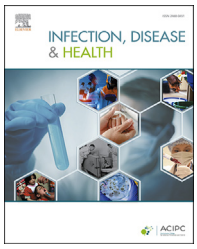
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Research paper

# Evaluating the accuracy of an automatic counting system to detect dispensing of hand hygiene product

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**KEYWORDS**
Hand hygiene;
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**Abstract** *Background:* Hand hygiene (HH) is an essential element of infection prevention and control programs. Direct observation of adherence to the 5 moments for HH is considered the gold standard in compliance monitoring. However, as direct observation introduces potential bias, other strategies have been proposed to supplement HH compliance data in healthcare facilities. This study evaluated the accuracy of an automatic counting system (MEZRIT™) to detect when a HH product (soap or alcohol-based hand rub) was dispensed, and thus measure product usage as opposed to compliance with the 5 moments for HH.
*Methods:* A quasi-experimental study was conducted in a nursing simulation lab where seven participants undertook basic nursing tasks which included performing HH. Sensors were attached to soap and alcohol-based hand rub dispensers to record the time at which a product was dispensed. HH events were video recorded (time-stamped) and validated against time-stamps from the automatic counting system.
*Results:* 260 HH events were detected by the automatic counting system and confirmed by video recordings. 5182 non-HH events were calculated from analysis of the video recordings. The automatic counting system had 90 % sensitivity (95%CI 85.8–93.1 %), and 100 % specificity (95%CI 99.9–100 %). This model generated a positive predictive value of 100 % (95%CI 98.4–100 %), and a negative predictive value of 99.5 % (95%CI 99.3–99.7 %).
*Conclusion:* The MEZRIT™ system accurately identified 90 % of HH events and excluded 100 % of non-HH events. The real-time monitoring of HH product usage may be beneficial in responding quickly to changes in product usage.
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**Highlights**

- Automated sensor technology systems can correctly identify hand hygiene usage in real-time.
- Real-time tracking of hand hygiene usage can benefit organisations where hand hygiene is crucial.
- Real-time data could be used to identify trends and help facilitate targeted early interventions.

## Introduction

Correct hand hygiene practice is fundamental to infection prevention. Monitoring of HH is therefore paramount to patient care in healthcare facilities. Although direct observation is considered the gold standard for monitoring HH compliance, the validity of this data has been questioned due to inherent biases, such as the Hawthorne Effect [1]. There is a large discrepancy between HH compliance rates recorded by direct observation and those measured by alternate methods for HH surveillance, with direct observation compliance reported to be inflated up to 10-fold [2]. Furthermore, direct observation is estimated to capture only 1.2 %—3.5 % of all HH opportunities [3]. Literature suggests a multimodal approach to HH monitoring, supplemented with ongoing education to improve HH performance [4]. Data collected from adjunct monitoring strategies can be used in parallel with direct observation to allow a more objective and complete picture to be formed [4,5] (Table 1). Despite advancements in

**Table 1** Hand hygiene monitoring strategies. Adapted from a systematic review on current practices and emerging technologies [8].

| Type of monitoring | Considerations |
|---|---|
| **Direct observational surveys** | |
| *Observation by trained observers*<br>Direct observation of hand hygiene (HH) to determine HH compliance rates amongst healthcare workers (HCWs). | • Gold standard for determining HH compliance<br>• Can assess quality of HH technique<br>• Overt or covert observation affects data<br>• Assesses a small number of HH opportunities<br>• Affected by observer bias |
| *Observation by patient observers*<br>Patients observe HH events of HCWs. | • HCW compliance rates reported by patients correlated very well with rates determined by an independent observer in one study<br>• Limited evidence to support the accuracy or implementation of this approach |
| *Self-reporting*<br>HCWs self-report their HH compliance. | • Unreliable data<br>• Not recommended as a standalone HH monitoring strategy |
| **Measuring product consumption** | |
| *Measuring product volume or weight*<br>Measuring the amount of HH product purchased. | • Assesses trends in consumption over time<br>• Does not determine HH compliance |
| *Electronic counting devices*<br>Devices are placed on HH product dispensers and record when a product is dispensed (proxy for HH event). | • Time and date-stamped data allows for more accurate information about the timing of HH usage/events<br>• Does not determine HH compliance<br>• Requires purchasing and maintenance of devices<br>• Few devices report the accuracy of counting systems |
| **Electronic HH compliance monitoring** | |
| *Automated HH monitoring systems that estimate compliance*<br>Electronic prompts (flashing lights, voice prompts) or wireless transmitters for HCWs performing HH | • Most studies report improved HH usage and/or compliance<br>• Requires purchasing and maintenance of devices<br>• Few devices report the accuracy of counting systems<br>• HH compliance can be assessed<br>• Signal transmission can vary between devices and is affected by distance and building infrastructure |
| *Remote video monitoring*<br>HH compliance is remotely assessed by surveillance video cameras | • Can assess HH compliance and quality of HH technique<br>• Privacy concerns<br>• Software infrastructure<br>• Requires purchasing and maintenance of devices<br>• Few studies report the accuracy of counting systems |

technology based approaches for HH monitoring there are differences between systems. Notably, HCWs identify lack of system accuracy as one of their concerns when implementing additional monitoring strategies [6]. There is a need for commercial products to be independently tested, and the accuracy metrics reported for facilities to make informed decisions and address the concerns of HCWs.

The MEZRIT™ system has the ability to remotely record the timing and frequency of when products are dispensed and do this in real time. In addition, the system collates data collected and presents it on a dashboard, allowing data to be displayed and analysed. The accelerometer sensors work by measuring the motion of hand hygiene products being dispensed. Sensor devices (patent pending PCT/AU2024/050674) are retrofitted to any existing alcohol-based hand rub (ABHR) or soap dispenser units (manually activated or touch free) that are connected to a wireless gateway, providing data to a central computing system. Reports and notifications regarding dispenser usage and predictive reports to facilitate stock ordering can then be generated. It is important to note that this system measures the number of times a product is dispensed and not HH compliance as per the WHO 5 moments for HH. In this short report, we evaluate the accuracy of the MEZRIT™ system's ability to identify when a HH product was dispensed. Specifically, we sought to determine the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the MEZRIT™ system.

## Methods

### Design and setting

We undertook a quasi-experimental study, in a clinical simulation ward at an Australian University in 2023. The simulation ward was equipped with hospital beds, nursing simulation mannequins and common pieces of medical equipment.

### Participants

Nursing students (>18 years old) were recruited through Avondale University, with written consent obtained prior to the study. Participants were required to be enrolled in an undergraduate nursing degree.

### Data collection

Automatic counting devices were placed on manually activated soap dispensers ($n = 5$) and ABHR bedside dispensers ($n = 2$) (Fig. 1). Four cameras were placed at various angles around the room recording time-stamped video footage (Supplementary Fig. 1). HH events were defined as the use of either ABHR or hand washing using soap and water. Non-HH events were defined as any activity that might cause movement potentially identified by the system which were not classified as a HH event. One example is feeding a patient. In undertaking this activity, there would be movement of the bed and bedside ABHR dispenser which could be misidentified as a HH event. Further examples and detail are provided in Supplementary Table 1.

Participants performed typical clinical nursing activities in simulation. These were directed and supervised by the research team. By nature, these activities required a mix of HH events and non-HH events. For example, after feeding the patient, the nurse would use ABHR to decontaminate their hands at the bedside. The purpose of the activities was to simulate routine clinical practice and determine whether the system correctly identified HH events. For this study, neither the quality of HH, nor compliance with the 5 moments for HH was assessed.

Time-stamped video recordings were used to determine the timing of HH events and compared to data captured by the sensor technology (MEZRIT™ system). False positive timepoints from the system were excluded from analysis if a duplicate timestamp (+0–1 s) was recorded, and video footage could not determine how many times the dispenser was pressed, as per similar validation of automated monitoring systems (Supplementary Table 2) [9–11]. Non-HH

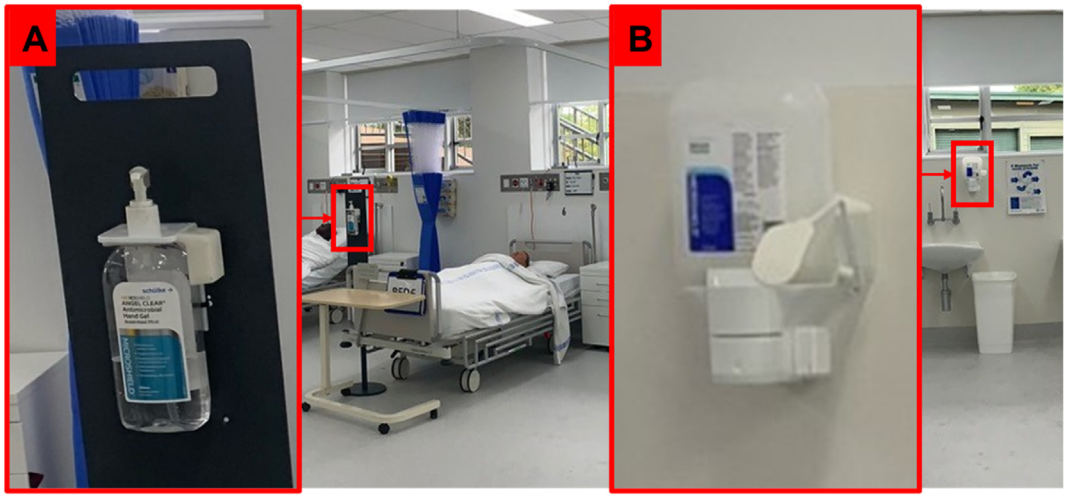



**Fig. 1** Example of the MEZRIT™ automatic counting device placed on A) bedside alcohol-based hand rub dispenser and B) soap dispenser.

events were calculated as: the time (s) multiplied by a factor of five (maximum number of times the accelerometer can record a HH event per s). As an example, if a non-HH event takes 10 s (e.g. a patient getting out of bed) there is the potential for the accelerometer to measure up to 50 incorrect HH episodes.

### Data analysis

All data were collated and cleaned in Microsoft Excel. Descriptive analysis of demographic data was conducted in SPSS. Statistical analysis of the data was calculated including the systems sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). Calculations can be found in Supplementary Table 3.

### Bias

Our study recorded HH dispenser activation events and compared these to video recordings of HH moments, reducing the risk of information bias (compared to self-reporting) and measurement error. Similarly, data captured from the sensor technology (MEZRIT™ system) was provided directly to researchers for independent analysis.

### Sample size

A total sample size of 3160 episodes (which includes 158 HH episodes) achieved 90 % power to detect a change in sensitivity from 0.99 to 0.95 using a two-sided binomial test and 100 % power to detect a change in specificity from 0.99 to 0.95 using a two-sided binomial test. The prevalence of HH episodes was $\leq$5 %.

## Results

Seven nursing participants enrolled in undergraduate nursing were included in the study. The study ran for 3 h during which the students' switched roles between patient and nurse. During the study 260 HH events occurred and 5182 non-HH events occurred (Table 2). A review of the video data identified that 96 % of the system data aligned within 1 s of the timestamped video, with the remaining 4 % of timepoints between 2 and 4 s apart (Supplementary Fig. 2).

The automated system correctly identified 90 % ($n$ = 234) of the 260 HH events, as per the video recorded data (Table 2). Of these HH events, 71 % were from the use of ABHR and the remaining 29 % from soap dispensers (Supplementary Table 3). A false negative was defined by the automated system failing to identify a HH event ($n$ = 26; Table 2). For the soap stations, this equates to a false negative rate of 12 % ($n$ = 78) and for the ABHR stations a false negative rate of 9 % ($n$ = 182) (Supplementary Table 3). The automated system had a sensitivity of 90 % (95%CI 85.8 %—93.1 %) and a specificity of 100 % (95%CI 99.9—100 %) (Table 3). The positive predictive value (PPV) was 100 % (95%CI 98.4—100 %). In contrast, the negative predictive value (NPV) was 99.5 % (95%CI 99.3—99.7 %) (Table 3).

**Table 3** Statistical analysis and accuracy metrics of the MEZRIT™ system.

| Accuracy metric | Reported value (95 % Confidence Interval) |
|---|---|
| Prevalence of HH events | 4.8 % (4.2—5.4 %) |
| Sensitivity | 90 % (85.8—93.1 %) |
| Specificity | 100 % (99.9—100 %) |
| Positive predictive value | 100 % (98.4—100 %) |
| Negative predictive value | 99.5 % (99.3—99.7 %) |

## Discussion

We found that the MEZRIT™ system was able to measure whether a HH product was dispensed with a high degree of specificity and sensitivity. Of note, the accuracy of electronic HH monitoring strategies, particularly automatic counting devices, is something not commonly reported. The findings of two systematic reviews highlight 25 articles that used electronic dispenser counters to record the frequency of HH [12,13]. Of these articles, only a small proportion included calculations for efficiency or accuracy. In a separate search, 8 articles reported the accuracy of automatic counting devices; two of which reported the sensitivity, specificity, PPV and NPV. A detailed comparison can be found in Supplementary Table 4. The MEZRIT system outperformed for specificity, PPV and NPV, whereas the SmartRub device reported 6.8 % higher sensitivity [14]. Furthermore, these sensors can be retrofitted to existing HH product dispensers whereas other sensors are built-into new product dispensers requiring a change in suppliers for soap and ABHR products.

The real-time monitoring of product usage allows the potential for closer monitoring of usage and subsequent alerts to supply teams when a product requires replacement, ensuring HH availability, which has been linked with increased HH compliance in the literature [15]. Another

**Table 2** The number of hand hygiene (HH) and non-HH events measured by the MEZRIT™ system as confirmed by video recorded data.

| | HH events | Non-HH events | Total events |
|---|---|---|---|
| Automated system identifies event | 234 (True positive) | 0 (False positive) | 234 (Test positive) |
| Automated system does not identify event | 26 (False negative) | 5182 (True negative) | 5208 (Test negative) |
| Total | 260 | 5182 | 5442 |

advantage of automated counting devices is their ability to provide data that can be used to identify the best locations for dispensers in hallways and patient rooms, based on the frequency of their use. Automated HH technology could also provide potential cost saving measures when considering staffing, ordering and storage of HH products. This should be balanced with the cost of purchasing and maintaining these systems. This technology may also have application to other industries, including areas of food production and manufacturing, where HH is critical.

One key advantage of automated systems, supported by multiple studies, is reduced bias compared to direct observation ([1,4,5,14,16,17], Supplementary material). The discrete nature of the monitoring system will have less Hawthorne effect impact on HCW HH behaviour as compared to the presence of a human auditor or other more overt monitoring approaches. Healthcare facilities have the potential to benefit from the discrete placement of HH counting devices in promoting a more accurate reflection of healthcare worker HH product use [18]. Previous research suggests that simply knowing that HH usage is being tracked is unlikely to have the same magnitude of bias that direct observation and the Hawthorne effect compels [16,17]. Additionally, direct data reporting to the cloud reduces the chance of system gamification by HCWs [19]. In the event that HCWs dispense multiple HH products in a short period of time to improve usage data reports, the time and date-stamped function of automatic counting devices are able to flag this and prompt further investigation.

Automated counting devices in healthcare facilities could be of benefit to both patients and hospitals. Having longitudinal and precise data may prove beneficial in identifying trends and responding to changes in product usage. For example, a targeted education intervention on a ward may be warranted when data indicates a downward trend in product usage. The availability of data may also be useful in outbreak situations. If product usage decreases, this may signify a decline in HH compliance, warranting the consideration of HH improvement initiatives to mitigate potential risks [20]. Conversely, if HH usage remains constant during an outbreak, or HH usage improves yet the outbreak persists - then time could be invested in mitigation strategies other than HH [20].

Innovative technology to improve the accuracy and efficiency of infection control process is needed, particularly in the context of competing demands on infection control teams time and resources. Automated technology to collect real-time HH usage data may be a useful contribution to the field. In the absence of a standard, whether a sensitivity threshold of 90 % is acceptable is subject to debate and may also be considered a limitation of the MEZRIT system. Additionally, the small number of sensors attached to ABHR dispensers [2], the short study period (3 h) and low level of HH events (260) may be considered limitations of the study. It is also important to reiterate that this study did not assess HH compliance.

In conclusion, the data suggest that the MEZRIT™ sensors have similar, if not greater, accuracy compared to other automatic counting devices. This system could be used in conjunction with existing HH monitoring strategies and ongoing education to improve HH performance.

## Ethics

Prior to the study, participants provided written informed consent. Ethics approval was granted by Avondale University Human Research Ethic Committee [approval number: ETH.2022.018].

## Authorship statement

Conceptualization; BM, Data curation; GM, Formal analysis; GM, Funding acquisition; BM, Investigation; BM, GM, KB, SD, HK, Methodology; BM, KB, SD, HK, PR, Project administration; KB, Resources; SD, HK, Software; BM, Supervision; BM, PR, Validation; KB, Visualization; BM, Roles/Writing - original draft; GM, KB and Writing - review & editing; GM, KB, BM, SD, HK, PR. All authors contributed to interpretation of the work, provided critical input, and approved the final version.

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## Provenance and peer review

Not commissioned; externally peer reviewed.

## Data availability statement

The full dataset is available upon request.

## Declaration of competing interest

Two authors have editorial affiliations with the journal. They played no role whatsoever in the peer review or decision-making processes related to this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.idh.2024.11.001.

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