Research Article

Comparison of Image Data and Visually Confirmed Sketches to Evaluate the Technique of Handwashing

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Abstract: Hand hygiene is crucial in preventing healthcare-associated infections. In this study, we aimed to quantify the accuracy of subjective evaluation of hand washing through visual inspection and objective evaluation through images. The participants were 24 consenting nursing students, and the study used black light and fluorescent paint to generate sketches and captured images of the unwashed areas, which were processed. Handwashing training was conducted once a week for four consecutive weeks. We collected data in the first and fourth training sessions. We found that the percentage of the unwashed palmar areas was significantly higher in the images than in the sketches ($p < 0.05$). The percentage of the uncleaned area as recognized visually significantly increased for sketches ($p = 0.01$) and decreased for images ($p = 0.009$) in the fourth session. The difference between the percentages of the image and sketch area notably decreased in the fourth session ($p = 0.002$). When we checked the recognition percentage of the unwashed area by dividing the right-hand palmar side into six areas, the fingertips had the highest percentage, and the ball of the thumb had the lowest percentage. The recognition of the unwashed areas was low when comparing the subjective visual assessment with the objective imagery assessment. In addition, the percentage of the unwashed areas decreased with repeated training, indicating a decrease in the difference between the subjective and objective ratings.

Keywords: Handwashing Evaluation; Image; Nursing Student; Sketch; Unwashed Area

1. Introduction

Hand hygiene is the most important and fundamental measure in preventing healthcare-associated infections [1,2]. Many institutions, therefore, implement interventions to encourage appropriate hand hygiene, one of which is the visualization of unwashed areas after handwashing [3]. Currently, adenosine triphosphate (ATP) wiping and observation using fluorescent lotion with a black light are used to confirm the remaining unwashed palmar areas. Among these, the process of using a black light and fluorescent lotion, which is relatively easy to perform, is frequently employed as education for compliance with the appropriate hand hygiene behavior. Most evaluations are based on subjective observations by counting the unwashed areas and visual confirmations [3-7]. How the practitioners themselves perceive the actual unwashed areas is unclear. This method has a strong impact on the implementer because the areas where the hand washing was insufficient can be visualized. Since visual confirmation by both the implementer and the evaluator is performed in a short time, the possibility that the implementer may have missed areas that were recognized as being unwashed by the

evaluator cannot be denied. In addition, records are rarely kept, making their use difficult for continuous education. In contrast, the ATP wiping test is expressed numerically and can lead to objective evaluation and continuous education. However, its impact is weak because it cannot visually confirm the actual remaining residue or the recognition of the implementer.

Several reports have been developed on objective evaluation through visualization, but the method is generally difficult to use because it requires expensive equipment and special programs [8-10]. Studies have also not evaluated implementers' perceptions. Therefore, we sought to clarify the accuracy of subjective evaluation by making a device using a commercially available item, thereby making objective evaluation possible.

Our study aimed to explain the accuracy of recognition by quantifying subjective evaluation through visual inspection and objective evaluation through images and confirming the homology. All the participants in this study had already learned how to wash their hands with running water and soap, as recommended by the World Health Organization (WHO) for handwashing lectures.

2. Materials and Methods

2.1 Participants

The study sample comprised 24 nursing students. The participants' age range was 20–24 years; 96% (n=23) were female, and 4% (n=1) were male. The institutional review board approved the protocol, and all participants provided written informed consent. All participants attended a lecture on hand hygiene as part of basic nursing education. Then, we applied fluorescent paint to the participants' hands without leaving any gaps. Participants followed WHO procedures and made their own judgments about handwashing practices. Researchers did not provide feedback during or after implementation. We conducted this handwashing training once a week for four consecutive weeks and collected data in the first and fourth sessions.

2.2 Data Collection Tools

We used a black light (BLB handwash checker, Saraya, Osaka) for sketching purposes. In addition, we used a handmade box with a fluorescent lamp, a black light installed inside a commercially available plastic cardboard box, and a commercial digital camera (PowerShot G7 X Mark II, Canon, Tokyo, Japan) for photography purposes. The capture box was a combination of a camera and a capture box (Figure 1). The following were the camera parameters: an f-stop of 2.8, a shutter speed of 1/60 second, and an ISO setting of 125. We selected the camera parameters such that they would not cause overexposure when visible light was turned on. The fluorescent cream used for the study was Glitter Bug^R (Potion, BREVIS, USA).
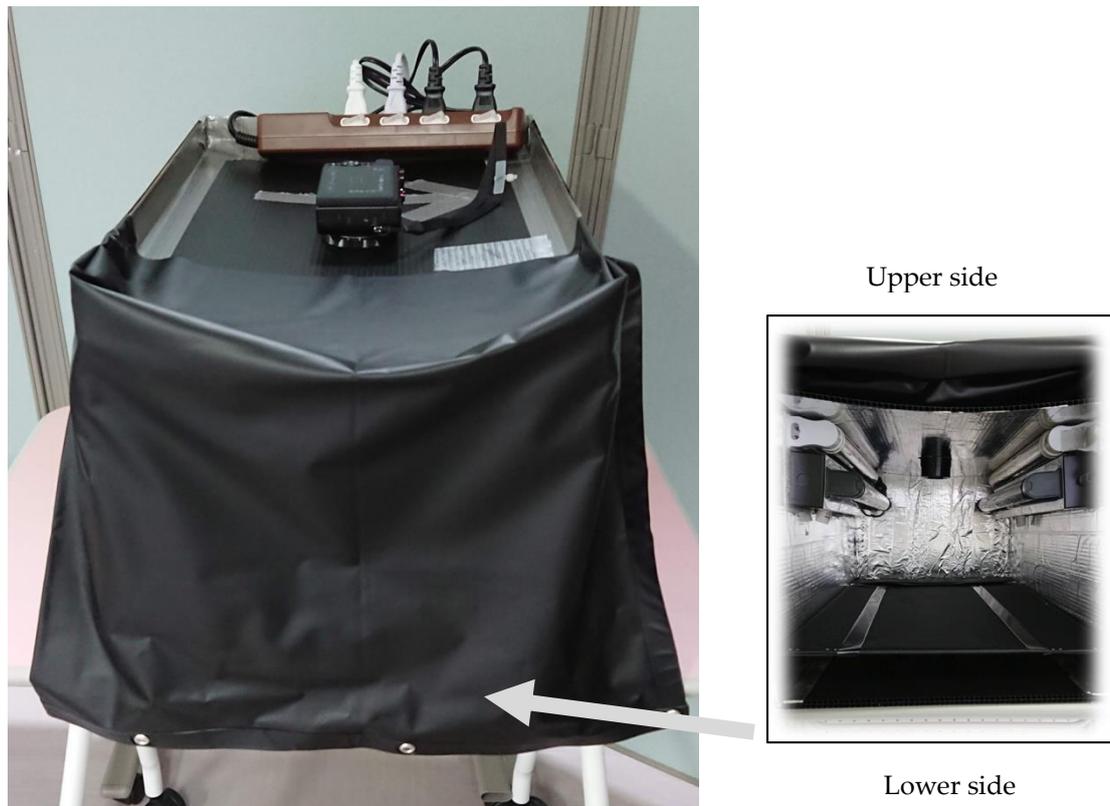
Figure 1. Image capture box. *Note:* The image capture box was composed of five carbon plastic boards, two blacklights, two LED lights, and a blackout curtain. A digital camera was selected and attached to the box to take photos.

2.3 Study Procedure

In this study, only the palmar side was photographed and analyzed. The procedure for taking photographs was as follows:

Step 1: Participants applied the fluorescent paint to their entire hands. We then checked the fluorescent-painted hand under ultraviolet light to see if the application was uniform.

Step 2: Participants washed their hands with soap and tap water according to the WHO guidelines. They then dried their hands using paper towels.

Step 3: Participants sat in front of the image capture box and inserted their right hand into the box with the palm facing upwards. After palm placement, we captured the palm's image, first in normal light and then in black light.

Step 4: Participants visually inspected their right palms and filled in the fluorescent areas on the prepared handprint paper.

Step 5: After the researchers collected the data, they returned the images and sketches to the participants.

2.4 Data Processing and Analysis

We processed the collected images using MATLAB 2017b (The MathWorks, Inc.) and the associated toolbox. For both photographs and sketches, we calculated the unwashed areas as the area of fluorescent spots in pixels. We derived the scores for handwashing skills by calculating ratios as follows:

Score = (area after hand washing) / (area before hand washing)

We calculated the percentage of the area where fluorescent paint remained after hand washing from the scores.

Statistical analyses were performed using IBM SPSS Statistics for Macintosh ver. 27.0.

We performed a Mann–Whitney U test to determine the first and fourth sketches, first and fourth images, and the unwashed area reduction rate of sketches and images. Additionally, we used Spearman's rank correlation coefficient to determine the correlation between sketches and images.

3. Results

3.1 Unwashed Area Ratio

For all participants, the mean percentage of the unwashed palmar areas in the first session was 0.7±1.4% for sketches and 15.5±6.6% for images. In the fourth session, the mean percentage of the unwashed palmar areas for all participants was 2.2±2.9% for sketches and 10.6±5.0% for images. We found that the percentage of the unwashed palmar areas was significantly higher in images than in sketches (p<0.01) (Figure 2).
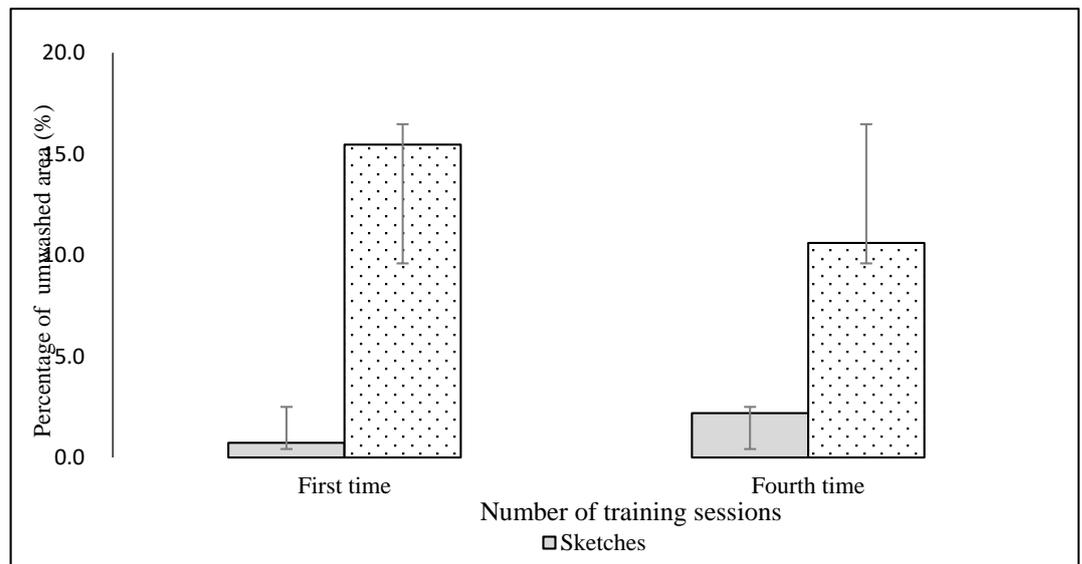
Figure 2. Comparison of unwashed area percentages in sketches and images. *Note:* Results shown by Mann-Whitney U tests. **p*<.05. Sketch: A picture drawn by visually checking; Image: A photo taken with a camera.

3.2 Correlation between the Sketches and Images

Spearman's rank correlation analysis of the sketches and images showed no significant correlation (first time, p=0.939; fourth time, p=0.08) (Figure 3).
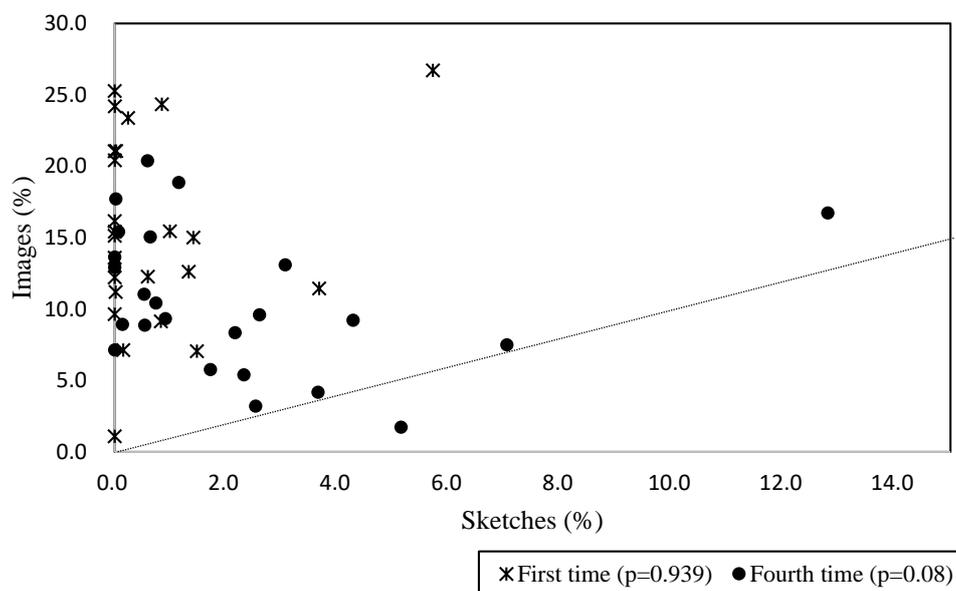
Figure 3. Correlation between image and sketch. ***Note:*** There was no correlation, but during the fourth time, the area ratio of the image and the sketch tended to approach the same level. Sketches: Unwashed areas sketched by participants; Images: Unwashed areas photographed by the capture box.

### 3.3 Comparison of Unwashed Area Ratio of Sketches and Images

Comparing the sketches from the first and fourth sessions, we noted a significant increase in the area ratio of the unwashed parts after hand washing during the fourth session (p=0.01). In contrast, a comparison of the photographic images from the first and fourth sessions revealed a significant decrease in the percentage of unwashed areas (p=0.009). Furthermore, to confirm the unwashed areas, which were beyond the participants' subjective view, we compared the sketch area ratio with the image area ratio between the first and fourth sessions. We found a marked difference in this area ratio, and this difference decreased in the fourth session (p=0.002) (Figure 4).
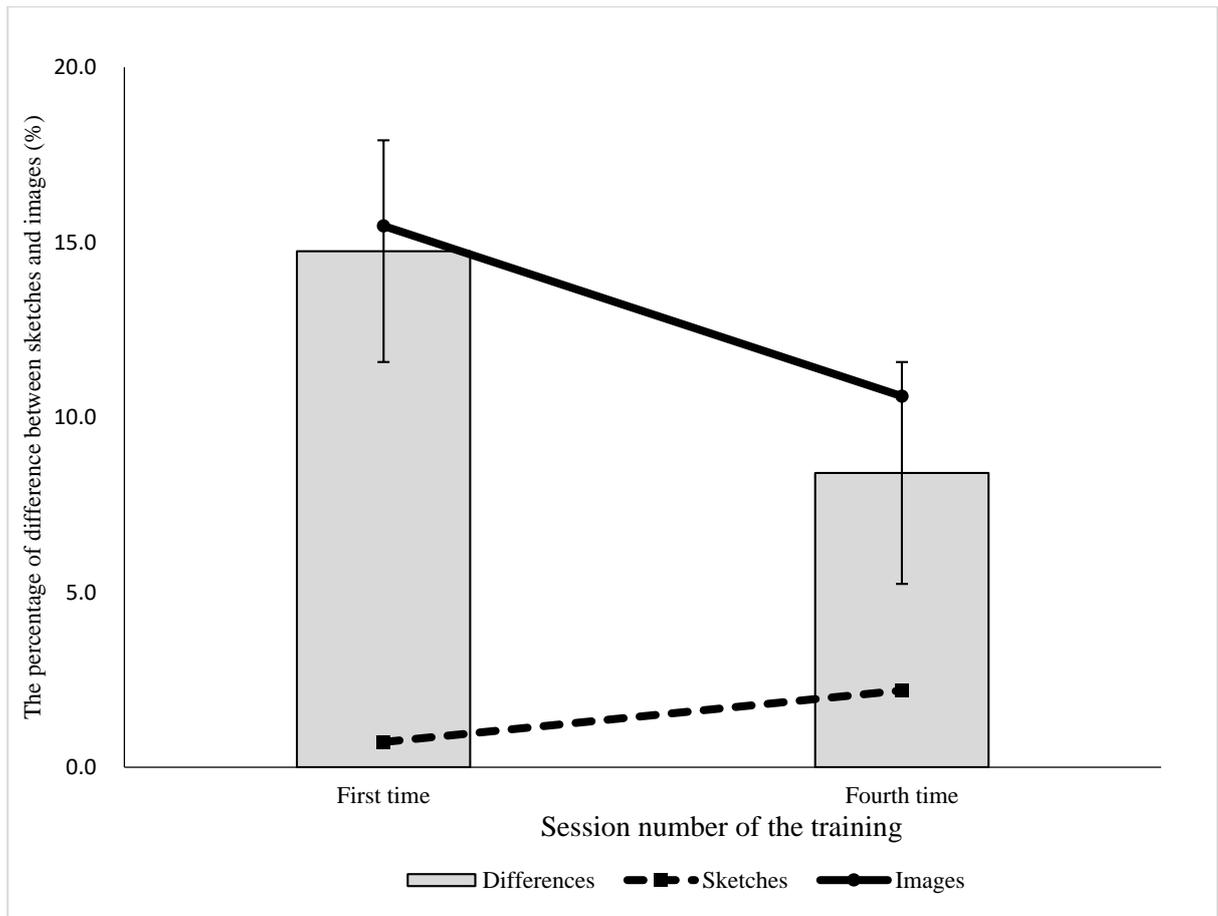
Figure 4. Changes in unwashed areas before and after training. ***Note:*** Results shown by Mann-Whitney U tests. *p<.05. **p<.01 differences: The difference in the area ratio calculated by subtracting the sketch area ratio from the image area ratio. Sketches: Unwashed areas sketched by participants; Images: Unwashed areas photographed by the capture box.

3.4 Recognition Rate and Ratio of Images and Sketches

We divided the palm side of the right hand into six areas (Figure 5). For each area, we checked the unwashed totals in the sketches and images and cross-tabulated them. Assuming that the unwashed areas recognized in the images were also recognized in the sketches, we investigated the ratio. We found that in the initial session, the sixth part (VI, 19.0%) was the lowest, while the first (I, 55.6%), second (II, 20.0%), third (III, 45.8%), fourth (V, 29.2%), and fifth (IV, 26.1%) parts had higher percentages. In the fourth training session, we found the sixth part (VI, 34.8%) to be the lowest; we also found a progressive increase in the fifth (V, 36.8%), fourth (IV, 43.5%), third (III, 45.8%), second (II, 54.5%), and first areas (I, 64.7%). In the fourth session, the recognition rate increased in all areas except the third, as compared to the first session (Table 1).
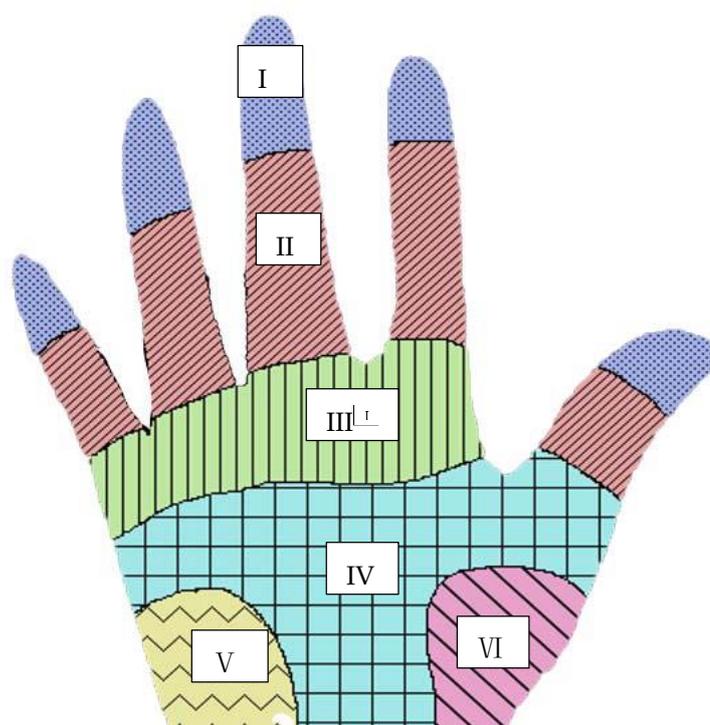
Figure 5. Division of hand. *Note:* I: Fingertips (Upper DIP joint), II: Between DIP and MP joints, III: Base of 2nd to 5th fingers, IV: Center of palm, V: Hypothenar, VI: Ball of the thumb.

Table 1. Recognizing the same unwashed areas as the images: Percentage values.

Area	First training	Fourth training	SD
I	55.6% (5/9)	64.7% (11/17)	n.s.
II	20.0% (4/20)	54.5% (12/22)	n.s
III	45.8% (11/24)	45.8% (11/24)	n.s.
IV	26.1% (6/23)	43.5% (10/23)	0.000*
V	29.2% (7/24)	36.8% (7/19)	n.s.
VI	19.0% (4/21)	34.8% (8/23)	.0000*

Note. The ratio of the number recognized in the sketches to the number identified as unwashed areas in the images. In parentheses are the number of unwashed areas found in both the images and the sketches. Results of the McNemar test, *p<.05.

4. Discussion

Numerous studies conducted in many countries worldwide have assessed handwashing residues [3–10]. However, they are often limited to scoring the unwashed areas and post-training awareness surveys. Only a few investigations have led to an objective evaluation of the technique of handwashing [3–10]. In this study, we used capture box images to generate objective data by calculating the percentage of the unwashed palmar areas. Similar to this study, Chisaki et al. (2013) also captured images and quantified them, but the image-capturing process took approximately 5 min. In the current study, the time required to capture images was considerably less, approximately 1 min, due to the use of a capture box. The capture box is made from inexpensive

commercial products, so it can be used for general purposes as well. The device is invaluable in that it facilitates continuous education in a limited time, which is crucial. We hope that this study's results will lead to the development of products that are easier to use. Our results showed a decrease in the percentage of the unwashed palmar area measured by the photographic images between the first (15.5 ± 6.6%) and fourth (10.6 ± 5.0%) sessions. Chisaki et al. (2013) reported that the scrubbing method using only running water resulted in a washing rate of approximately 30%. Our study considered the handwashing method using soap; hence, no comparison between this study's findings and those of Chisaki et al. can be made. However, if we assume that the unwashed palmar areas were further reduced by the effect of soap, we could consider the results comparable.

A comparison of the photographic images with the visual sketches showed that in the first session, the sketches revealed a lower percentage of unwashed areas for all participants. Previous studies have reported that visual effects improved awareness of the palmar areas left unwashed [3–12]. However, our results showed that the area left unwashed in the initial sketch was 0.7%, which is much lower than that captured in the photographic image. Therefore, we speculated that the actual unwashed areas might not have been fully recognized in the first session.

Conversely, the fourth session showed an increase in the area recognized by the sketch and a decrease in the area recognized by the image. This supports the idea that repeated training improves handwashing skills and visual recognition. Studies suggest that repeated practice with objective feedback improves the effectiveness of hand disinfection and reduces the missed areas on hand surfaces [13]. Our study's findings indicate similar results.

The percentage of the initial agreement was the lowest in the ball of the little finger (19.0%), followed by the area between the distal interphalangeal (DIP) and the metacarpophalangeal (MP) joints of the first to fifth fingers (20.0%) and the ball of the thumb (26.1%). This was inferred from the sites easily irradiated by the black light. The residual fluorescent paint was assumed to be missed on the ball of the little finger and the ball of the thumb because these areas had insufficient irradiation.

However, the percentage of agreement increased to 34.8% for the ball of the little finger and 43.5% for the ball of the thumb in the fourth session, and the percentage of agreement increased or was similar for the other palmar areas. This suggests that the regular repetition of hand hygiene training with objective evaluation may help individuals practice better hand hygiene.

The most frequently unwashed areas were reported to be the fingertips, palm creases, ball of the thumb, and wrist [11,14,15]. This study did not include the wrist due to the limitations of image analysis. However, the wrist is also a common area that is left unwashed. Hence, further analysis that considers the wrist area of the hand is needed.

The image analysis results showed that the most frequently ignored area during washing was the ball of the little finger. This is different from the fingertips, thumbs, interdigital spaces, and wrists, which have been pointed out as areas that are frequently overlooked during washing. Undeniably, participants were less conscious of these areas as they were presented with the areas that were frequently left unwashed while receiving the instructions to wash their hands. However, we must recognize that the ball of the little finger is often left unwashed, and training the participants to be fully aware of the entire hand area is important.

5. Conclusions

This study found significant differences between subjective evaluation through visual inspection and objective evaluation using images. The results suggest the need to consider introducing objective evaluation in addition to subjective visual confirmation.

At present, evaluations through photographic images are not common. Therefore, both the equipment and the analysis must be improved to ensure their easy accessibility.

Furthermore, a program that enables correct evaluation by visual inspection based on the results obtained through subjective and objective indices must be considered. We believe that the combination of subjective and objective evaluation will help improve awareness of the technique of handwashing and its importance for hand hygiene.

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