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State of the Science Review

A systematic review to evaluate the evidence base for the World Health Organization's adopted hand hygiene technique for reducing the microbial load on the hands of healthcare workers

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Hand hygiene
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Background: Effective hand hygiene prevents healthcare-associated infections. This systematic review evaluates the evidence for the World Health Organization's (WHO) technique in reducing the microbial load on the hands of healthcare workers (HCWs).

Methods: This study was conducted in accordance with Joanna Briggs Protocol 531. Index and free-text terms for technique, HCW, and microbial load were searched in CINAHL, Medline, Web of Science, Mednar, Proquest, and Google Scholar. Inclusion criteria were articles in English that evaluated the WHO 6-step hand hygiene technique for healthcare staff. Two reviewers independently performed quality assessment and data extraction.

Results: All 7 studies found that the WHO technique reduced bacterial load on HCW hands, but the strongest evidence came from 3 randomized controlled trials, which reported conflicting evidence. One study found no difference in the effectiveness of the WHO 6-step technique compared to the Centers for Disease Control and Prevention's 3-step technique ($P = .08$); another study found the WHO 6-step technique to be more effective ($P = .02$); and the third study found that a modified 3-step technique was more effective than the 6-step technique ($P = .021$).

Conclusions: This review provides evidence of the effectiveness of the WHO technique but does not identify the most effective hand hygiene technique. Questions to be addressed by further research are identified. Meanwhile, current practices should continue.

BACKGROUND

Hand hygiene is a cornerstone of infection prevention. Although hand hygiene is a superficially simple procedure, its use in a range of real-world settings is actually quite complex. The importance of hand hygiene in saving patient lives was first demonstrated in 1847.[1] Since that time, research has continued to focus on understanding hand hygiene and on establishing links between contaminated hands of healthcare staff and problems concerning both epidemics and endemic healthcare-associated infections.[2,3] It is widely acknowledged that effective hand hygiene among healthcare staff is one of the most important infection prevention strategies available;[4,5] however, uncertainty remains concerning a range of issues related to hand hygiene.[1]

One major issue relates to which technique to use when performing hand hygiene.[5-10] The World Health Organization (WHO) recommends[1] the adoption of a hand hygiene technique originally developed in 1978 by Professor Graham Ayliffe.[11] This approach, called the WHO 6-step technique in this review, focuses on the physical rubbing of specific areas of the hands and involves the following procedures: palm-to-palm friction; right palm over left dorsum with interlaced fingers and vice versa; palm to palm with fingers interlaced; back of fingers to opposing palms with fingers interlaced; rotational rubbing of left thumb clasped in right palm and vice versa;

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and rotational rubbing backwards and forwards with clasped fingers of right hand in left palm and vice versa.[1]

This technique was originally developed to standardize testing of hand hygiene products, not for performing hand hygiene in clinical practice.[11] It has now been adopted globally as the gold standard for hand hygiene[12] for use in clinical practice; compliance, however, is low.[13-15] One possible way to increase compliance with the technique is to provide healthcare workers (HCWs) with evidence of why it is important to decontaminate their hands using the recommended technique.[16] In addition, given that the technique was devised for testing hand hygiene products and not for use in clinical practice, a review providing this evidence would be helpful. Therefore, the objective of this systematic review was to evaluate the evidence for the WHO hand hygiene technique in effectively reducing microbial load on the hands of HCWs.

METHODS

Details of the study protocol, its inclusion criteria, and the particularities of data analysis are documented in the protocol, which is registered with the Joanna Briggs Institute.[17]

Inclusion criteria

Studies were included if they named the WHO 6-step technique or a variation of the technique; described the technique they used, which was consistent with the WHO 6-step technique; or cited the WHO 6-step technique in the Methods section. Inclusion criteria also included HCWs performing either handrub or handwashing in any healthcare context, in any country.

Exclusion criteria

Studies based in operating theaters using surgical hand asepsis were excluded, since the hand hygiene techniques and duration differ within this setting. Studies were also excluded if they were not specifically about hand hygiene technique but were, instead, investigating the efficacy of hand hygiene products or evaluating hand hygiene compliance. Studies not conducted with HCWs were excluded as well, as were those that were not primary research or did not measure microbial load.

Outcomes

The primary outcome required in the reviewed studies was reduction in the microbial load of HCW hands after application of the aforementioned hand hygiene techniques. Secondary outcomes were a measure of hand coverage and time of hand decontamination alongside, but not instead of, microbial load.

Types of studies

To enable the identification of the current available evidence, we considered randomized controlled trials (RCTs), non-randomized controlled trials, before-and-after studies, case-control studies, cohort studies, and observational-descriptive studies.

Search strategy

A 3-step search strategy was employed. Keywords and index terms were searched in CINAHL, Medline, Proquest, and Web of Knowledge databases. Advice was sought from a librarian to ensure the development of a comprehensive search strategy, using a combination of keywords and index terms. The full search for Medline (Appendix) was individualised for the other databases according to their functionality. The search strategy included articles published in English between 1978 (the first year we were aware of the technique being used) and May 2017. Moreover, since keyword terms could not be combined in Mednar and Google Scholar, only the broadest keywords were searched in these databases. Finally, the reference lists of articles identified for possible inclusion in the review were searched.

Study selection

The titles and abstracts of identified articles retrieved from the searches were stored and independently screened for relevance by 2 reviewers, according to the inclusion criteria relating to study design, population, intervention, and outcomes, as described above. The full text of articles that met the inclusion criteria after the title and abstract search, and those in which there was insufficient evidence in the title and abstract to make a decision, were reviewed independently by the 2 reviewers. Discrepancies were discussed and resolved between the 2 reviewers.

Quality assessment and data extraction

Full-text copies of included articles were independently evaluated by the 2 reviewers to assess their quality. The reviewers used standardized critical appraisal checklists for descriptive/case series and experimental studies[18] as appropriate for the study design.

Data were independently extracted by the 2 reviewers using an original comprehensive data extraction tool adapted by the authors from standardized data extraction tools.[17,18] The standardized tool was expanded to include details pertinent to the review, such as participant details, intervention delivery methods, and required outcomes.

Because a meta-analysis was not appropriate due to substantial heterogeneity of the designs and outcomes, the results are presented in a narrative summary.

RESULTS

Search results

Figure 1 depicts the database search results. In stage 1, 23,081 bibliographic records were identified through database searching; 2125 of these were duplicates, resulting in 20,956 records being eligible for stage 2 of the process. Most of the records (n = 20,948) did not meet the inclusion criteria: they were not empirical studies, participants were not HCWs, the aim was to test a product or measure hand hygiene compliance, the hand hygiene technique used was not the WHO 6-step technique, or the techniques used could not be identified.

As a result, 7 articles were eligible for inclusion: Widmer et al. (2007),[20] Laustsen et al. (2008),[7] Tschudin-Sutter et al. (2010),[21] Chow et al. (2012),[22] Pires et al. (2017),[23] Reilly et al. (2016),[24] and Tschudin-Sutter et al (2017).[25]

The characteristics of these studies are shown in Table 1.

According to the Cochrane Effective Practice and Organisation of Care study design criteria,[26] of the studies included, 2 were RCTs,[22,24] 1 was a randomized controlled cross-over trial,[25] 3 were controlled before-and-after studies,[7,20,21] and 1 was a non-randomized cross-over trial.[23] All studies used alcohol-based handrub (ABHR) to investigate some aspect of the WHO 6-step hand hygiene technique, with the primary outcome of bacterial load on the hands of HCWs measured in colony-forming units (CFUs). Secondary outcomes of time and hand coverage were assessed in 2[22,24] and 3[20,21,24] studies, respectively. The settings for 6 studies were hospitals,[7,20,22-25] with 1 being a university[21] and participants being doctors and nurses,

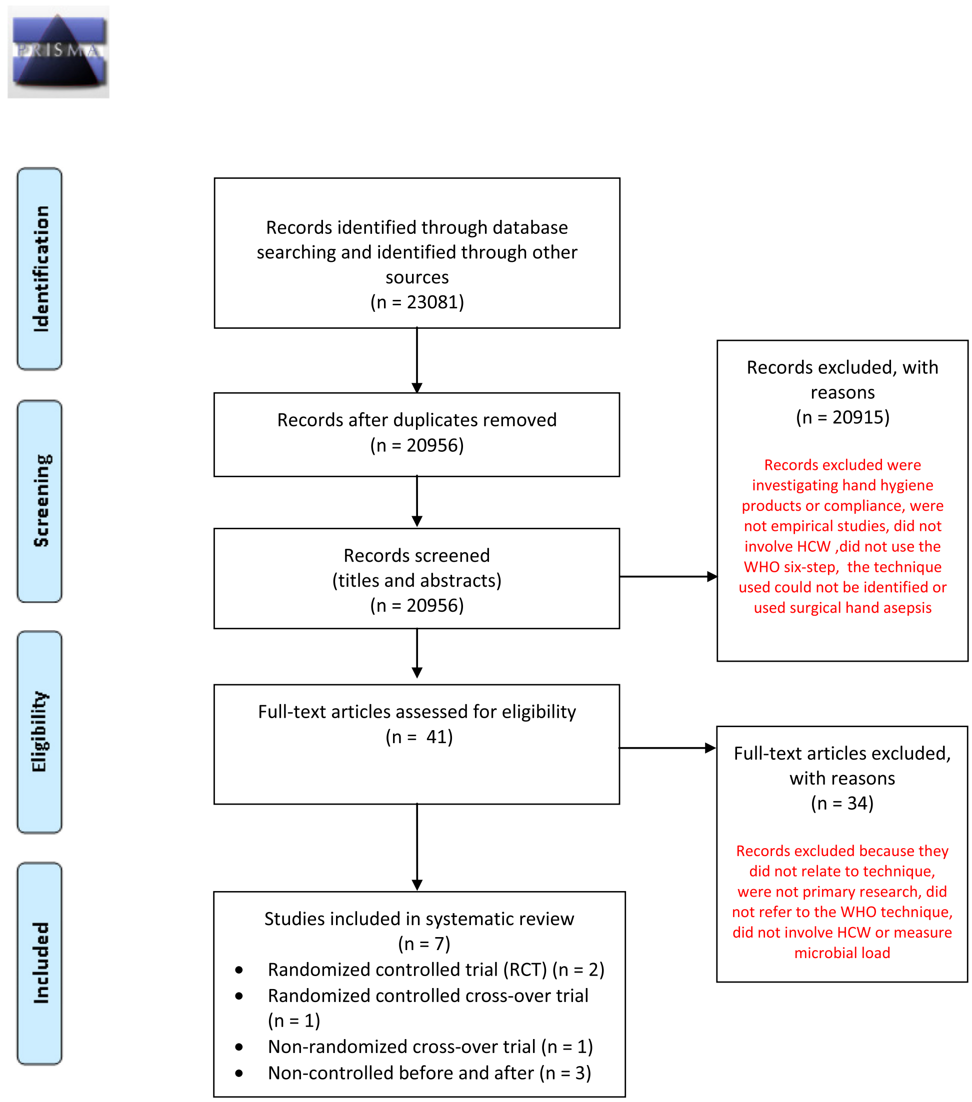

Fig 1. PRISMA 2009 flow diagram[19]

and 2 studies focused solely on medical students.[21,25] Study outcomes and methodological quality of the RCTs and other study designs are subsequently discussed.

Primary outcomes

RCTs

Tschudin-Sutter et al. (2017),[25] Reilly et al. (2016),[24] and Chow et al. (2012)[22] all found a reduction in bacterial load after application of the WHO 6-step technique. However, findings were inconsistent. Chow et al. (2012)[22] found that the WHO 6-step technique was no more effective than covering all surfaces of the hands in no particular order (Centers for Disease Control and Prevention [CDC] 3-step technique) ($P = .07$). In contrast, Reilly et al. (2016)[24] reported that the WHO 6-step technique was more effective than the CDC 3-step technique ($P = .02$). Similar to Reilly et al. (2016),[24] Tschudin-Sutter et al. (2017)[25] also compared a 3-step technique to the WHO 6-step technique. This 3-step technique was different from that used by Chow et al. (2012)[22] in that it consisted of covering all surfaces of the hands and, in addition, rotationally rubbing fingertips in the palm of the alternate hand and rotationally rubbing both thumbs. This technique was found to be more effective at reducing bacterial load than the WHO 6-step technique ($P = .021$).

Other study designs

Although all studies showed a reduction in bacterial load on the hands of HCWs using the WHO 6-step technique, the studies reported different findings. Tschudin-Sutter et al. (2010)[21] found that the bacterial load on the hands of medical students was reduced after the use of the WHO 6-step technique ($P < .001$). Laustsen et al. (2008)[7] and Widmer et al. (2007)[20] reported that when participants performed the WHO 6-step technique either correctly or incorrectly, bacterial load was reduced; however, the correct application of the technique, as opposed to the incorrect application, resulted in a greater reduction (Widmer $P < .001$; Laustsen P = not reported). This finding was also supported by Reilly et al. (2016),[24] who reported a significant difference in those who had performed the WHO 6-step technique with 100% accuracy compared to those who had not ($P = .01$). Finally, Pires et al. (2017)[23] reported that a modified “Fingertips First” WHO 6-step technique resulted in a greater reduction in bacterial load than the currently recommended WHO 6-step technique ($P = .002$).

Table 1
Characteristics of studies

Author, Date, Country	Aim	Design	Setting	Participants	Intervention(s)	Outcome measure(s)	Results
Chow et al. (2012)[22] Singapore	1. To compare the efficacy of hand hygiene protocols during routine inpatient clinical care 2. To evaluate the time effectiveness of each protocol	RCT	Adult, tertiary care general hospital	Medical and nursing staff (n = 120); 20 medical and 20 nursing staff to each of the 3 intervention groups	<u>Three intervention groups:</u> 1. CDC 3-step technique (handrubbing with alcohol covering all hand surfaces in no particular order) 2. WHO 6-step technique (handrubbing with alcohol using the WHO technique)	<u>Primary outcome:</u> CFUs using the modified glove-juice technique of the dominant hand of each participant (1) after patient contact but before hand hygiene and (2) after hand hygiene <u>Secondary outcome(s):</u> Mean time of each hand hygiene protocol	Overall, hand hygiene resulted in a substantial reduction in bacterial load of 77.65 x10[2] CFU/ml ($P < .01$) After adjusting for staff category compared with protocol 1, protocol 2 (-5.17 x 10[2] CFU/ml, $P = .07$) resulted in slightly greater bacterial load reduction, however the differences between the two protocols were non- significant. Both protocols were effective in reducing hand bacterial load. Protocol 1 required less time (median, 26.0 seconds) than protocol 2 (median 38.5 seconds; $P = .04$)
Reilly et al. (2016)[24] Scotland	To evaluate the microbiologic effectiveness of the WHO 6-step and the (CDC) 3-step hand hygiene techniques using alcohol-based handrub	RCT	Acute care inner city teaching hospital	Medical and nursing staff (n = 120); doctors (n = 42) and nurses (n = 78)	<u>Two intervention groups:</u> 1.WHO 6-step technique 2. CDC 3-step technique	<u>Primary outcomes:</u> CFUs (residual bacterial load) using the modified glove-juice technique of each participant (1) after patient contact but beforehand hygiene and (2) after hand hygiene <u>Secondary outcomes:</u> Compliance with the technique Hand coverage Duration (seconds)	The 6-step technique reduced the count from 3.28 CFU/mL (95% CI, 3.11-3.38 CFU/mL) to 2.58 CFU/mL (2.08-2.93 CFU/mL), whereas the 3-step reduced it from 3.08 CFU/mL (2.977-3.27 CFU/mL) to 2.88 CFU/mL (–2.58 to 3.15 CFU/mL) ($P = .02$). Only 65% (n = 39/60) were fully compliant with the WHO technique i.e. followed the instructions exactly. Among those fully compliant, the median bacterial load went from 3.18 (before) to 2.08 (after hand hygiene) $\log_{10}$ CFU/mL, compared with 3.36 (before) to 2.55 (after hand hygiene) log10 CFU/mL among those not fully compliant ($P = .01$) No significant difference in total hand coverage between WHO (98.8%) vs CDC technique (99.0%, $P = .15$) Percentage of hand area not covered WHO technique (Median 1.20) CDC technique (Median 102 $P = .97$) The WHO technique required 15% (95% CI, 6-24%) more time than the CDC technique (42.5 vs 35 seconds, $P = .002$)

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Table 1
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Author, Date, Country	Aim	Design	Setting	Participants	Intervention(s)	Outcome measure(s)	Results
Tschudin-Sutter et al. (2017)[25] Switzerland	To assess a modified 3-step technique and compare it to the conventional WHO 6-step technique in terms of bacterial counts reduction on HCW hands	RCT (crossover)	University hospital	Medical students (n = 32)	Intervention group: Modified 3-step technique consisting of: a. covering all surfaces of the hands b. rotational rubbing of fingertips in the palm of the alternate hand c. rotational rubbing of both thumbs Control group: WHO 6-step technique	Primary outcome: CFUs using the modified glove-juice technique	Pre hand hygiene: Log bacterial counts did not differ between the control group (WHO technique) (median 6.37 $\log_{10}$ CFU, IQR 6.19-6.54) and the intervention group (median 6.34 $\log_{10}$ CFU, IQR 6.17-6.60, one-sided $P = .513$) Post hand hygiene: Reductions in CFU were evident for both intervention and control groups. There were lower bacterial counts in the intervention group (median 1.96 $\log_{10}$ CFU, IQR 1.25-2.52) compared to control group (median 2.34 $\log_{10}$ CFU, IQR 1.80-2.71, one-sided $P = .055$) The logarithmic reduction factor was higher in the intervention group (median 4.45 $\log_{10}$ CFU, IQR 4.04-5.15 versus 3.91 $\log_{10}$ CFU, IQR 3.69-4.62, one-sided P-value=.010, two-sided P-value 0.021)
Laustsen et al. (2008)[7] Denmark	To investigate the use of the correct application of WHO 6-step technique before and after performance of a clinical procedure	Non-controlled before and after	University hospital	Staff members from 10 departments working during a randomly chosen weekday (n = 117). Staff members with hand dermatitis were excluded (n = 2)	WHO 6-step technique before and after a clinical procedure)	Primary outcome: CFUs from finger imprint technique of the dominant hand	Before clinical procedure: **Imprint 1**- before WHO technique **Imprint 2**- after WHO technique 56% (n = 66/117) performed correct WHO technique **Correct use** of WHO six-step technique significantly reduced number of CFUs by 90% (from 18.1 CFU per plate [95% CI, 13.5-24.2] to 1.8 CFU per plate [95% CI, 1.1-2.7]; $P < .001$) **Incorrect use** of WHO six-step technique significantly reduced number of CFUs by 60% (from 25.5 CFU per plate [95% CI, 18.4-35.1] to 10.2 CFU per plate [95% CI, 7.2-14.3]; $P < .001$) After clinical procedure: **Imprint 3**- before WHO technique **Imprint 4**- after WHO technique 58% (n = 68/117) performed correct WHO handrub technique **Correct use** of WHO handrub technique significantly reduced the number of CFUs by 82% (from 10.0 CFU per plate [95% CI, 7.4-13.5] to 1.8 CFU per plate [95% CI, 1.1-2.7]; $P < .001$) **Incorrect use** of WHO handrub technique significantly reduced the number of CFUs by 54% (from 16.3 CFU per plate [95% CI,11.6-22.7] to 7.5 CFU per plate [95% CI, 5.2-10.7]; $P < .001$)

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Table 1
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Author, Date, Country	Aim	Design	Setting	Participants	Intervention(s)	Outcome measure(s)	Results
Pires et al. (2017)[23] Switzerland	To evaluate whether modifying the sequence of the WHO technique by performing step 6 first would result in greater bacterial reduction on HCW hands	Non-randomized cross-over trial	University hospital	HCWs (n = 16) Nurses (n = 7) and medical doctors/pharmacists/ biologists (n = 9)	Two intervention groups: 1. WHO 6-step technique 2. Modified version, WHO "Fingertips First"	Primary outcome: CFUs retrieved from finger imprint technique at baseline and after each of the 2 different techniques	Overall, the $\log_{10}$ reduction in bacterial concentration was significantly higher when performing the WHO "Fingertips First" (3.44(±1.33, 3.20)) compared with the WHO six-step technique (2.68 (±1.48, 2.85)) After adjustment for hand size and gender, the mean reduction of bacterial concentration was 0.77 log10 greater (95% CI, 0.27-1.26; $P = .002$) following the WHO "Fingertips First" technique than following the WHO six-step technique
Tschudin-Sutter et al. (2010)[21] Switzerland	To evaluate the level of bacterial killing on hands of medical students using the WHO technique	Non-controlled before and after	University	Medical students (n = 563)	WHO 6-step technique	Primary outcome: CFUs from finger imprint technique before and after use of handrub Secondary outcome: Hand coverage	Before WHO handrub technique: Bacterial density was- 26-100 CFU per plate (n = 259, 46%) >100 CFU per plate (n = 207, 36.8%) <26 CFU per plate (n = 97, 17.2%) After WHO handrub technique: No detectable bacteria (n = 244, 43.3%) <25 CFUs per plate (n = 262, 46.5%) 25-100 CFUs per plate (n = 45, 8%) <100CFUs per plate (n = 12, 2.1%) The difference in the density of CFUs before and after WHO handrub technique was highly significant ($P < .001$) Not reported
Widmer et al. (2007)[20] Switzerland	To evaluate the impact of the WHO 6-step technique	Non-controlled before and after	University-affiliated geriatric hospital	All physicians and 10 nurses per ward were selected by an infection control professional (n = 180)	WHO 6-step technique	Primary outcome: CFUs from finger imprint technique Secondary outcome: Hand coverage	Before training with WHO handrub technique: Only 31% HCWs used proper technique, yielding a low reduction factor of 1.4 $\log_{10}$ CFU bacterial count After training with WHO handrub technique: Proper technique used by 74% of HCWs with an increased reduction factor to 2.2 $\log_{10}$ CFU bacterial count Improvement in application of the technique improved the antimicrobial effect of the technique. ($P < .001$) Not reported

CDC, Centers for Disease Control and Prevention; *CFU*, colony-forming unit; *HCW*, healthcare worker; *RCT*, randomized controlled trial; *WHO*, World Health Organization.

Secondary outcomes of all studies

Secondary outcome measures were mean time of hand hygiene and hand coverage.

Median time of hand hygiene

Chow et al. (2012)[22] and Reilly et al. (2016)[24] both monitored the median time for conducting hand hygiene using the WHO 6-step and the CDC 3-step techniques and reported a single median time for each respectively. Chow et al. (2012) found that,[22] despite the CDC 3-step technique requiring significantly less time to complete than the WHO 6-step technique ($P = .04$), it was still as effective in reducing bacterial load. In contrast, Reilly et al. (2016)[24] found that the WHO 6-step technique was more effective than the CDC 3-step technique but agreed that it took longer to perform ($P = .002$).

Hand coverage

Widmer et al. (2007)[20] and Tschudin-Sutter et al. (2010)[21] examined hand coverage using an ultraviolet light box to detect areas missed on the hands after hand hygiene, but they did not report specific results on this. Reilly et al. (2016)[24] also evaluated hand coverage. They found that the WHO 6-step technique did not increase the total hand coverage area ($P = .15$) and that a reduction in bacterial count was not related to hand coverage ($P = .97$).

Methodological quality of RCTs

Chow et al. (2012)[22] and Reilly et al. (2016)[24] both used a parallel group RCT to compare the microbiological effectiveness of the WHO 6-step and the simpler CDC 3-step hand hygiene techniques. Both studies used pre-prepared sealed envelopes to allocate participants,[22,24] thereby reducing selection bias. The robustness of the studies was enhanced by blinding of the microbiologists,[22,24] thereby reducing detection bias. However, the data collectors were not blinded to the allocated protocols in either study,[22,24] because they timed the performance of the allocated hand hygiene technique and performed the glove-juice technique for collection of the microbiological samples. They were, however, trained in the application of the glove-juice technique and timing of the hand hygiene technique, thereby enhancing reliability of the data collection methods,[22,24] but neither study tested the inter-rater reliability of the data collectors.

Tschudin-Sutter et al. (2017)[25] performed a randomized crossover trial to assess a modified 3-step technique (intervention group) against the WHO 6-step technique (WHO reference group) in terms of bacterial load reduction. Participants were randomly assigned to each group, and then assignments were reversed after 1 day. Unlike the previous studies,[22,24] Tschudin-Sutter et al. (2017)[25] did not mention blinding of the data collectors, who performed the glove-juice technique for the collection of microbiological samples, or if the data collectors had completed any training. Therefore, it is difficult to assess the reliability of the data collection process in this study. The studies by Chow et al. (2012)[22] and Reilly et al. (2016)[24] were powered, and recruitment targets were achieved,[22,24] whereas Tschudin-Sutter et al. (2017)[25] did not mention this, so it is unclear whether their sample size was adequate.

All 3 studies used the modified glove-juice sampling method.[22,24,25] Chow et al. (2012)[22] stated that this method provides a more accurate measurement of the actual bacterial burden that could be transferred via hand contact. However, it could be argued that the glove-juice method measures the reduction in resident skin flora as well as transient skin flora. Thus, although the RCTs using this method demonstrated reductions in CFUs, they were not necessarily measuring reductions relevant to the transmission of infection in a clinical setting. Furthermore, the CFUs detected after patient contact but before hand hygiene would be affected by the number of transient organisms acquired during the clinical procedure(s). In addition, the glove-juice sampling technique might have also removed some bacteria from participants' hands before ABHR was applied, thereby overestimating the bacterial reduction. This number will vary considerably; and if the comparison of reduction outcomes is valid, evidence is required to show that there is a true random distribution of contamination density across the 2 groups. It is unknown whether this can be guaranteed in a relatively small sample of clinicians delivering different aspects of care. Therefore, this is a flaw of these study designs.

These studies have other limitations. Unlike Reilly et al. (2016),[24] Chow et al. (2012)[22] were unable to determine whether specific areas of the hand had been missed by the hand hygiene techniques, because they did not evaluate hand coverage and sites missed. Previous studies[8,20] showed that the thumb and fingertips are the most frequently missed areas on the hands. In the study by Reilly et al. (2016),[24] correlation between bacterial reduction and hand surface coverage was also a limitation, because these data were collected at 2 different time points. Therefore, Reilly et al. (2016)[24] could not be certain that the technique was performed by participants in exactly the same way each time, although standardization by showing each participant an instruction card with a diagram of the allocated technique should have helped minimise the risk.

Methodological quality of other study designs

Four of the included studies were designs other than RCTs. The sample size in these studies ranged from 7 to 563.[7,20,21,23] None of these studies mentioned if they were powered, so it is unclear whether their sample sizes were adequate for the analyses they performed. The sampling strategy varied in the different studies, with 3 of 4 studies[20,21,23] using a non-randomized strategy and thereby being prone to selection bias.

All 4 studies used a different sampling method, involving the finger-imprint technique, compared to the RCTs. A limitation of the finger-imprint technique is it only allows bacterial measurement from the fingertips. As the study by Reilly et al. (2016)[24] showed, the back of the hands, the back of the thumbs, and the back of the index fingers were the most frequently missed sites regardless of the technique used. However, it could be argued that the finger-imprint technique is perhaps a more valid method of bacterial measurement in terms of transmission of infections because it solely removes transient organisms.

Finally, only 2 of the 4 studies mentioned training data collectors.[7,20] In both of these studies, a high inter-rate agreement was obtained prior to data collection, enhancing reliability. However, despite this, these studies[7,20,21] had no control groups, making it difficult to differentiate between the observed effect being due to the hand hygiene technique or to other confounding variables, thereby affecting the validity of the outcomes.

DISCUSSION

Hand hygiene is the single most important intervention to reduce the risk of cross transmission of infection.[1] Despite this, to our knowledge, this is the first systematic review to evaluate the evidence for the WHO technique in reducing the microbial load on the hands of HCWs. All 7 included studies found that the WHO 6-step technique reduced bacterial load on the hands of HCWs; however. the strongest evidence came from 3 RCTs, which presented conflicting evidence. Chow et al. (2012)[22] found no difference in the effectiveness of the WHO 6-step technique compared to the CDC 3-step technique, whereas Reilly et al. (2016)[24] found the WHO 6-step technique to be more effective. Tschudin-Sutter et al. (2017)[25] reported that a modified 3-step technique that focused on the fingertips and thumbs was more effective than the WHO 6-step technique. These 3 studies were all conducted in a hospital setting; therefore, it should be noted that these findings are relevant to this particular healthcare setting. The remaining evidence comes from studies with poor-quality research designs due to their lack of randomization and control groups. As a result, only limited conclusions can be drawn from these studies.

Of particular note is the study by Chow et al. (2012),[22] which found that coverage of all aspects of the hands was as effective as the WHO 6-step technique and quicker. This supports similar findings from Tschudin-Sutter et al. (2017)[25] and from an earlier study by Kampf et al. (2008),[8] the latter of which which was not included in this review because it included non-healthcare participants. However, the former study used a different technique from Chow et al. (2012),[22] in that it included fingertip- and thumb-rubbing steps. Having a simple and quick technique, effectively reducing key reported behavioral barriers,[1] could be important in clinical practice. It may also increase compliance and potentially improve hand hygiene practice within the clinical setting, given that suboptimal rates of HCW compliance with the WHO 6-step technique have been previously reported in studies worldwide.[13-15] However, there are limits to the amount of time that can be saved with different techniques. According to current understanding, when using ABHR the hands should be allowed to dry after performing “the technique” and before proceeding.[1]

Interestingly, Reilly et al. (2016)[24] found that the efficacy of the WHO 6-step technique was enhanced when it was performed with 100% accuracy (correct steps, correct order), whereas Pires et al. (2017)[23] showed that the efficacy of the WHO 6-step technique was enhanced when the order of steps was changed—when the finger tips, normally the last step, was performed first. This not only raises questions about what technique is best but also suggests that techniques can be modified to enhance their effectiveness.

From the whole body of evidence, it is difficult to differentiate between the efficacy of different hand hygiene techniques. In addition, potential confounding factors, such as time taken to perform hand hygiene and accuracy in performance of the technique, have not always been controlled for and may have influenced the results.

Historically, in infection prevention and control studies, the default research design has been observational studies; however, randomized controlled studies of hand hygiene techniques, as discussed in this review, are possible. The included studies provide some relevant and interesting findings that demonstrate that the techniques reduce bacterial load on HCWs’ hands; but overall the level of evidence is low, and the generalizability of the findings is limited. These studies can, however, form the basis of more robust future studies. Therefore, we recommend that RCTs directly comparing the effectiveness of the different techniques be performed in clinical practice.

CONCLUSION

Implications for practice

Although this review provides evidence supporting the use of the WHO 6-step hand hygiene technique in clinical practice, it is evident that further research involving more robust research designs should be undertaken to identify the best hand hygiene technique. Compliance with the recommended hand hygiene is suboptimal, and improving current techniques or developing new ones may help improve this. However, hand hygiene is an essential part of infection prevention, and control measures and current practices should be maintained while additional evidence is gathered.

Implications for research

Further robust research, using well-designed RCTs that specifically focus on the different hand hygiene techniques, is required to determine which technique is the most effective and in what context. All of the following measures are required: determining the bacterial load on the hands of healthcare staff before and after application of techniques, during clinical practice in acute-care hospitals; controlling the time of application and the products used; including inter-rater reliability testing of data collectors; blinding microbiologists to study protocols; and having adequate sample sizes to power the studies. Randomization of the population should help control for differences in participant experiences, previous training, and expectations of the hand hygiene technique; but the reporting of these data will demonstrate if this has been achieved. The use of the glove-juice technique or the finger-imprint technique for the collection of microbiological samples is open to debate. When conducting experiments on hand hygiene, the European Standard EN 1500 guidelines[27] recommend the finger-imprint method, whereas the U.S. Food and Drug Administration[28] recommends the glove-juice method. Secondary outcomes could include reduction in the number and type of organisms. Regarding the performance of hand hygiene systematic reviews, our search retrieved a large number of articles that were excluded because they were not empirical studies. We recommend that others performing similar searches include study design as one of the search domains. Finally, when reporting the findings of hand hygiene research, this review identified the need to include a thorough description of the hand hygiene techniques, sampling strategy, and population/sample in each study, using reporting templates such as Consort,[29] Strobe,[30] and Orion.[31]

This review highlighted current evidence regarding the effectiveness of the WHO hand hygiene technique in reducing microbial load on the hands of HCWs. The findings provide direction for current practice and future research. Hand hygiene research must continue to evolve to inform global action to prevent and control healthcare-associated infections and contain antimicrobial resistance.

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APPENDIX

Search Terms	
Context	
1	(MH "Delivery of Health Care")
2	(Healthcare OR health care OR health): ti,ab
Population	
3	(MH "Health personnel") OR "personnel": ti,ab
4	(MH "Allied health personnel")
5	(MH "emergency medical technicians") OR "emergency medical technician*": ti,ab
6	(MH "nurses'aides+") OR "nurses' aides": ti,ab
7	(MH "nutritionists") OR nutritionists: ti,ab
8	(MH "operating room technicians") OR "operating room technician*": ti,ab
9	(MH "physical therapist assistants") OR "physical therapist*": ti,ab
10	(MH "physician assistants+") OR "physician assistant*: ti,ab
11	(MH "infection control practitioners") OR "infection control practitioner*": ti,ab
12	(MH "medical laboratory personnel")
13	(MH "medical staff+") OR "medical staff": ti,ab
14	(MH "nurses+") OR nurses: ti,ab
15	(MH "nursing staff+") OR "nursing staff": ti,ab
16	(MH "physicians+") OR physicians: ti,ab
17	(MH "social workers") OR "worker*": ti,ab
18	professional: ti,ab
19	employee: ti,ab
20	podiatrist*: ti,ab
21	"occupational therapist*": ti,ab
22	dietician*: ti,ab
23	radiographer*: ti,ab
24	medic*:ti, ab
25	physiotherapist*:ti,ab
26	"dialysis technician*": ti,ab
27	"dietetic technician*": ti,ab
28	"pharmacy technician*": ti,ab
29	"cardiopulmonary technician*": ti,ab
30	"cardiovascular technician*: ti,ab
31	"nuclear medicine technician*": ti,ab
32	"radiologic technologist*": ti,ab
33	"orthop#edic technologist*": ti,ab
34	practitioner*:ti, ab

(*continued on next page*)

APPENDIX

Continued

Search Terms	
Intervention	
35	(MH "Hand Hygiene+") OR ("hand hygiene"): ti,ab
36	(MH "Hand Disinfection") OR ("hand disinfection"): ti,ab
37	(handwashing OR "hand washing"): ti,ab
38	("hand decontamination"): ti,ab
39	(handrub* OR "hand rub*"): ti,ab
40	("hand sanit*"): ti,ab
41	("hand clean*"): ti,ab
42	("hand asepsis"): ti,ab
43	("hand degerming"):ti, ab
44	("hand gel*"): ti,ab
45	("alcohol based hand rub*"): ti,ab
46	("alcohol based hand sanit*"): ti,ab
47	(ABHR OR ABHS): ti,ab
48	Ayliffe*: ti,ab
49	technique: ti,ab
50	procedure: ti,ab
51	approach:ti, ab
52	method*:ti, ab
53	practice*:ti, ab
54	guideline*:ti, ab
55	protocol*:ti, ab
56	recommendation*:ti, ab
57	("6 step*" OR "six step*"): ti,ab
58	("7 step*" OR "seven step*"): ti,ab
59	(WHO OR WHO's OR "world health organi?ation*": ti,ab
Primary Outcomes	
60	(MH "colony count, microbial+") OR (MH "bacterial load")
61	"microbial count" OR "microbial load" OR "microbial contamination" OR "microbial coloni?ation": ti,ab
62	"colony count": ti,ab
63	"bacterial count" OR "bacterial load" OR "bacterial contamination" OR "bacterial coloni?ation": ti,ab
64	"antibacterial efficacy":ti, ab
65	"skin flora": ti,ab
66	microorganism* OR "micro organism*" OR microbes: ti,ab
67	(MH "Bacteria+")
68	(MH "Fungi+")
69	(MH "Infection+")
70	pathogen* OR bacteria OR virus*OR yeast* OR infection*: ti,ab
71	("colony forming units" OR cfu):ti, ab
Secondary Outcomes	
72	(MH "Disease transmission, infectious")
73	(MH "infectious disease transmission, professional-to-patient")
74	(MH "infection control")
75	(MH "disease outbreaks+")
76	(MH "mortality+")
77	"disease transmission" OR "infection control" OR "infection prevention" OR "cross transmission" OR "communicable disease control" OR "communicable disease prevention" OR "cross infection" OR nosocomia*: ti, ab
78	mortality OR fatalit*: ti, ab
79	outbreak*: ti, ab
80	compliance OR adherence: ti,ab
Combining searches	
81	1 OR 2
82	3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30 OR 31 OR 32 OR 33 OR 34
83	35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42 OR 43 OR 44 OR 45 OR 46 OR 47
84	48 OR 49 OR 50 OR 51 OR 52 OR 53 OR 54 OR 55 OR 56 OR 57 OR 58 OR 59
85	60 OR 61 OR 62 OR 63 OR 64 OR 65 OR 66 OR 67 OR 68 OR 69 OR 70 OR 71 OR 72 OR 73 OR 74 OR 75 OR 76 OR 77 OR 78 OR 79 OR 80
86	81 AND 82 AND 83 AND 84 AND 85
87	86 Limits: June2011-June2017, English language

*wildcard tool used in searching.