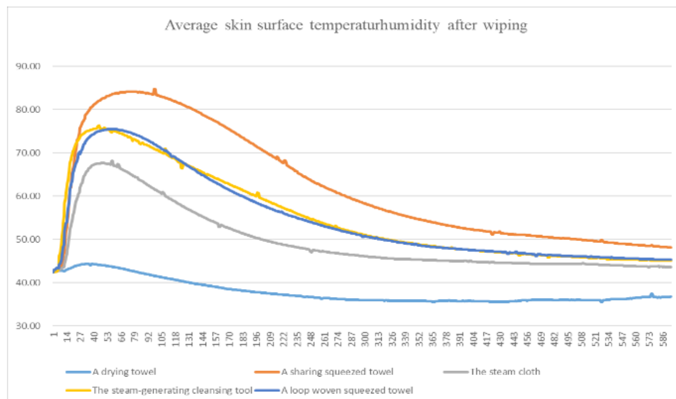

Figure 3: Skin surface humidity change after cleaning: standardization (N=20).

The drying towel did not contain moisture upon wiping and maintained a high skin surface temperature. The cotton loop-woven towel had the highest temperature increase, but a temperature decreases in 1℃ was observed after 40 s. The other samples showed no decrease in temperature after wiping. Regarding humidity, the shirring squeezed towel had the highest humidity, followed by the steam-generating cleaning tool, looped woven squeezed towel, and steam cloth. In both cases, the humidity on the skin surface was highest after 40 s and gradually decreased until 5 min later. After drying the towels, humidity decreased from baseline [18].

Skin Surface Moisture Content

The absorbance increased in the following order: the steam cloth, the steam-generating cleaning tool, drying towel, loop-woven squeezed towel, and shirring squeezed towel. The ranking of the wipe samples according to moisture content is shown in (Figure 4), [9].

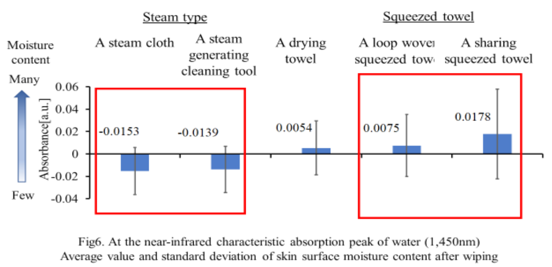

Figure 4: At the near-infrared characteristic absorption peak of water (1,450 nm (N=20). Average value and standard deviation of skin surface moisture content after wiping (N=20).

Image

The images showed high correlation coefficients between all swab samples (r=0.693–0.924). High correlation coefficients were found between the steam cloth and the steam-generating cleaning tool (r=0.924, p<0.01) and between the steam cloth and cotton loop-woven towels (r=0.917, p<0.01). Both the steam-generating cleansing tools and the steam cloths made of nonwoven fabric apply steam to the skin surface, so the temperature is high. A loop-woven squeezed towel also has high-temperature similarities because it does not easily shed moisture and is able to retain heat within (Figure 5).

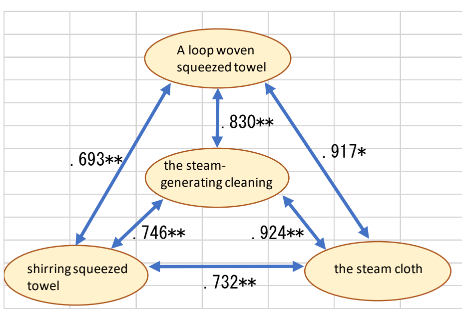

Figure 5: Correlation of wipe samples (N=20).

Wiping with a drying towel did not provide warmth or sophistication but rather a feeling of dry tension and coldness. The loop-woven towel gave only a low feeling of coldness and low sense of well-being in terms of overall thermal sensation factors and happiness/unhappiness factors. The shirring squeezed towel provides 'gentle feeling', 'happy', 'feeling laid back', and 'feeling soft'. The steam cloth gave a feeling of 'warm', 'happy', and steaming. The steam-generating cleansing tool gave a feeling of 'warm', 'comfortable', 'happy', 'healthy', and 'progressive' (Figure 6).

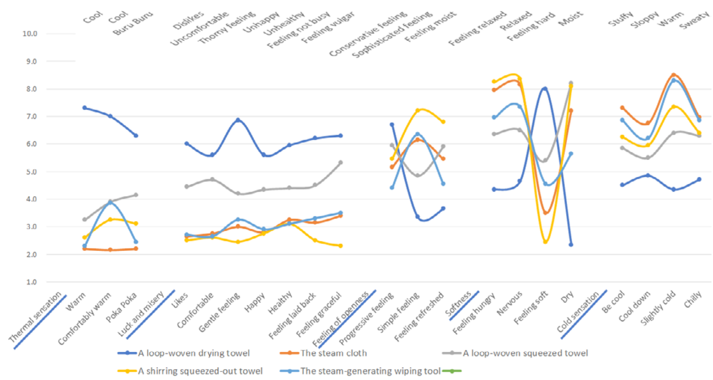

Figure 6: Average value of image questionnaire responses for five types of cleaning samples (N=20).

Brain Waves and Images

Significant changes were shown in the peak value of the slow α-band among the conditions at F3, F4, Fz, Cz, and C3 ($p \leq 0.05$), with the highest peak value occurring during cleaning with the steam-generating cleaning tool. There was no significant difference in the area of the slow α-band among the wiping methods. The peak value of β-band showed a tendency of significant change in C4, with the highest value observed with the steam-generating cleaning tool. Furthermore, the area of β-band showed a significant change in C4 ($p \leq 0.05$). The shirring squeezed towel had the highest value, followed by the steam-generating cleaning tool. As a result of the SD method, participants felt warmer, more comfortable, happier, healthier, and most progressive with the steam-generating cleansers. The shirring squeezed towels evoked in the participants a strong sense of 'gentle feeling', 'happy', 'feeling laid back', and 'feeling soft'. The drying towel provided the participants with a strong refreshing feeling.

Irregularities on the Skin Surface

Immediately after wiping, the unevenness and frictional unevenness of the skin surface increased in all five wipe samples [12]. Shirring squeezed towels and loop-woven squeezed towels had the largest increase, followed by the steam cloths and the steam-generating cleaning tools. Furthermore, the unevenness of friction on the skin surface after wiping had the highest increase with the loop-woven squeezed towel, followed by the steam-generating cleansing tool, shirring squeezed towel, and steam cloth. However, the peak appearance of the shirring squeezed towel was delayed and continued (Figure 7, 8).

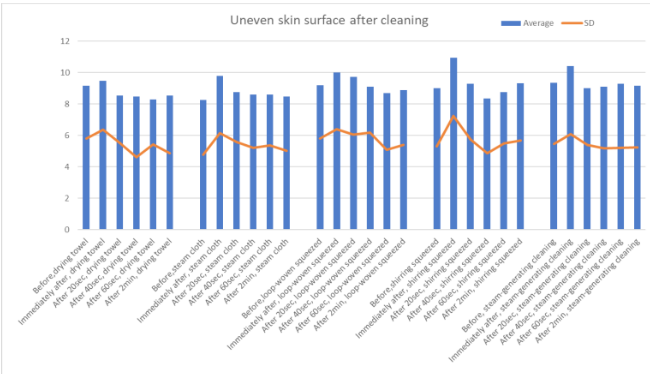

Figure 7: Degree of uneven skin surface after wiping (N=20).

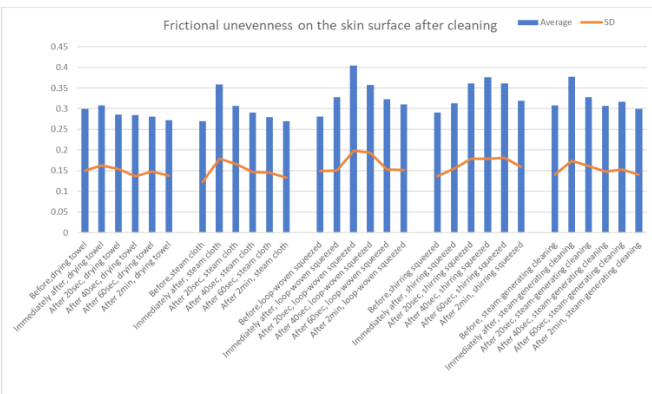

Figure 8: Degree of skin surface friction after wiping (N=20).

Discussion

Skin Surface Temperature and Humidity After Wiping

The temperature and humidity of the skin surface after wiping differed depending on the wipe sample. Skin temperature was maintained in the following order: drying towel, the steam cloth, shirring squeezed towel, and the steam-generating cleansing tool. No significant temperature loss was observed after use. However, the loop-woven squeezed towel reduced the skin surface temperature by approximately 1°C. This demonstrated that the temperature drop was even greater than the experimental results of [1]. The measurements were taken indoors at mid-September in Japan in an average of 20 men and women; therefore, the drop-in temperature is obvious and debilitating for vulnerable patients.

Although the humidity curves after wiping had a similar pattern, the humidity was higher for the shirring squeezed towel, the steam-generating tool/loop-woven squeezed towel, the steam cloth, and drying towel. Because the drying towel removes humidity from the skin surface and increases the temperature of the skin surface, it is believed to be caused by the frictional heat generated on the dry skin surface.

Moisture Content on the Skin Surface Measured by Near-Infrared Rays

When the skin surface moisture content was measured using near-infrared rays, the moisture content was highest in the order of shirring squeezed towel, loop-woven squeezed towel, drying towels, the steam-generating cleansing tool, and the steam cloth. It can be said that the steam-generating cleaning tool and the steam cloth with negative absorbance values had high skin smeared steam temperatures, had no sudden drop-in skin surface temperature, and were cleansing with a low moisture content. The fact that the drying towel produced a small amount of moisture compared with the baseline may be due to the heat from the friction of the drying towel replenishing the moisture on the skin surface and because the steam cloth or the steam-generating cleaning tool causes moisture to be lost and progression to dryness. This suggests that transpiration was accelerated by high-temperature steam. This measurement clarified the differences in moisture content on the skin surface, increasing the ability to explain differences in water retention and smearing due to the raw material and texture of the material.

Effects on Imagery and Somatosensory Activity

Previous studies using PS analysis have reported that an increase in Q-band and a decrease in slow β-band are associated with a relaxing effect on the brain [17]; however, the present results did not show similar PS changes. With the steam-generating cleansing tool, we observed an increase in the peak value of the slow α-band, mainly in the forehead. Previous studies reported that the α-band increased due to aromatherapy [19], positive sound stimulation [20], listening to Mozart music [21], and audio-visual relaxation [22]. Another report indicated that olfactory-visual stimuli increased α-band and β-band [23]. Furthermore, it was reported that α power was correlated with resilience [24], and a correlation was observed between α peak frequency and calm score [25]. In comparison with the results of the SD method, the steam-generating cleaning tool had a more "progressive feel" than other cleaning methods. Therefore, the peak value of the slow α-band was higher with the steam-generating cleaning tool, which may be related to the novelty of cleaning with the steam-generating cleaning tool and the attentiveness of the examinee.

Due to the mechanism by which the peak value of the slow α-band increases, the synchronization of slow-frequency α waves maight have increased. Previous researcher pointed out a correlation between alpha waves and thalamic activity [26], which needs to be investigated. Because brain waves are data on electrical conversion of sensations, psychological stimuli such as attention may also have had an influence. The average data of 20 people this time did not support the results of one case measurement [8], so there is a possibility of individual differences. The skin surface temperature of the steam-generating cleansing tool was relatively low. The reason for this is that, since the material applied to the skin is vapor, it does not produce heat of vaporization, so it feels warm, creating a peaceful state like sleep, which is what slow α means.

Irregularities and Friction on the Skin Surface Using Biological Imaging

The difference in surface unevenness before and after wiping between the cleaning materials was the largest in the order of shirring squeezed towel, the steam cloth, the steam-generating cleaning tool, and loop-woven squeezed towel. The difference in friction before and after was that of the steam cloth, the steam-generating cleaning tool, loop-woven squeezed towel, and shirring squeezed towel. This measurement suggests that friction may have increased because the smoothness of the skin surface caused by sebum was removed by hot water or steam.

Characteristics of the Wipe Samples

Loop-woven drying towel

Based on the characteristics of near-infrared rays, temperature, and humidity after wiping, the temperature of the skin surface increased even when the drying towel rubbed the skin. Drying towel increased the skin temperature, verifying its validity in preventing cold.

Loop-woven squeezed towel

This sample is immersed in hot water at 50°C and then squeezed, increasing the temperature of the skin, but the large amount of water smeared on the skin causes a rapid drop-in skin temperature. Therefore, after wiping, you may feel a cooling or refreshing sensation, but this is a wiping sample that is likely to generate heat of vaporization.

Shirring squeezed towel

Based on the results of near-infrared measurement, this sample smears a lot of moisture on the skin surface by wiping, and skin temperature did not decrease after 4 min. However, it is possible. Because this skin surface humidity evaporates rapidly, it may generate heat of vaporization even if it does not decrease skin temperature. In the image, it gave feeling graceful and feeling soft, but it did not have a relaxing effect.

The Steam Cloth

Of the wet samples, the steam cloth had less moisture and humidity on the skin surface, did not generate heat of vaporization, and kept the skin temperature high, giving a feeling of warmth. Since the skin surface moisture content and images were obtained similar to those of the steam-generating cleansing tool, it is expected that the user will be able to easily achieve the state of peace that comes with the cleansing tool. When the steam cloth was actually applied to four terminally ill cancer patients, physical pain was alleviated, and they made comments about pain relief. This discourse was accompanied by joy and empathy, and it restored a sense of vitality to the patient that would not have been possible if it were not implemented [27,28]. Because the participants in this study were healthy university students, the relaxation effect may have been limited.

The Steam-Generating Cleaning Tool

Based on the brain wave results, this product is expected to have a relaxing effect. Unlike a towel, the surface is made of nonwoven fabric; therefore, it is a new cleaning tool that can provide a feeling of warmth and happiness even if the skin surface temperature is low [29]. In addition to providing warmth, this cleaning tool is expected to give an image of feeling laid-back and relaxed feeling and to relieve tension [27,28].

Conclusion

The materials used as cleaning samples have different irritants to people and skin reactions depending on how they are used. Furthermore, the sample that provides high-temperature steam to the skin surface wipes away sebum from the skin, giving a sense of peace compared with conventional hot water squeezing and can provide high-quality cleansing to frail patients. However, the novelty of the steam generating cleaning tool and the fact that the participants' attentiveness affected the brain waves became an issue.

Therefore, it is necessary to select the cleaning material according to the target and purpose of cleaning. To date, there have been no data based on the latest medical engineering evaluation in addition to psychological evaluation. We obtained important knowledge for explaining the sensation of the human skin.

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Ethical considerations

Based on the Declaration of Helsinki, this research complied with the ethical guidelines for life science and medical research involving Japanese participants and was approved by the ethics committee of the institution to which the researchers belong. (Kagawa University approval number: 2021-089, jRCT1060210045).

Conflicts of Interest

None.

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