



## Research article

# Compliance with hand hygiene practices and its appropriateness among healthcare workers during COVID-19 pandemic in public health facilities of Tamil Nadu, India<sup>☆</sup>

Yuvaraj Krishnamoorthy<sup>\*</sup>, Kala M, Deivasigamani Kuberan, Murali Krishnan, Devidas Tondare

Department of Community Medicine, ESIC Medical College and PGIMS, K.K. Nagar, Chennai, India

## ARTICLE INFO

## Keywords:

COVID-19  
Hand hygiene  
Healthcare associated infection  
Patient safety

## ABSTRACT

**Background:** Compliance with appropriate hand hygiene practises is the most efficient and cost-effective intervention that can be implemented in the healthcare setting. Given its importance, we tried to capture the compliance with hand hygiene practises and their appropriateness among healthcare workers during the COVID-19 pandemic in public health facilities in Tamil Nadu.

**Methods:** This cross-sectional study involved doctors, nurses, and allied healthcare professionals from various departments in 18 public healthcare facilities spanning six districts in Tamil Nadu. A random-intercept model was employed for the multivariable logistic regression analysis to evaluate the factors influencing hand hygiene compliance and its adequacy. The effect size was presented as an adjusted odds ratio (aOR) accompanied by a 95% confidence interval (CI).

**Results:** In total, 2733 hand hygiene observations were made. Only during 19.4% (95%CI: 17.9%–20.9%) of these observations, hand washing was done. Only during 37.9% (95%CI: 33.9%–42.1%) of these observations, hand washing was done appropriately by following all the essential steps of hand hygiene. Nurses (aOR = 2.49; 95%CI: 1.90–3.26), healthcare workers in General Surgery (aOR = 2.18; 95%CI: 1.53–3.10) and Obstetrics & Gynaecology departments (aOR = 1.75; 95%CI: 1.26–2.43), working in inpatient departments (aOR = 2.64; 95%CI: 1.38–5.04) had significantly higher compliance to hand hygiene practices. Nurses (aOR = 2.58; 95%CI: 1.33–5.01) and General Medicine department healthcare workers (aOR = 1.98; 95%CI: 1.09–3.61) had significantly higher compliance to appropriate hand hygiene practices.

**Conclusion:** Our study shows that only during one-fifth of the observations did healthcare workers do hand washing, and less than 10% did it appropriately by following all the essential steps of hand hygiene.

## 1. Introduction

Hand hygiene practices among healthcare workers (HCWs) play a vital role in patient safety. Healthcare facilities are high-risk

<sup>☆</sup> Yuvaraj Krishnamoorthy reports financial support was provided by Tamil Nadu Health System Reforms Project.

<sup>\*</sup> Corresponding author.

E-mail addresses: [yuvi.1130@gmail.com](mailto:yuvi.1130@gmail.com) (Y. Krishnamoorthy), [drkaladorai@gmail.com](mailto:drkaladorai@gmail.com) (K. M), [dkuberan@gmail.com](mailto:dkuberan@gmail.com) (D. Kuberan), [physiomuralikrishna@gmail.com](mailto:physiomuralikrishna@gmail.com) (M. Krishnan), [ntondare@gmail.com](mailto:ntondare@gmail.com) (D. Tondare).

<https://doi.org/10.1016/j.heliyon.2023.e15410>

Received 24 September 2022; Received in revised form 5 April 2023; Accepted 6 April 2023

Available online 14 April 2023

2405-8440/© 2023 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

areas, where both the care providers and patients are exposed to numerous microorganisms. A breach in hygiene practices has often resulted in nosocomial infections or healthcare associated infections (HAIs), which are unfortunate and accidental. HAIs caused by resistant microorganisms pose a serious threat, as these infections are difficult to treat. This impacts the healthcare system in terms of cost and quality of services in addition to contributing to significant rise in morbidity and mortality [1]. According to a WHO report, 7% of patients admitted to hospitals develop HAIs amongst developed countries, while this burden rises to 10% amongst developing countries [2].

With the ongoing COVID-19 pandemic, awareness of hand hygiene has gained significant momentum globally. However, poor compliance among healthcare workers still ranges from 9% in low-income countries to not more than 70% in high-income countries [3]. The CDC reports that HCWs wash their hands less than half the time as recommended for them [4]. These calls for a greater commitment to these life-saving practices, particularly in healthcare settings.

Hand hygiene compliance includes washing hands with soap and water using an appropriate technique to remove microorganisms. If done appropriately, it is the most efficient and cost-effective intervention that can be implemented in the healthcare setting [5]. It reduces the growth of microorganisms and has an inverse relationship with the incidence of HAIs [6]. To increase awareness among HCWs, WHO launched the “Save Lives: Clean Your Hands” campaign in 2009. Every year, through this campaign, WHO aims to galvanize the adoption of hand hygiene measures by HCWs at the right time and in the right way. The “five moments of hand hygiene” were developed as a standard guide to be followed by HCWs [7]. In lower and middle-income countries, factors like overcrowding, access to water resources, lack of awareness and proper training, etc. make it more challenging to adhere to hand hygiene protocols. The lessons from the ongoing pandemic have been learned well. However, it is an undeniable fact that the healthcare facilities have been overburdened like never before. With such a great burden comes even more greater responsibility to safeguard the well-being of patients. There is a dearth of literature on compliance with hand hygiene in Indian settings during the COVID-19 pandemic. Our aim through this survey was to observe the hand hygiene compliance of HCWs during the COVID-19 pandemic as per the “WHO five moments of hand hygiene” in selected secondary and tertiary care facilities of Tamil Nadu.

## 2. Methods

### 2.1. Study design and study setting

This cross-sectional investigation was carried out within the framework of an extensive mixed-methods research project examining patient safety practices in public healthcare facilities throughout Tamil Nadu [8]. Situated in the southern region of India, Tamil Nadu features a three-tiered healthcare delivery system. Our survey was focused primarily on the secondary and tertiary care facilities in Tamil Nadu, as the patient safety framework was primarily focused on the secondary and tertiary levels of the healthcare delivery system.

This study was approved by Institutional Ethics Committee of ESIC Medical College & PGIMS, Chennai dated 04.05.2021 with IEC No. IEC/2021/1/12.

### 2.2. Sampling strategy

We employed a two-stage stratified random sampling technique to choose public healthcare facilities. Initially, districts were categorized into low, medium, and high groups according to their respective human development index (HDI) scores [9]. Two districts were selected randomly from each of these strata using the lottery method. Then, 18 public health facilities (6 medical colleges and 12 Government Hospitals) were selected.

### 2.3. Sample size calculation

The sample size was determined based on a prior study reporting a 22% non-compliance rate for hand hygiene [10], a 10% relative precision, and a design effect of 2. With these parameters, we needed to observe approximately 2700 hand hygiene opportunities. Given that our sample included 18 facilities, we aimed to observe 150 hand hygiene opportunities at each facility ( $150 \times 18 = 2700$ ).

### 2.4. Data collection process

We recruited research assistants as data collectors for this survey. They received a week-long training to familiarize them with the data collection methods, tools, and facility-level observations. The research assistants then conducted direct, non-participant, structured, undisguised observations of healthcare professionals' hand hygiene practices. Biomedical waste disposal practices were also observed on a different day with different set of healthcare workers and the findings of the study are published elsewhere [11].

Various healthcare worker (HCW) cadres, including doctors, nurses, laboratory technicians, and pharmacists, were observed in the chosen facilities. Observations took place in the following departments: General Medicine, General Surgery, Obstetrics & Gynaecology, Orthopaedics, and Paediatrics. Within each department, observations were conducted in the outpatient department (OPD), inpatient department (IPD), injection OPD, Procedure room, and intensive care unit (ICU). The Principal Investigator and Co-Investigators periodically monitored the data collection process.

After consulting with subject experts and reviewing the literature, observation checklists were developed. Hand hygiene compliance was assessed during the five moments of hand hygiene (as defined by WHO) [12]:

- Before touching a patient,
- Before clean/aseptic procedures,
- After body fluid exposure/risk,
- After touching a patient,
- After touching patient surroundings.

Additionally, information regarding training and awareness sessions on hand hygiene was gathered at each facility as part of the broader patient safety study.

## 2.5. Operational definitions

**Compliance with hand hygiene practices:** HCWs were considered compliant with hand hygiene practices if they performed handwashing using soap and water or an alcohol-based hand rub during any of the five moments of hand hygiene, as outlined by the WHO [13].

**Appropriate hand hygiene practices:** HCWs were deemed to have performed appropriate hand hygiene practices if they followed all six essential steps of handwashing recommended by WHO. These steps include: palm-to-palm contact, right palm over the left dorsum and vice versa, palm-to-palm contact with fingers interlaced, backs of fingers against opposing palms, rubbing of thumbs, and rubbing of fingertips [13].

## 2.6. Statistical analysis

Data entry was completed using EpiCollect5, and analysis was conducted using STATA software version 14.2 (StataCorp, College Station, TX, USA). Continuous variables were presented as mean and standard deviation (SD), while categorical variables were expressed as frequency and percentages. Outcome variables, including hand hygiene compliance and appropriate hand hygiene practice, were reported with 95% Confidence Intervals (CIs). Hand hygiene compliance and appropriateness were treated as dependent variables, while factors such as HCW type, department, department section, and hand hygiene moment were considered explanatory variables. A logistic regression model was employed to assess determinants of hand hygiene compliance and appropriateness. Factors with p-values less than 0.20 in univariable analysis were incorporated in the multivariable analysis.

To account for the multiple levels involved in the sampling strategy, multilevel modeling was performed. The impact of clustering at the level of healthcare facility was evaluated using a random-intercept model [14]. A likelihood ratio test (LR test) was conducted to compare this model with the naïve model (final model in multiple logistic regression). In cases where the LR test proved significant, a multivariable logistic regression analysis based on the random-intercept model was performed. The effect size was reported as an adjusted Odds Ratio (aOR) with a 95%CI. Variables with p-values less than 0.05 were deemed statistically significant.

## 3. Results

A total of 2733 hand hygiene observations were conducted throughout the surveyed healthcare facilities. Table-1 presents a

**Table 1**  
Hand hygiene observations across public health facilities in Tamil Nadu (n = 2733).

Characteristics	Categories	Frequency (%)
Designation	Doctor	887 (32.5)
	Nurse	1552 (56.8)
	Other allied staffs <sup>a</sup>	294 (10.7)
Department	General Medicine	1475 (54.0)
	General Surgery	251 (9.2)
	Obstetrics & Gynecology	350 (12.8)
	Pediatrics	333 (12.2)
	Orthopedics	324 (11.8)
	Outpatient department	863 (31.6)
Division	Inpatient department	1297 (47.5)
	Injection OPD	447 (16.3)
	Procedure room	126 (4.6)
	After body fluid exposure	47 (1.7)
Which of the “5 moments of hand hygiene” was observed?	After touching the patients	1033 (37.8)
	After touching patient surroundings	483 (17.7)
	Before clean or aseptic procedure	69 (2.5)
	Before touching patients	1101 (40.3)
	Yes	530 (19.4)
Whether hand hygiene was performed during the event	No	2203 (80.6)
Whether hand hygiene was performed appropriately during the event (n = 530)	Yes	201 (37.9)
	No	229 (62.1)

<sup>a</sup> Laboratory technicians, pharmacists.

summary of the hand hygiene observations made among healthcare workers in public health facilities across Tamil Nadu. Most observations were among nurses (56.8%), followed by doctors (32.5%) and other allied staff (10.7%). Over half of the observations took place in the general medicine department. Almost half of the observations occurred in the IPD (47.5%), followed by general OPD (31.6%) and injection OPD (16.3%). The majority of healthcare facilities (16 out of 18) provided hand hygiene training for HCWs, while only 10 out of 18 facilities conducted awareness sessions on hand hygiene measures for the general public.

Majority of the observations were made before and after touching the patients amongst the “5 moments of hand hygiene”. Only during one-fifth (19.4%; 95%CI: 17.9%–20.9%) of the observations, hand washing done by the healthcare workers. Among the 530 observations during which hand washing was done, only during 201 (37.9%; 95%CI: 33.9%–42.1%) of the observations, hand washing was done appropriately by following all the essential steps of hand hygiene.

Tables-2 & 3 show the determinants of compliance and appropriateness for hand hygiene practices. Clustering at healthcare facility level was found with significant LR test ( $p < 0.001$ ) for both of these models. Intraclass correlation coefficient (ICC) was 0.36 and 0.14 respectively.

Initially, in the unadjusted analysis of the compliance model, factors such as designation, department, section of the department, and moment of hand hygiene were found to be significant determinants. All of these factors were then included in the adjusted analysis.

When compared to doctors, nurses (aOR = 2.49; 95%CI: 1.90–3.26) and allied healthcare staffs (aOR = 2.61; 95%CI: 1.75–3.88) had significantly higher compliance with hand hygiene practices. HCWs in General Surgery (aOR = 2.18; 95%CI: 1.53–3.10) and Obstetrics & Gynaecology departments (aOR = 1.75; 95%CI: 1.26–2.43) had significantly higher compliance to hand hygiene practices when compared to those working in General Medicine department. HCWs in IPD (aOR = 2.64; 95%CI: 1.38–5.04) had significantly higher compliance with hand hygiene practices when compared to those in procedure room. HCWs had maximum compliance to hand hygiene practices after exposure to body fluids (aOR = 15.8; 95%CI: 7.74–32.1), before clean or aseptic procedure (aOR = 8.70; 95%CI: 5.10–14.85) and after touching the patients (aOR = 2.23; 95%CI: 1.77–2.82).

In the unadjusted analysis of appropriateness model, designation and department were significant determinants. However, five moments of hand hygiene had  $p$ -value less than 0.20 and were also included in the multivariable model.

Nurses exhibited notably better compliance to appropriate hand hygiene practices (aOR = 2.58; 95%CI: 1.33–5.01) compared to allied healthcare staff. Additionally, HCWs in the General Medicine department demonstrated significantly higher compliance to appropriate hand hygiene practices (aOR = 1.98; 95%CI: 1.09–3.61) in contrast to those working in the General Surgery department.

#### 4. Discussion

Healthcare-associated infection is one of the most common complications associated with healthcare management [2]. It is a serious complication as it can lead to high rate of morbidity and mortality, length of hospital stays, and costs associated with it [2]. Hence, implementation of effective infection prevention & control practices is central to the provision of high-quality care for patients and HCWs in hospitals. The ongoing COVID-19 crisis has actually had a positive impact on the infection control measures, as most of the public health facilities have conducted training for HCWs on hand hygiene, installed hand washing stations with sanitizers and

**Table 2**  
Determinants of compliance to hand hygiene measures amongst HCWs in surveyed public healthcare facilities of Tamil Nadu (N = 2733).

Characteristics	Total, N	Compliance to hand hygiene, n (%)	Adjusted Odds Ratio <sup>#</sup> (95%CI)	P-value
<b>Designation</b>				
Doctors	887	90 (10.1)	Ref	–
Nurses	1552	372 (24.0)	2.49 (1.90–3.26)	<0.001*
Other allied staff <sup>§</sup>	294	68 (23.1)	2.61 (1.75–3.88)	<0.001*
<b>Department</b>				
General Medicine	1475	221 (15.0)	Ref	–
General Surgery	251	93 (37.0)	2.18 (1.53–3.10)	<0.001*
Obstetrics & Gynaecology	350	106 (30.3)	1.75 (1.26–2.43)	0.001*
Paediatrics	333	57 (17.1)	1.31 (0.92–1.87)	0.13
Orthopaedics	324	53 (16.4)	1.04 (0.72–1.50)	0.83
<b>Section</b>				
OPD	1310	175 (13.4)	2.05 (1.07–3.90)	0.03*
IPD	1297	341 (26.3)	2.64 (1.38–5.04)	0.003*
Procedure room	126	14 (11.1)	Ref	–
<b>Five moments of hand hygiene</b>				
After body fluid exposure	47	35 (74.5)	15.8 (7.74–32.1)	<0.001*
After touching the patients	1033	247 (23.9)	2.23 (1.77–2.82)	<0.001
After touching patient surroundings	483	65 (13.5)	1.00 (0.72–1.37)	0.98
Before clean or aseptic procedure	69	39 (56.5)	8.70 (5.10–14.85)	<0.001
Before touching patients	1101	144 (13.1)	Ref	–

Ref - Reference value.

\*p value statistically significant.

<sup>§</sup>Laboratory technicians, pharmacists.

<sup>#</sup>Clustering at the level of healthcare facility was adjusted using random-intercept model.

**Table 3**

Determinants of appropriate hand hygiene practices amongst HCWs in surveyed public healthcare facilities of Tamil Nadu (N = 530).

Characteristics	Total, N	Appropriate hand hygiene, n (%)	Unadjusted Odds Ratio* (95%CI)	P-value
<b>Designation</b>				
Doctors	90	28 (31.1)	1.73 (0.90–3.54)	0.19
Nurses	372	157 (42.2)	2.58 (1.33–5.01)	0.005*
Other allied staff <sup>§</sup>	68	15 (22.1)	Ref	–
<b>Department</b>				
General Medicine	221	87 (39.4)	1.98 (1.09–3.61)	0.02*
General Surgery	93	33 (35.5)	Ref	–
Obstetrics & Gynaecology	106	44 (41.5)	1.78 (0.90–3.54)	0.09
Paediatrics	57	19 (33.3)	1.23 (0.56–2.71)	0.60
Orthopaedics	53	17 (32.1)	1.29 (0.56–2.95)	0.55
<b>Section</b>				
OPD	175	66 (37.7)	{Not included in the model}	
IPD	341	129 (37.8)		
Procedure room	14	5 (35.7)		
<b>Five moments of hand hygiene</b>				
After body fluid exposure	35	18 (51.4)	1.91 (0.75–4.86)	0.18
After touching the patients	247	85 (34.4)	0.95 (0.51–1.79)	0.88
After touching patient surroundings	65	23 (35.4)	Ref	–
Before clean or aseptic procedure	39	18 (46.1)	1.43 (0.59–3.43)	0.43
Before touching patients	144	56 (38.9)	1.15 (0.58–2.27)	0.69

Ref - Reference value.

\*p value statistically significant.

<sup>§</sup>Laboratory technicians, pharmacists.<sup>#</sup>Clustering at the level of healthcare facilities was adjusted using random-intercept model.

awareness sessions for the patients.

Despite such positive findings regarding the implementation of hand hygiene facilities and regular staff training sessions in almost all of the facilities, hand washing was done by the HCWs only during one-fifth of the observations and less than 10% did hand washing appropriately by following all the essential steps of hand hygiene. This result was in line with prior research conducted in Southern India and comparable settings [15–20]. However, few studies showed at least 30–60% compliance to hand hygiene practices, representing a wide variation in the compliance with hand hygiene practices across public health facilities [21–23]. Nonetheless, findings from our study are a primary area of concern, given that the WHO has cited hand hygiene as one of the crucial components of COVID-19 containment, and for which overall compliance was less than 20% and appropriate practice was less than 10%. We further explored hand hygiene compliance and appropriateness across several factors to understand the pattern of non-compliance and generate workable recommendations.

We found that the nurses were more compliant to hand hygiene opportunities and appropriate hand hygiene practices than doctors or allied healthcare staffs. This was also found to be similar to previous study findings across Indian settings and other low middle income countries [19,20,22,24,25]. There might be various factors responsible for such poor compliance to hand hygiene among doctors, like work pressure, high caseload, and possibility of superiority complex or following Monkey's Rule (i.e., "why should I follow when others are not Following"), which makes them less receptive to learning from other HCWs—especially nurses.

We found that compliance with hand hygiene was better in IPD compared to OPD and procedure room. However, there was no significant difference in terms of appropriate hand hygiene practices across the settings. This again reiterates the fact that lack of time, work pressure and high case load are the possible reasons for lower compliance with hand hygiene practices at OPD. However, the most worrying finding is the lack of hand hygiene compliance in highly sterile settings like procedure room. But the number of observations in these setting was very low, given the lack of accessibility during the survey.

We have also assessed hand hygiene compliance and appropriateness based on the five moments of hand hygiene. We found that HCWs who had exposure to body fluids had the highest compliance to hand hygiene practices followed by HCWs prior to performing any clean or aseptic procedure, while the least compliance was found before touching any patient or after touching patient surroundings. This finding was similar to the results reported in previous evidence in Indian setting [10,22,26]. The probable reason for such difference could be the perception of HCWs towards practicing hand hygiene when there is higher risk of contracting infections from the patients, i.e., exposure to bodily fluids. For a longer period of time, performing hand hygiene has been a routine practice before performing any clean or aseptic procedure. Hence, the compliance was better during these moments. Nonetheless, it is crucial to change these perceptions and ensure that HCWs comprehend the importance of each moment (as outlined in the WHO's five moments of hand hygiene) in preventing the spread of infection within healthcare facilities. However, a further root cause analysis should be done to identify the possible reasons for the lower compliance and the difference identified across various factors. These data indicate to policymakers which type of health worker, which setting, and what moment of hand hygiene should be prioritized in designing and targeting the infection prevention & control interventions.

Our study possesses several strengths. We employed a standard framework (provided by the WHO) to evaluate hand hygiene practices. Additionally, we conducted a survey of hand hygiene practices across varied tier of health facility (secondary and tertiary), covering various settings (General OPD/IPD/Procedure room/Injection OPD/ICU/OT) and types of HCWs (doctors/nurses/allied

staff). Despite these strengths, our survey faced some limitations. Observer bias could have been present during the hand hygiene observations, as the hospital administrators were informed that such observations would be made on the HCWs within a specific timeframe. Consequently, the dissemination of this information to all the HCWs in the facility might have influenced their practices during the survey.

## 5. Conclusion

Our study shows that only during one-fifth of the observations, healthcare workers did hand washing and less than 10% did it appropriately by following all the essential steps of hand hygiene. Further root cause analysis is necessary to identify the possible reasons for the lower compliance and the difference identified across various factors.

## Author contribution statement

Yuvaraj Krishnamoorthy: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Kala M; Deivasigamani Kuberan; Murali Krishnan; Devidas Tondare: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

## Funding statement

This study was conducted as a part of an Operations Research project with grant from the Tamil Nadu Health Systems Reforms Program, to study the patient safety practices in public health facilities of Tamil Nadu. The grant was awarded to Dr. Yuvaraj Krishnamoorthy. We thank the members of the Operation Research Team for their support throughout the study.

## Data availability statement

Data will be made available on request.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

## Acknowledgments

The authors would like to acknowledge the contributions of Dr. Anuradha R, Dr. Aruna B Patil, Dr. Vijayaprasad Gopichandran, Dr. Venmathi E, Dr. Sathish Rajaa, who gave their valuable inputs during the conduct of the research.

## References

- [1] C.A. Umscheid, M.D. Mitchell, J.A. Doshi, R. Agarwal, K. Williams, P.J. Brennan, Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs, *Infect. Control Hosp. Epidemiol.* 32 (2011) 101–114.
- [2] World Health Organization. Healthcare associated infections: FACT SHEET. [Internet] [cited 24 Jan 2022]. Available from: [https://www.who.int/gpsc/country\\_work/gpsc\\_ccisc\\_fact\\_sheet\\_en.pdf](https://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf).
- [3] M.E.A. de Kraker, E. Tartari, S. Tomczyk, A. Twyman, L.C. Francioli, A. Cassini, et al., Implementation of hand hygiene in health-care facilities: results from the WHO Hand Hygiene Self-Assessment Framework global survey 2019, Available from: *Lancet Infect. Dis.* (2022) <https://www.sciencedirect.com/science/article/pii/S1473309921006186>.
- [4] Hand Hygiene in Healthcare Settings | CDC [Internet] [cited 2022 Mar 26]; Available from: <https://www.cdc.gov/handhygiene/index.html>, 2020.
- [5] G.T. Engdaw, M. Gebrehiwot, Z. Andualem, Hand hygiene compliance and associated factors among health care providers in Central Gondar zone public primary hospitals, Northwest Ethiopia, *Antimicrob. Resist. Infect. Control* 8 (2019) 190.
- [6] V. Mouajou, K. Adams, G. DeLisle, C. Quach, Hand hygiene compliance in the prevention of hospital-acquired infections: a systematic review, *J. Hosp. Infect.* 119 (2022) 33–48.
- [7] World Hand Hygiene Day [Internet]. [cited 2022 Mar 28]; Available from: <https://www.who.int/campaigns/world-hand-hygiene-day>.
- [8] Y. Krishnamoorthy, D. Govindan, S. Rajaa, I. Sinha, K. Kanth, M. Krishnan, G. Samuel, Evaluation of national patient safety implementation framework in selected public healthcare facilities of Tamil Nadu: an operational research, *J. Patient Saf.* (2023), <https://doi.org/10.1097/PTS.0000000000001114> ([Epub ahead of print]).
- [9] State Planning Commission, Government of Tamil Nadu. Tamil Nadu human development report 2017 – status of human development. Available from: <http://www.spc.tn.gov.in/TNHDR2017/chapter2.pdf>.
- [10] S. Chavali, V. Menon, U. Shukla, Hand hygiene compliance among healthcare workers in an accredited tertiary care hospital, *Indian J. Crit. Care Med.* 18 (2014) 689–693.
- [11] Y. Krishnamoorthy, R. A. S. Rajaa, G. Samuel, I. Sinha, Biomedical waste disposal practices among healthcare workers during COVID-19 pandemic in secondary and tertiary care facilities of Tamil Nadu, *Indian J. Med. Microbiol.* 40 (4) (2022) 496–500, <https://doi.org/10.1016/j.ijmmb.2022.08.011>.
- [12] D.T. Chou, P. Achan, M. Ramachandran, The World Health Organization '5 moments of hand hygiene': the scientific foundation, *J. Bone Joint Surg Br* 94 (4) (2012 Apr) 441–445, <https://doi.org/10.1302/0301-620X.94B4.27772>.
- [13] T.J. Toney-Butler, A. Gasner, N. Carver, Hand Hygiene. [Updated 2021 Aug 4]. in: StatPearls [Internet]. Treasure Island (FL), StatPearls Publishing, 2022. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK470254/>.

- [14] A.H. Leyland, P.P. Groenewegen, *Multilevel Modelling for Public Health and Health Services Research: Health in Context* [Internet], Springer, Cham (CH), 2020 (Chapter 3), *What Is Multilevel Modelling?* 2020. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK565712/>.
- [15] M. Tyagi, C. Hanson, J. Schellenberg, S. Chamarty, S. Singh, Hand hygiene in hospitals: an observational study in hospitals from two southern states of India, *BMC Publ. Health* 18 (1) (2018 Dec) 1–9.
- [16] S.S. Nair, R. Hanumantappa, S.G. Hiremath, M.A. Siraj, P. Raghunath, Knowledge, Attitude, and Practice of Hand Hygiene Among Medical and Nursing Students at a Tertiary Health Care Centre in Raichur, India, *Int. Scholar. Res. Notices* 2014 (2014).
- [17] J. Bathke, P.D. Cunico, E.C. Maziero, F.L. Cauduro, L.M. Sarquis, E.D. Cruz, Infrastructure and adherence to hand hygiene: challenges to patient safety, *Revista Gaucha de Enfermagem* 34 (2013) 78–85.
- [18] K.I. Onyedibe, N.Y. Shehu, D. Pires, S.E. Isa, M.O. Okolo, S.S. Gomerep, et al., Assessment of hand hygiene facilities and staff compliance in a large tertiary health care facility in northern Nigeria: a cross sectional study, *Antimicrob. Resist. Infect. Control* 9 (1) (2020) 30.
- [19] T. Bharara, R. Gur, S. Duggal, V. Chugh, Evaluation of hand hygiene compliance over the years, in an intensive care unit of a north Delhi hospital preparing for accreditation: a 3-year study, *J. Fam. Med. Prim. Care* 9 (4) (2020 Apr 30) 1939–1943.
- [20] T. Powell-Jackson, J.J. King, C. Makungu, N. Spieker, S. Woodd, P. Risha, C. Goodman, Infection prevention and control compliance in Tanzanian outpatient facilities: a cross-sectional study with implications for the control of COVID-19, *Lancet Global Health* 8 (6) (2020 Jun 1) e780–e789.
- [21] D. Sureshkumar, V. Ramasubramanian, K. Abdulghafur, V. Nagvekar, Hand hygiene compliance in India, *BMC Proc.* 5 (suppl 6) (2011) 259.
- [22] A.S. Sastry, R. Deepashree, P. Bhat, Impact of a hand hygiene audit on hand hygiene compliance in a tertiary care public sector teaching hospital in South India, *Am. J. Infect. Control* 45 (5) (2017 May 1) 498–501.
- [23] V. Anargh, H. Singh, A. Kulkarni, A. Kotwal, A. Mahen, Hand hygiene practices among health care workers (HCWs) in a tertiary care facility in Pune, *Med. J. Armed Forces India* 69 (1) (2013 Jan) 54–56, <https://doi.org/10.1016/j.mjafi.2012.08.011>.
- [24] D. Pittet, P. Mourouga, T.V. Perneger, Compliance with handwashing in a teaching hospital. *Infection Control Program, Ann. Intern. Med.* 130 (1999) 126–130.
- [25] A. Karaaslan, E. Kepenekli Kadayifci, S. Atıcı, U. Sili, A. Soysal, G. Çulha, et al., Compliance of healthcare workers with hand hygiene practices in neonatal and pediatric intensive care units: overt observation, *Interdiscip Perspect Infect Dis* 2014 (2014) 1–5.
- [26] A. Mathai, S. George, J. Abraham, Efficacy of a multimodal intervention strategy in improving hand hygiene compliance in a tertiary level intensive care unit, *Indian J. Crit. Care Med.* 15 (2011) 6.