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EDUCATION OF HAND RUBBING TECHNIQUE TO PROSPECTIVE MEDICAL STAFF, EMPLOYING UV-BASED DIGITAL IMAGING TECHNOLOGY

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The aim of this study was to objectively assess the hand hygiene performance of medical students. Hand rubbing technique was evaluated by employing innovative UV-light-based imaging technology, identifying patterns and trends in missed areas after applying WHO's six-step protocol. This specially designed hand hygiene education and assessment program targeted 1,344 medical students at two distant sites in Central Europe. Students were introduced to a short video, presenting the basics of hand hygiene, and then received further demonstration from professional trainers, focusing on the correct execution of WHO's six-step technique. To verify the acquired skill, participants rubbed their hands with UV-marked alcohol-based solution. Digital images of the hands were recorded under UV light, followed by computer evaluation and assessment. Immediate objective visual feedback was given to the participants showing missed areas on their hands. The statistical analysis of missed spots was based on retrospective expert-driven manual evaluation. Significant difference in rubbing quality was found between female and male participants [35.3% (CI 95%: 33–38%) versus 29.0% (CI 95%: 27–31%), $p < 0.001$], dominant and non-dominant hands [43.4% (CI 95%: 39–48%) versus 34.9% (CI 95%: 32–38%), $p = 0.002$], and various zones of the hands' dorsal side. Based on the participants' feedback and the evaluation of the infection control specialists, it can be stated that the identification of typically missed patterns and the instant visual feedback have a vital role in improving the hand hygiene technique of prospective medical staff.

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Introduction

"Have we forgotten the lesson of Semmelweis?" – stands the question in Lancet [1], referring to the generally weak hand hygiene (HH) performance of physicians in hospitals. Fortunately, the 4% compliance rate reported at a gynecology ward represents an extremely low value [2], but the usually reported rates of 20–50% are still far below expectations [3–5]. The main reported reasons for this poor performance include the tight time schedules, forgetfulness, unsatisfactory knowledge on HH guidelines, denying the importance of hands as a source of infection, negative influence of older, more experienced specialists, and skin irritations caused by hand rub solutions [6, 7]. Education and training play a vital role in promoting HH [8, 9].

It is a widely shared concept that the nursing staff shows a better compliance on average than the physicians [3, 10]. The unsatisfactory quality of knowledge is clearly supported by the observation that according to physicians' opinion, less HH moments are enough than the amount believed necessary by other healthcare workers [11]. As an interesting analogy, the question of antibiotic resistance is generally believed of high importance by medical students; however, it will be treated superficially during their later work as physicians, similarly to the question of HH [12]. Nurses consider the danger of infection transmission during healthcare processes higher than the beginner physicians. Specialist physicians fear the least of infections, as they do not consider that patients may die of nosocomial infections [11].

Investigations polling future physicians show the same image. The root causes may also include the hierarchy in healthcare [13, 14], because the observed behavior greatly influences the students, serving as role model [6, 15]. Investigations also revealed that medical students do not have exact knowledge about the use of alcohol-based hand rub (ABHR) solutions, or about glove usage guidelines [6, 16–19]. Only one-third of the students claimed having rubbed their hands between seeing two patients [20]. In the case of visiting the ward without touching the patients, only half of the students rub their hands [21]. Moreover, hardly over 50% of the interviewed students were aware of the World Health Organization's (WHO) HH protocols relating to ABHR [6].

Teaching the HH basics in an early stage of education, when students do not have sufficient knowledge on microbiology and infections, does not give the possibility for the students to properly understand the connections between HH and nosocomial infections. This may be the cause why medical students develop

the feeling of secondary importance of HH in healthcare [22, 23]. Even compared to other healthcare-related majors, medical students have worse knowledge on nosocomial infections [6, 17, 24–26].

Background

The methodological guidelines published by the Hungarian National Centre for Epidemiology (OEK) in 2010 allow two kinds of tests for the assessment of HH efficiency [27].

1. Studying the number of colony-forming units of bacteria, determined before and after the use of ABHR by the finger imprint technique.
2. The so-called fluorescein probe: hand rubbing with UV-sensitive hand rub solution (that contains fluorescein), followed by monitoring the surface of hands and forearms under UV light.

Both methods have been applied worldwide under a wide range of circumstances. For example, a study conducted at University of Basel (Switzerland) that employed both methods to assess the hand rubbing quality of medical students, found residual flora on 168 out of 257 second-year and 151 out of 306 third- and fourth-year medical students' hands [28].

A UV-checker box was employed in a study conducted at University of Debrecen (Hungary), where the hand rubbing of 253 medical students was monitored. Missed areas were recorded in 188 cases [29]. Another UV-box-based study was carried out at Aachen University Hospital (Germany), aimed to compare the quality of hand rubbing before and after HH education. In the case of first-year medical students, the training led to 22% reduction in missed areas, while for third-year students, this ratio was found to be 74% [30].

Methods

Study

We conducted our study within the frames of the Basic Surgical Techniques class offered for third-year medical students at Semmelweis University, Budapest. It is a regular class, consisting of two hours lecture and three hours practice every second week, teaching the basics of interventional medicine. During practice hours, students are intended to learn appropriate behavior in surgical wards to know the surgical equipment, devices, and techniques. Surgical hand washing (SHW) is included in the topic of the first practice hours. Hand washing education

is based on a short movie, which is followed by learning and practicing the steps of surgical hand washing under the supervision of the instructor.

Since 2011, the practical education also includes the UV-box-based assessment of students' HH quality. Following the regular steps of SHW, after the soap-based hand washing, students are to rub their hands four times using an ABHR solution. As a last step, students used a UV-dye enabled ABHR (SchülkeOptik, Schülke&Mayr GmbH, Norderstedt, Germany) for the study. After that, the Hand-in-Scan device (HandInScan Kft, Debrecen, Hungary) was employed to monitor the hand coverage, and to give immediate visual feedback concerning the missed areas. The quality of the acquired HH technique was evaluated with this computerized technology, investigating the most frequently missed areas [31].

The statistical analysis of missed areas was based on retrospective expert evaluation of the recorded images. Missed areas were grouped according to their location on the hand. Only those students were declared passed, who did not miss any spots on either side of their hands.

Population

Data collection was performed during a four-year period at Semmelweis University (Budapest, Hungary) and University of Medicine and Pharmacy of Tîrgu Mureş (Romania). 1,344 medical students participated in the study: 518 males and 826 females. Participants were not differentiated by age, as they all were third-year medical students. Each participant received a unique identifier when the personal information was recorded (gender and dominant hand), which was also used to connect each recorded image with the corresponding person in an anonymous manner.

Statistics

The statistical analysis of the collected data was performed using the R program package, version 2.15.0 (the R Foundation for Statistical Computing, Vienna, Austria). The difference between two sets of samples was considered significant, if the p-value was found less than 0.01. Confidence intervals were computed using the Wilson method.

Results and Discussion

On the palmar side of hands, there was a negligible incidence of missed areas: a total number of nine participants were failed to achieve full coverage, and

only four of them on both palms. As rubbing the palms is the first step of hand rubbing, it is performed when there is still an abundant amount of ABHR on the hand surface, allowing for satisfactory coverage of the palms.

On the dorsal side of hands, a total number of 2,306 missed spots were found aggregated for the participants, out of which 1,277 were on the right hand, and 1,029 on the left hand.

Hand rubbing performances were classified into two groups: those who passed and those who failed the assessment, where all those failed the assessment who had at least one missed spot. The highest number of missed spots encountered on the participant's hands was 11.

Out of 1,344 participants, 513 (38.2%, CI 95%: 36–41%) failed to perform acceptable hand rubbing as given in the above condition. In the case of female participants, the failure rate was 34.9% (CI 95%: 32–38%), while for males it was 43.4% (CI 95%: 39–48%), $p = 0.002$. Our findings are similar to the results obtained at University of Debrecen [29], where 45% (females) and 54% (males) failed at first attempt. We found insufficient coverage on both hands of 22.8% of female (CI 95%: 20–26%) and 31.7% of male (CI 95%: 28–36%) participants, $p < 0.001$.

Not only in hand rubbing efficiency, but also in terms of compliance to HH moments, female healthcare workers reportedly perform better than males [32–34]. This difference between genders may stem from the attitude towards HH. People working outside healthcare systems were involved in a study which proved that 10% more of women wash their hands after using the toilet than men [35–37].

Regarding the role of the dominant hand, close to 90% of the participating students were right handed, a ratio corresponding to the general statistics [38]. Missed spots were found on 35.3% (CI 95%: 33–38%) of the dominant hands and 29.0% (CI 95%: 27–31%) of the non-dominant hands, $p < 0.001$. Almost the same figures were obtained when the coverage on the right and left hands was compared. Coverage was insufficient on 34.8% (CI 95%: 32–37%) of the right hands and 29.5% (CI 95%: 27–32%) of the left hands, $p < 0.004$. Results show that the dominant hand gets worse coverage than the non-dominant one, which can be explained by the fact that the dominant hand is used to rub the non-dominant hand and vice versa, and people can perform activities more precisely with their dominant hand.

When we investigate the location of missed areas, coverage patterns seem to be similar on both hands' dorsum. Three distinct zones were defined on the dorsal side of the hands (Figure 1). A great majority of missed spots are situated on fingers' distal areas, which account for 48% of total mistakes on the left hand, and 44% on the right hand. According to the WHO six-step protocol, fingertips are rubbed in the last (sixth) step. Based on our results, it can be asserted that the sixth

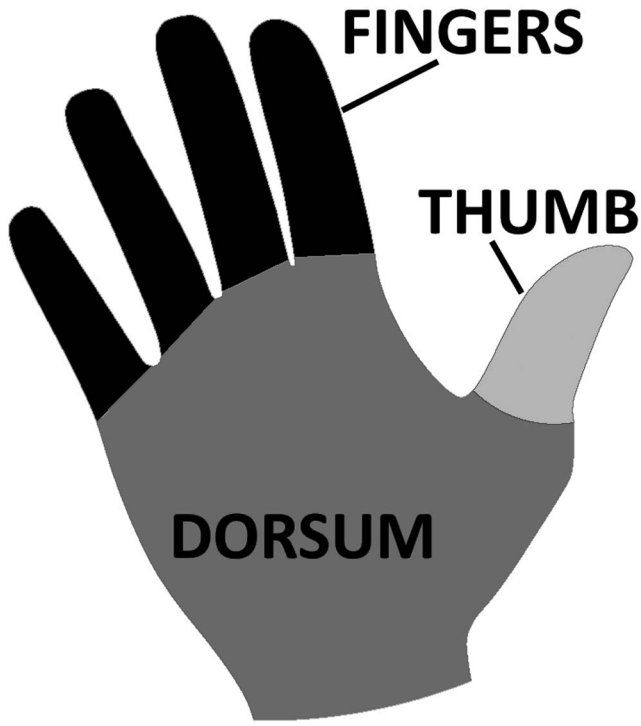

Figure 1. Zones defined on the dorsal side of the hands

step does not fulfil its goals, either because of improper performance, or because most of the ABHR evaporates before this step happens, thus fingertips cannot be covered sufficiently.

The site with second highest number of missed spots is the thumb with an incidence of 24% on both hands. Further on, missed spots are found on the dorsum in the proximity of the thumb with 7% and 9% incidence on the left and right hands, respectively. During the fifth step of the protocol, the surface of the left (right) thumb is rubbed by the right (left) hands' palm, and simultaneously, the outstretched thumb of the right (left) hand can rub approximately one-third of the left (right) hands' dorsum. The above-mentioned mistakes on the thumb and dorsum originate from the improper execution of this fifth step.

Table I reflects insufficient coverage rates (number of mistaken cases divided by the number of all cases) under various circumstances, emphasizing the significant differences encountered between genders (male versus female) and hands (dominant versus non-dominant and left versus right). From any

investigated point of view, females performed significantly better than men. If we compare the missed areas on dominant and non-dominant hands, there is a statistically significant difference on the thumb and dorsum of the hands in the favor of the non-dominant hand, but not on the fingers. This finding may suggest that the WHO six-step protocol is either too complicated, or not explained thoroughly enough to medical students and healthcare workers.

Figure 2 exhibits a three-layered representation of the distribution of missed areas in the case of failed HH performances. Missed areas on the dorsal side of the hands were attributed to the zones of fingers, thumb, or dorsum. As indicated by the inner core, out of the 513 failed participants, 16% (CI 95%: 13%–20%) had missed spots in all three zones. The middle layer indicates that two zones were affected by missed spots in 40% (36%–44%) of the failed cases. The outer layer accounts for those cases where only one of the zones is partly missed. This graph

Table I. Rates of insufficient coverage observed in various circumstances. All rates were computed from the total number of 1,344 participants

Location of insufficient coverage	Rates (CI 95%)	*p*-value
Non-dominant hand Dominant hand	29.0% (27–31%) 35.3% (33–38%)	<0.001
Left hand Right hand	29.5% (27–32%) 34.8% (32–37%)	<0.004
Non-dominant hand of male participants Non-dominant hand of female participants	34.0% (30–38%) 25.9% (23–29%)	<0.002
Dominant hand of male participants Dominant hand of female participants	40.9% (37–45%) 31.8% (29–35%)	<0.001
Left hand of male participants Left hand of female participants	34.9% (31–39%) 26.2% (23–29%)	<0.001
Right hand of male participants Right hand of female participants	40.2% (36–44%) 31.5% (28–35%)	<0.002
Both hands of male participants Both hands of female participants	31.7% (28–36%) 22.8% (20–26%)	<0.001
Either hand of male participants Either hand of female participants	43.4% (39–48%) 34.9% (32–38%)	0.002
Fingers of dominant hand Fingers of non-dominant hand	20.8% (19–23%) 19.0% (17–21%)	>0.26
Thumb of dominant hand Thumb of non-dominant hand	22.5% (20–25%) 17.7% (16–20%)	<0.003
Dorsum of dominant hand Dorsum of non-dominant hand	10.8% (9–13%) 7.2% (6–9%)	<0.002

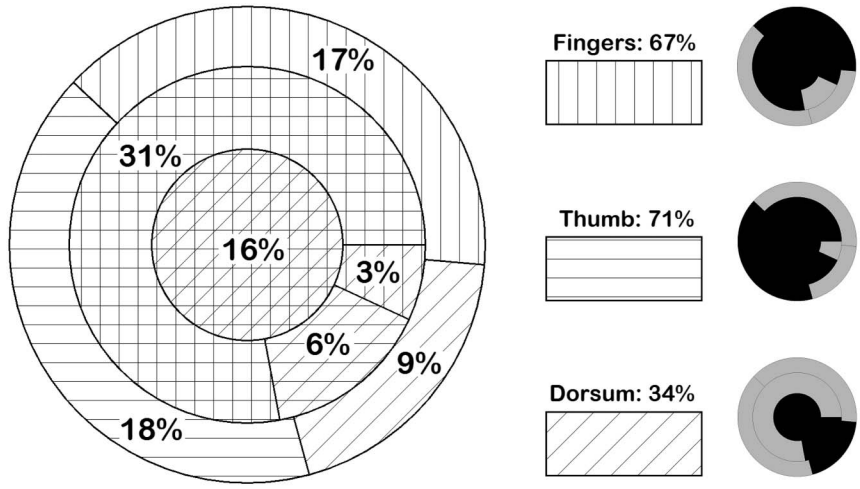

Figure 2. Distribution of missed spots on the dorsal side of hands. All rates were computed from the performances of the 513 participants who failed the assessment

reveals the high correlation between mistakes occurring in different zones. It also shows that the thumb is involved in over 70% of mistaken cases, while fingers account for over 66%.

Conclusions

The foundations of HH were laid by the observations of Ignaz Semmelweis [39]. His investigations revealed that HH is the most important pillar of nosocomial infection prevention. Yet we see a low compliance rate and poor HH technique of physicians in the 21st century that can only be changed by raising awareness.

The use of electronic devices and computer applications is currently widely accepted among university students. Based on this, we integrated the newest trend of modern technology driving HH education with the intention of improvement. The benefits of employing standard UV-checker boxes in HH education of medical students have been reported [29, 30]. In our study, computerized evaluation was involved, relying on the Hand-in-Scan device, a UV-based digital technology that provides immediate feedback to the users regarding the missed spots. Students were shown the pictures of their own hands indicating the missed spots with red color after hand rubbing. The computerized image processing can guarantee that the human factor is excluded from the evaluation, thus the outcome

is better accepted. Real-time feedback was employed in the study, since that is the most efficient tool in behavior change [31, 40]. The visualization of missed areas helps students understanding the hand's role in infection transmission [41].

Having acquired the theoretical and practical knowledge, graduating medical students can serve as positive examples in their future work, contributing to the improvement of the current situation in hospitals. With positive deviant behavior, they can be the mentors of future student generations [15, 24, 42]. The basis of avoiding malpractice stands in teamwork [43, 44], but hierarchy strongly influences the team members. Being a young member of a team and instructing the older, more experienced colleague, is not accepted in healthcare [14]. That is why the positive deviation, as a conscious tool of raising awareness, is of high importance for the future healthcare system [24, 45, 46], influencing the currently established hierarchical thinking.

The instant visual feedback has a vital role in helping medical students to acquire and maintain a correct hand rubbing technique. With the use of modern technology and electronic equipment, there is a chance to educate prospective physicians to better understand the importance of hand hygiene in infection control, improving the overall quality of our healthcare system.

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Conflict of Interest

Á. Lehotsky, L. Szilágyi, and T. Haidegger are the co-founders of HandInScan Kft. No further conflict of interests declared.

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