

Factors Influencing Hand Hygiene Compliance Rates of Health Care Workers: A Hand Hygiene Surveillance Project in a Tertiary General Hospital-Zhejiang

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Abstract

Objectives: To propose the improvements measures by analysing the influencing factors of hand hygiene (HH) compliance by observing the behaviour of health care workers (HCWs). **Method:** The observational study was conducted at a public tertiary hospital in Zhejiang, China, from September 2018 to March 2021. A total of 58 HH observers were trained to conduct a direct observation on the HH behaviors of personnel in the hospital amongst the health care workers. We have observed over 9000 hand hygiene opportunities. The collected data were classified according to time factors, department parameters, and profession conduct of the observed. Hand hygiene (HH) compliance rates were calculated for each category, and a chi-square test was used to analyze differences of the HH compliance rates. Furthermore, binary logistic regression was used for multivariate analysis in each of the hand hygiene moments. **Results:** The HH compliance rates of HCWs were statistically different before and after the Corona Virus Disease 2019 (COVID-19) pandemic, in the morning and the afternoon, this was observed per parameters stated into objectives on weekdays vs non weekdays. And we found that HH compliance rates drop off a cliff from weekdays to non-weekdays. **Conclusions:** COVID-19, departments, professions, and weekdays were all factors that influence HH compliance amongst HCWs. However, the influencing factors were not all present in every HH behavior, and had different intensities of influence on HH compliance amongst the HCWs. These findings provide some reference for us to propose improvement measures.

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Keywords

Hand Hygiene Behaviors, Healthcare-Associated Infections, Infection Prevention, Health Care Workers

1. Introduction

Healthcare-associated infections (HAIs) are the popular adverse events in healthcare and the prominent complications in hospitalized patients [1]. Approximately 5% - 10% of hospitalized patients in the developed countries acquired HAI [2]. However, in local clinics in developing countries or large hospitals in developed countries, hand hygiene (HH) is a low-cost and effective measure that can reduce HAIs and improve patients' safety [3]. As one of the simplest and the most effective methods to reduce the risk of infection, the First Global Patient Safety Challenge, launched by the World Health Organization (WHO) in October 2005, used HH as an entry point to improve the control of HAIs [4]. According to the WHO guidelines, the 5 moments that call for the use of HH include the moment before touching a patient, before performing aseptic/clean procedures, after body fluid exposure risk, after touching a patient, and after touching patient surroundings [2] [5].

However, despite the global emphasized on the importance and benefits of HH, achieving and maintaining high HH compliance rates in healthcare settings was undoubtedly a challenging task [6] [7]. According to WHO statistics, HH compliance rates for best practices during care for critically ill patients were only around 9% in low-income countries, and rarely exceeded 70% in high-income countries, and the overall average being 38.7% [8]. Due to the neglect of HH behaviors is often the outcomes of a multi-factor synergy [9]-[11], heavy workloads [8], interruption by other things such as patient calls, etc. [9], forgetting to wash hands [10], shortages of HH facilities [12], intolerance to the hand skin disinfectant caused by frequent HH, and the outbreak of COVID-19 [13] affected HH behaviors health care workers (HCWs). It is difficult to be able to consistently improve HH compliance with single-factor interventions, such as improving hand hygiene knowledge, facilities or regulation [14]. Therefore, according to the time factor, department parameters and profession conduct continuous monitoring of HH behavior to propose more preventive measures to improve HH compliance rates, thereby reducing the risk of cross-infection for all patients in the hospital. Although intelligent HH systems based on the Internet of Things have been used to monitor the HH behaviors of HCWs, it is still difficult to accurately identify the moments of HH implementation [15] [16]. Human observation is currently an irreplaceable method of investigation and provides more abundant data for specific scenarios. Monitoring household behaviors through human observation can be effectively utilized to detect and address significant health issues in household management [17] [18]. This proactive approach allows for timely interventions that contribute to controlling infection rates and reducing the risk of pathogen transmission during this critical period [19]-[21].

2. Materials & Methods

2.1. Aim and Design

This is an explorative and descriptive-quantitative design. The purpose of this study was to analyze the influencing factors of hand hygiene (HH) compliance by observing the HH behaviors of healthcare workers (HCWs) according to WHO guidelines [22].

2.2. Data Collection

This observational study was conducted in a public tertiary hospital in Zhejiang, China, from September 2018 to March 2021. The hospital has 1200 beds and 2500 staff, and the bed-care ratio is 1:0.4 in the ward and 1:3.2 in the intensive care unit (ICU). According to the HH observational method presented by the WHO, a total of 58 HH observers from medical schools conducted daily monitoring of the HH practices of HCWs in this hospital [4]. They randomly visited various hand hygiene facilities in the hospital for a non-consecutive 4-hour period between 8:00 a.m. and 5:00 p.m. These HH observers had to pass 8 hours of intensive teaching, video training, and on-site training, such as the role of hand hygiene in keeping patients safe, hand hygiene indications and timing, hand hygiene methods, hand hygiene compliance observation methods, hands-on training on hand hygiene observation, and also pass examinations before they took up their posts. We calibrated and evaluated the consistency of the observations through a structured observation record form; the contents of the observation record form include the identity information of HCWs, the moments of HH, and the details of the HH behavior (Figure 1). We stipulated that HH observers should not simultaneously observe more than three HCWs, and no more than three HH moments should be observed by each HCW. In addition, to ensure that the Hawthorne effect was minimized, we employed 58 medical students as HH volunteers to observe hand hygiene using the concealed observation method, each HCW should be observed for no more than 20 min. The observers were as unobtrusive as possible, but were not hidden.

2.3. Promotional Programme

Like general hospitals in other countries [23], our hospital organizes a hand hygiene tour in May every year, aiming to raise awareness of hand hygiene and promote the importance of hand hygiene in a fun way; hand hygiene compliance rate is fed back quarterly and is included in the performance appraisal; hand hygiene facilities and equipment are well-equipped, including hand sanitizers, hand drying facilities, handwashing charts, and quick-drying hand sanitizers, etc., and are easily accessible to staff members; and non-contact hand hygiene products are provided free of charge for the hospital's public areas (including the elevators in the outpatient building, inpatient department, and administrative building, self-service kiosks, restrooms, and other areas of high-frequency contact).

Hand Hygiene Compliance Questionnaire of the First Affiliated Hospital of Zhejiang Chinese Medical University											
Department _____				Observer _____				Date _____			
Hand hygiene facilities: <input type="checkbox"/> Hand disinfectant			<input type="checkbox"/> Hand sanitizer			<input type="checkbox"/> Hand towel			<input type="checkbox"/> Hand washing chart		
Profession: <input type="checkbox"/> Doctor (department: _____) <input type="checkbox"/> Nurse <input type="checkbox"/> Medical technician <input type="checkbox"/> Trainee <input type="checkbox"/> Other personnel			Profession: <input type="checkbox"/> Doctor (department: _____) <input type="checkbox"/> Nurse <input type="checkbox"/> Medical technician <input type="checkbox"/> Trainee <input type="checkbox"/> Other personnel			Profession: <input type="checkbox"/> Doctor (department: _____) <input type="checkbox"/> Nurse <input type="checkbox"/> Medical technician <input type="checkbox"/> Trainee <input type="checkbox"/> Other personnel					
Time			Time			Time					
Moment			Behaviour			Seven-step hand-washing method					
1 <input type="checkbox"/> Before touching a patient			<input type="checkbox"/> Hand-washing			<input type="checkbox"/> Right					
<input type="checkbox"/> Before performing aseptic and clean procedures			<input type="checkbox"/> Hand disinfectant			<input type="checkbox"/> Wrong					
<input type="checkbox"/> After being at risk of exposure to body fluids			<input type="checkbox"/> Undone			<input type="checkbox"/> Wiping hands					
<input type="checkbox"/> After touching a patient			<input type="checkbox"/> Gloves: Replaced			<input type="checkbox"/> Right					
<input type="checkbox"/> After touching patient surroundings			<input type="checkbox"/> Not replaced			<input type="checkbox"/> Wrong					
2 <input type="checkbox"/> Before touching a patient			<input type="checkbox"/> Hand-washing			<input type="checkbox"/> Right					
<input type="checkbox"/> Before performing aseptic and clean procedures			<input type="checkbox"/> Hand disinfectant			<input type="checkbox"/> Wrong					
<input type="checkbox"/> After being at risk of exposure to body fluids			<input type="checkbox"/> Undone			<input type="checkbox"/> Wiping hands					
<input type="checkbox"/> After touching a patient			<input type="checkbox"/> Gloves: Replaced			<input type="checkbox"/> Right					
<input type="checkbox"/> After touching patient surroundings			<input type="checkbox"/> Not replaced			<input type="checkbox"/> Wrong					
3 <input type="checkbox"/> Before touching a patient			<input type="checkbox"/> Hand-washing			<input type="checkbox"/> Right					
<input type="checkbox"/> Before performing aseptic and clean procedures			<input type="checkbox"/> Hand disinfectant			<input type="checkbox"/> Wrong					
<input type="checkbox"/> After being at risk of exposure to body fluids			<input type="checkbox"/> Undone			<input type="checkbox"/> Wiping hands					
<input type="checkbox"/> After touching a patient			<input type="checkbox"/> Gloves: Replaced			<input type="checkbox"/> Right					
<input type="checkbox"/> After touching patient surroundings			<input type="checkbox"/> Not replaced			<input type="checkbox"/> Wrong					
Total			Total			Total					
Hand hygiene compliance =			Hand hygiene compliance =			Hand hygiene compliance =					
Number of actual execution moments			Number of actual execution moments			Number of actual execution moments					
Number of moments to be executed			Number of moments to be executed			Number of moments to be executed					
Correctness of hand hygiene =			Correctness of hand hygiene =			Correctness of hand hygiene =					
The correct number of seven-step hand-washing method			The correct number of seven-step hand-washing method			The correct number of seven-step hand-washing method					
Number of seven-step hand-washing method			Number of seven-step hand-washing method			Number of seven-step hand-washing method					

Note: Please use gloves when indicated. Wearing gloves is not a substitute for hand hygiene.

Figure 1. Hand hygiene observation record form.

2.4. Data Analysis

Based on the observation record form completed by HH observers, the data collected were analyzed by time-, department- and profession-dependent characteristics. HH compliance rates were calculated for each category, and multivariate logistic regression analysis was performed on each of the 5 HH moments. The departments involved in the study included cardiovascular medicine, respiratory, hematology, general surgery, orthopedics, pediatrics, gynecology, ICU, clinical

laboratory, etc. All departments were classified into medical wards, surgical wards, gynecological and pediatric wards, outpatient department (including departments with traditional Chinese medicine technology), ICU, and other departments (e.g., laboratory, pharmacy, B ultrasonic room, etc.). All personnel were classified as doctors, nurses, trainees, medical technicians, and other personnel (including nursing workers and cleaning workers). Monday through Friday were classified as working days, while Saturday and Sunday were classified as non-working days. Other official holidays, such as the Chinese New Year Spring Festival and May Day, were not involved. The classification before and after COVID-19 refers to the time when the epidemic broke out in China and the actual prevention and control measures were taken, with January 1, 2020 as the time node.

In the data processing, due to the simultaneous occurrence of multiple HH moments, every HH moment was converted into a Boolean value for statistics. We regarded every HH moment as a piece of data. Once some information was missing in a piece of data, such as incomplete time-dependent information, uncertain departmental information, and omission of information related to professions, the piece of data would be deleted. Data processing was carried out using the SPSS 26.0 software (IBM Corp., Armonk, NY, USA), the Chi-square test was used to analyze the differences in HH compliance rates, and multivariate logistic regression analysis was performed using the binary logistic regression at each HH moment. $P < 0.01$ was considered statistically significant.

2.5. Ethical Considerations

This study was approved by the Ethics Committee of the REDACTED (Approval No. 2021-KL-138-01). The purpose and method of this study were explained to the HH observers. An oral informed consent was also obtained from the HH observers for participation in the study. They were also assured about the confidentiality of their information and responses.

3. Results

A total of 9029 HH moments were monitored and a total of 8420 HH moments were included in the analysis, after the exclusion of 609 HH moments for partially missing information. The results of single-factor comparison of HH compliance rates are shown in **Table 1**. The factors influencing hand hygiene adherence in five hand hygiene timing correlations are shown in **Figure 2**. The mean HH compliance rate for all personnel was 62.60% (CI: 61.57 - 63.63).

3.1. The Effects of COVID-19 on HH

The HH compliance rate amongst the HCWs before and after the COVID-19 pandemic was 59.23% (CI: 57.66 - 60.79) and 65.36% (CI: 63.99 - 66.73) respectively (**Table 1**). There were statistically significant differences in compliance rates before and after the COVID-19 pandemic ($P < 0.001$). COVID-19 was found as a factor, influencing the HH compliance of HCWs before touching a patient and

performing aseptic/clean procedures, after body fluid exposure risk, and after touching a patient, with odds ratio (OR) values of 1.649, 2.084, 2.188, and 1.431, respectively. However, COVID-19 did not affect compliance rate after touching patient surroundings (OR = 1.172, P = 0.168) (Table 2).

Table 1. Univariate analysis of hand hygiene compliance rate.

Variable	Not performed	Performed	Compliance rate (95% CI)	χ^2	P value
COVID-19 comparison					
Before COVID-19 pandemic	1544	2243	59.23% (57.66 - 60.79)	33.430	<0.001
After COVID-19 pandemic	1605	3028	65.36% (63.99 - 66.73)		
Half day comparison					
In the morning	1689	2982	63.84% (62.46 - 65.22)	6.887	0.009
In the afternoon	1460	2289	61.06% (59.49 - 62.62)		
Day comparison					
Sunday	90	262	65.65% (59.86 - 71.44)	91.502	<0.001
Monday	342	941	63.66% (60.58 - 66.73)		
Tuesday	490	1161	57.80% (54.95 - 60.64)		
Wednesday	789	2002	60.59% (58.45 - 62.73)		
Thursday	525	1481	64.55% (62.11 - 66.99)		
Friday	406	1429	71.59% (69.25 - 73.93)		
Saturday	507	1144	55.68% (52.80 - 58.56)		
Weekday comparison					
Weekdays	597	809	57.54% (54.95 - 60.13)	91.502	<0.001
Non-weekdays	2552	4462	63.62% (62.49 - 64.74)		
Profession comparison					
doctors	756	1050	58.14% (55.86 - 60.42)	165.149	<0.001
nurses	1738	3553	67.15% (65.89 - 68.42)		
Trainees	276	330	54.46% (50.48 - 58.43)		
Medical technicians	162	188	53.71% (48.46 - 58.96)		
Other personnel	217	150	40.87% (35.82 - 45.93)		
Department comparison					
Medical wards	1555	3962	60.75% (59.23 - 62.27)	62.527	<0.001
Surgical wards	731	1825	59.95% (57.70 - 62.20)		
Gynecological and pediatric wards	127	306	58.50% (52.95 - 64.05)	62.527	<0.001
ICU	75	279	73.12% (67.88 - 78.35)		
Outpatient department	160	607	73.64% (70.13 - 77.16)		
Other departments	501	1441	65.23% (62.77 - 67.69)		
Total	3149	5271	62.60% (61.57 - 63.63)		

CI, confidence interval; COVID-19, coronavirus disease 2019.

Table 2. Multivariate logistic regression analysis of factors affecting hand hygiene compliance.

Variable	β	SE	P value	OR (95% CI)
Before touching a patient				
COVID-19	0.500	0.093	<0.001	1.649 (1.374 - 1.979)
Weekdays	0.192	0.099	0.051	1.212 (0.999 - 1.471)
Half days	-0.014	0.089	0.877	0.986 (0.828 - 1.175)
Medical wards	Reference	-	-	1
Surgical wards	0.210	0.102	0.040	1.234 (1.010 - 1.507)
Gynecological and paediatric wards	-0.001	0.197	0.998	0.999 (0.679 - 1.470)
ICU	0.865	0.239	<0.001	2.374 (1.487 - 3.790)
Outpatient department	0.923	0.159	<0.001	2.516 (1.841 - 3.439)
Other departments	0.626	0.126	<0.001	1.871 (1.461 - 2.395)
Doctors	Reference	-	-	1
Nurses	0.567	0.107	<0.001	1.763 (1.429 - 2.175)
Trainees	-0.161	0.178	0.366	0.851 (0.600 - 1.207)
Medical technicians	-0.131	0.219	0.548	0.877 (0.571 - 1.346)
Other personnel	-0.891	0.246	<0.001	0.410 (0.253 - 0.665)
Before performing aseptic/clean procedures				
COVID-19	0.734	0.140	<0.001	2.084 (1.584 - 2.741)
Weekdays	0.917	0.144	<0.001	2.501 (1.885 - 3.319)
Half days	-0.034	0.132	0.798	0.967 (0.746 - 1.253)
Medical wards	Reference	-	-	1
Surgical wards	0.353	0.145	0.015	1.423 (1.072 - 1.890)
Gynecological and paediatric wards	-0.686	0.344	0.046	0.504 (0.257 - 0.988)
ICU	0.106	0.401	0.792	1.111 (0.506 - 2.439)
Outpatient department	1.293	0.287	<0.001	3.644 (2.077 - 6.392)
Other departments	0.895	0.197	<0.001	2.448 (1.664 - 3.601)
Doctors	Reference	-	-	1
Nurses	0.463	0.178	0.009	1.589 (1.120 - 2.255)
Trainees	-0.560	0.260	0.031	0.571 (0.343 - 0.950)
Medical technicians	-0.281	0.368	0.446	0.755 (0.367 - 1.554)
After body fluid exposure risk				
COVID-19	0.783	0.243	0.001	2.188 (1.360 - 3.521)
Weekdays	1.003	0.228	<0.001	2.726 (1.742 - 4.266)
Half days	-0.304	0.231	0.188	0.738 (0.469 - 1.160)
Medical wards	Reference	-	-	1
Surgical wards	-0.019	0.249	0.940	0.982 (0.602 - 1.599)
Gynecological and paediatric wards	-0.012	0.597	0.984	0.988 (0.306 - 3.183)
ICU	-0.437	0.472	0.355	0.646 (0.256 - 1.629)

Continued

Outpatient department	0.291	0.400	0.466	1.338 (0.612 - 2.929)
Other departments	-0.496	0.272	0.068	0.609 (0.357 - 1.038)
Doctors	Reference	-	-	1
Nurses	0.238	0.243	0.328	1.268 (0.788 - 2.042)
Trainees	-0.470	0.476	0.324	0.625 (0.246 - 1.589)
Medical technicians	-1.062	0.425	0.012	0.346 (0.150 - 0.796)
Other personnel	-0.376	0.398	0.345	0.687 (0.315 - 1.499)
After touching a patient				
COVID-19	0.359	0.095	<0.001	1.431 (1.188 - 1.725)
Weekdays	0.324	0.098	0.001	1.382 (1.141 - 1.673)
Half days	-0.066	0.089	0.462	0.937 (0.786 - 1.115)
Medical wards	Reference	-	-	1
Surgical wards	-0.038	0.088	0.665	0.963 (0.811 - 1.143)
Gynecological and paediatric wards	0.051	0.183	0.781	1.052 (0.735 - 1.507)
ICU	0.773	0.225	0.001	2.166 (1.393 - 3.369)
Outpatient department	1.220	0.162	<0.001	3.389 (2.468 - 4.653)
Other departments	0.941	0.125	<0.001	2.562 (2.004 - 3.275)
Doctors	Reference	-	-	1
Nurses	0.911	0.092	<0.001	2.487 (2.078 - 2.977)
Trainees	0.087	0.148	0.554	1.091 (0.817 - 1.458)
Medical technicians	-0.027	0.222	0.904	0.974 (0.630 - 1.505)
Other personnel	-0.029	0.203	0.887	0.971 (0.653 - 1.446)
After touching patient surroundings				
COVID-19	0.159	0.115	0.168	1.172 (0.935 - 1.468)
Weekdays	-0.069	0.129	0.594	0.934 (0.725 - 1.202)
Half days	0.030	0.105	0.773	1.031 (0.839 - 1.266)
Medical wards	Reference	-	-	1
Surgical wards	-0.348	0.099	<0.001	0.706 (0.581 - 0.858)
Gynecological and paediatric wards	-0.412	0.223	0.065	0.662 (0.428 - 1.026)
ICU	0.822	0.248	0.001	2.275 (1.399 - 3.701)
Outpatient department	1.077	0.231	<0.001	2.936 (1.866 - 4.618)
Other departments	0.501	0.139	<0.001	1.650 (1.257 - 2.166)
Doctors	Reference	-	-	1
Nurses	0.765	0.114	<0.001	2.148 (1.719 - 2.684)
Trainees	-0.183	0.174	0.293	0.833 (0.592 - 1.171)
Medical technicians	-0.880	0.208	<0.001	0.415 (0.276 - 0.623)
Other personnel	-0.439	0.169	0.009	0.645 (0.463 - 0.898)

CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio; SE, standard error; ICU, intensive care unit.

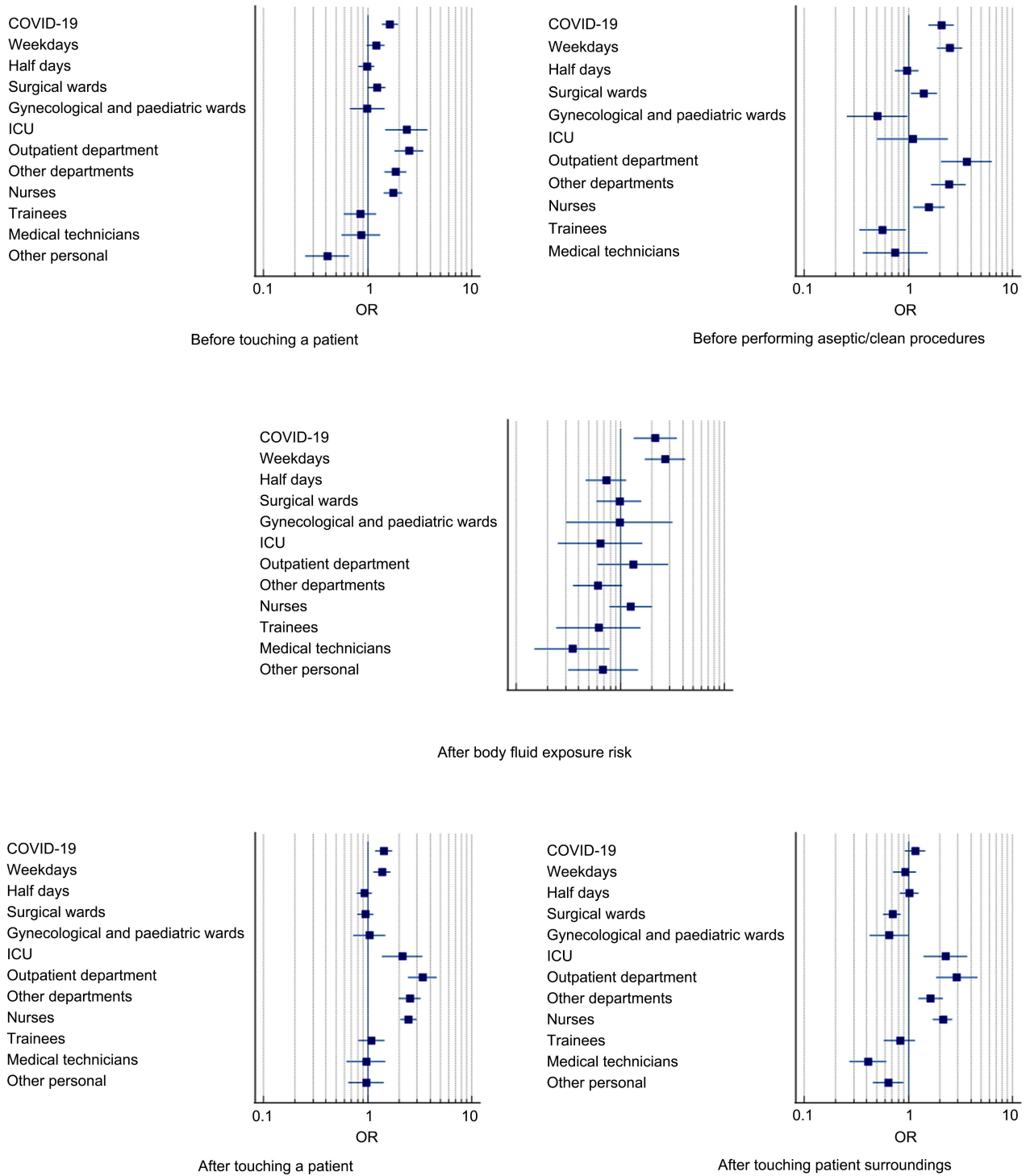


Figure 2. The Impact of COVID-19, departments, professions, and time (weekdays) on Hand Hygiene Compliance at Five Hand Hygiene Opportunities.

3.2. Time Trends in HH Compliance

We analyzed changes in HH compliance rates among HCWs over the course of the day and over the course of the week. The compliance rate was 63.84% (CI:

62.46 - 65.22) in the morning and 61.06% (CI: 59.49 - 62.62) in the afternoon, and there was a significant difference between them ($P = 0.009$) (Table 1). Moreover, the HH compliance rate showed significant fluctuations within a week ($P < 0.001$) (Figure 2). From Sunday to Tuesday, the HH compliance rate decreased gradually. From Wednesday to Friday, the HH compliance rate gradually increased and reached a peak of 71.59% on Friday (CI: 69.25 - 73.93), and then dropped sharply to a minimum of 55.68% on Saturday (CI: 52.80 - 58.56) (Figure 3).

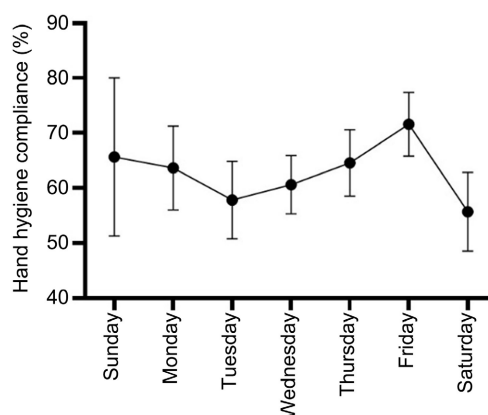


Figure 3. Trends of HH compliance rates within a week.

When the diurnal difference was generalized to weekday versus non-weekday differences, we found that the HH compliance rate on weekdays was 63.62% (CI: 62.49 - 64.74) and that was 57.54% on non-weekdays (CI: 54.95 - 60.13), and there was a significant difference between the two groups ($P < 0.001$) (Table 1). The impact of this weekday on HH compliance was observed before performing aseptic/clean procedures (OR = 2.501, $P < 0.001$), after body fluid exposure risk (OR = 2.726, $P < 0.001$), and after touching a patient (OR = 1.382, $P < 0.001$). However, it did not affect the moments before touching a patient (OR = 1.212, $P = 0.051$) and after touching patient surroundings (OR = 0.934, $P = 0.594$) (Table 2).

3.3. Department Differences in HH Compliance Rate

The differences in HH compliance rate between different departments are illustrated in Table 1. Among them, the HH compliance rate was the highest in outpatient departments, while that was the lowest in gynecology and pediatric wards, accounting for 73.64% (CI: 70.13 - 77.16) and 58.50% (CI: 52.95 - 64.05), respectively. The HH compliance rates in medical wards, surgical wards, ICU, and other departments were 60.75% (CI: 59.23 - 62.27), 59.95% (CI: 57.70 - 62.20), 73.12% (CI: 67.88 - 78.35), and 65.23% (CI: 62.77 - 67.69), respectively (Table 1). After body fluid exposure risk, there was no significant difference in the HH compliance rate between different departments ($P = 0.317$). Before touching a patient, before performing aseptic/clean procedures, after touching a patient, and after touching patient surroundings, department was found as the factor that influenced the HH compliance rate of HCWs ($P < 0.001$) (Table 2).

3.4. Differences in HH Compliance Rates among Different Professions

Nurses had the highest HH compliance rate among all professions, reaching 67.15% (CI: 65.89 - 68.42). The HH compliance rates of doctors, trainees, medical technicians, and other personnel decreased successively, which were 58.14% (CI: 55.86 - 60.42), 54.46% (CI: 50.48 - 58.43) and 53.71% (CI: 48.46 - 58.96), and 40.87% (CI: 35.82 - 45.93), respectively, and all of them were lower than the average level of the whole hospital (Table 1). In different HH moments, HCWs with different professions showed different HH behaviors (Table 3 and Figure 4). Among the 5 HH moments, the highest and the lowest HH compliance rates were 74.50% (CI: 71.36 - 77.63) after body fluid exposure risk and 58.39% (CI: 56.60 - 60.18) before touching a patient, respectively. There was no significant difference in the HH compliance rates among HCWs with different professions before performing aseptic/clean procedures and after body fluid exposure risk, with P values of 0.027 and 0.06, respectively. However, there were statistically significant differences before touching a patient, after touching a patient, and after touching patient surroundings ($P < 0.001$). The doctors had the highest HH compliance rate (74.36%) after body fluid exposure risk, and the lowest (54.13%) after touching patient surroundings. The compliance rate of the nurses was the highest (77.06%) after body fluid exposure risk, and the lowest (61.33%) before touching a patient. The compliance rate of the trainees was the highest (73.33%) after body fluid exposure risk, and the lowest (45.05%) after touching patient surroundings. The HH compliance rate among medical technicians was the highest (71.15%) before performing aseptic/clean procedures, and the lowest (40.46%) after touching patient surroundings. The HH compliance rate among other personnel was the highest (65.12%) after body fluid exposure risk, and the lowest (31.25%) before touching a patient. Using the results of multivariate logistic regression analysis, we identified profession as a factor, influencing HH compliance rates at all moments ($P < 0.001$) except for after body fluid exposure risk ($P = 0.015$) (Table 2).

Table 3. Comparison of HH compliance rates among HCWs with different professions at each moment.

	Before touching a patient			Before performing aseptic/clean procedures			After body fluid exposure risk			After touching a patient			After touching patient surroundings		
	Not performed	Performed	Compliance rate (95% CI)	Not performed	Performed	Compliance rate (95% CI)	Not performed	Performed	Compliance rate (95% CI)	Not performed	Performed	Compliance rate (95% CI)	Not performed	Performed	Compliance rate (95% CI)
Doctors	283	653	56.66% (52.85 - 60.47)	82	255	67.84% (62.07 - 73.61)	50	195	74.36% (68.18 - 80.54)	368	947	61.14% (58.03 - 64.25)	222	262	54.13% (49.68 - 58.59)
Nurses	717	1854	61.33% (59.11 - 63.55)	405	1074	62.29% (59.39 - 65.19)	100	436	77.06% (73.10 - 81.03)	730	2564	71.53% (69.78 - 73.28)	568	1126	66.47% (64.22 - 68.72)
Trainees	90	177	49.15% (41.72 - 56.59)	49	103	52.43% (42.62 - 62.24)	8	30	73.33% (56.54 - 90.13)	113	265	57.36% (51.37 - 63.35)	111	91	45.05% (38.13 - 51.97)
Medical technicians	54	128	57.81% (49.14 - 66.48)	15	52	71.15% (58.42 - 83.89)	17	41	58.54% (42.79 - 74.28)	41	139	70.50% (62.83 - 78.18)	103	70	40.46% (33.08 - 47.85)
Other personnel	66	96	31.25% (21.81 - 40.69)	0	0	0	15	43	65.12% (50.28 - 79.96)	57	122	53.28% (44.30 - 62.26)	131	93	41.52% (35.02 - 48.02)
Total	1210	2908	58.39% (56.60 - 60.18)	551	1484	62.87% (60.41 - 65.33)	190	745	74.50% (71.36 - 77.63)	1309	4037	67.57% (66.13 - 69.02)	1135	2777	59.13% (57.30 - 60.96)

CI, confidence interval.

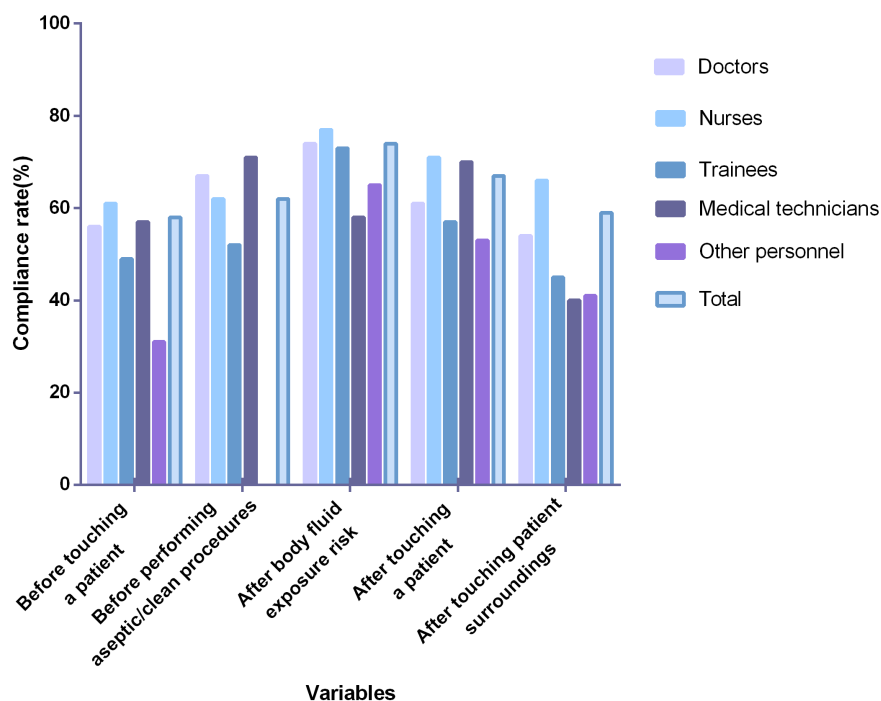


Figure 4. Compliance rate performance of five hand hygiene opportunities in different professions.

4. Discussion

Departments [24] [25], professions [26] [27], weekdays and non-weekdays (time) [28] were factors that could directly affect HH compliance of HCWs. Meanwhile we found the effects of the COVID-19 pandemic on the HH compliance rates and trends in HH compliance rates over the course of the week. We also excluded the effects of morning and afternoon factors on HH compliance rates during the day. Furthermore, we analyzed the influences of these factors on HH compliance rates at each moment of HH, and found that these factors were not fully present in every HH moment. The COVID-19 pandemic and weekdays did not affect the HH compliance rates after touching a patient. Departments and professions did not influence the HH compliance rates after body fluid exposure risk. Weekdays did not affect the HH compliance rates before performing aseptic/clean procedures. For a longer period of time, performing hand hygiene has been a routine practice before performing any clean or aseptic procedure. Therefore interventions based on these factors may be valuable to discover and resolve the important problems in HH supervision, and accordingly to take targeted measures.

The results of the present study showed that the COVID-19 pandemic significantly improved HH compliance rates among HCWs, which may be related to HCWs' subjective risk perception [27]. As the COVID-19 pandemic increased the risk of acquired infections, this was confirmed to be a factor in promoting HH behaviors [28] [29], which in turn increased HCWs' crisis awareness and motivated them to adopt more stringent protective measures. This phenomenon was

similar to the high HH compliance rates among HCWs after body fluid exposure risk. In addition, the risk of occupational exposure to HCWs was relatively low before touching a patient, thus, HH compliance rates were the lowest at this time. The results suggested that hospital infection management should further concentrate on raising crisis awareness and establishing a belief that HH was actually effective among HCWs, rather than only increasing their knowledge on HH procedures [30]. Providing evidence to HCWs that HH behaviors are highly beneficial could be undoubtedly an effective strategy to encourage HCWs to perform HH.

Whereas, for weekdays compared to non-workdays, we found that the hand hygiene compliance rate was significantly higher on weekdays than on non-workdays. In this case, the compliance rate of hand hygiene gradually increased from Tuesday to Friday (weekdays), while a significant downward trend was observed on Saturday (non-working days). This may be due to the fact that on weekdays, the hospital has a more mobile population and thus the observed persons are surrounded by significantly more people than on non-working days, and there is more contact and communication with the patients. On the one hand, subject to a partial Hawthorne effect, during weekdays the observed persons would be more likely to comply with the five moments of hand hygiene, especially after contact with patients, before performing aseptic operations and after exposure to body fluids. On the other hand, influenced by diminishing marginal utility, hand hygiene adherence was highest on Friday (*i.e.*, the last day of the workday), after five days of observation, tending to a plateau. In contrast, on Saturday (*i.e.*, the first day of a non-working day), not only ambulatory staff, but also all specialties in the hospital were reduced compared to working days [31]. Also lack of motivation, lazy attitude of the observed, less time in emergency situations made the rate of hand hygiene compliance lower compared to weekdays [32].

In our study, we found that the outpatient department had the highest hand hygiene compliance rate, although it was only 0.52% higher than the ICU, but this was slightly different from some other hospitals [33]. This may be related to the fact that our hospital has more traditional Chinese medicine techniques, such as acupuncture, tui na, etc. Since such doctors need to be in frequent contact with patients' bodies as well as their skin in the course of their outpatient work, their chances of hand hygiene are much higher. It is also possible that the Hawthorne effect is more likely to be present in outpatient clinics because the presence of a bystander in the clinic is more easily detected. The lowest hand hygiene compliance rate was observed in gynecology and pediatrics, where we found that they would often wear polyethylene gloves for diagnostic and treatment operations. The use of gloves was observed alongside the negative action of HH in the five moments recommended by the WHO. The inappropriate glove use had a great impact on HH adherence and was perceived as one of the factors that can hinder this practice by health professionals, with an emphasis on the indications "before aseptic procedures" and "after body fluid exposure risk" [33].

We found that nurses had the highest hand hygiene compliance rates, significantly higher than other practitioners within the hospital. Nurses had higher levels of compliance with hand hygiene opportunities and appropriate hand hygiene practices compared to physicians or allied health professionals. This is similar to findings from other low- and middle-income countries [4]. There may be many factors that contribute to poor hand hygiene compliance among physicians, such as high work pressure, high workload, and possible feelings of superiority [34]. Other personnel (including nursing workers and cleaning workers) had the lowest hand hygiene adherence rates, which were well below the average. This may be related to their literacy and education level. We randomly asked and learned that most of these caregivers as well as cleaning staff were from less developed areas of China with relatively backward economic level, and they had not received high school education, and some of them had not even attended elementary school. Therefore, they lacked the concept of hand hygiene and the understanding of cross-infection. On the other hand, physicians, trainees, medical technicians and other personnel have the lowest compliance rate for hand hygiene after exposure to the patient's surroundings. In the healthcare process, it includes contact with the patient (e.g., taking a pulse or blood pressure) or with inanimate objects in the patient's vicinity. Because these contacts are a common social behavior, they do not necessarily trigger an inherent need to clean hands, although they do carry a risk of cross-transmission. According to behavioral theories, this is the component of hand hygiene most likely to be omitted by busy HCWs and it has been repeatedly confirmed by field observations [35]. Nurses had the lowest rates of hand hygiene compliance prior to patient contact. This may be due to fatigue or burnout, and it has been noted in the literature that as nurses work shifts, long consecutive shifts can lead to burnout and thus relaxation of hand hygiene at certain moments, which is consistent with what we have observed. And poor working conditions, increased stress levels, and inadequate communication can all contribute to decreased hand hygiene compliance among nurses [9].

It has been known for many years that HCWs encounter difficulties in complying with hand hygiene indications at different levels. Insufficient or very low compliance rates have been reported from both developed and developing countries [36]. The most frequently observed factors determining poor hand hygiene compliance are: 1) belonging to a certain professional category (*i.e.* doctor, nursing assistant, physiotherapist, technician); 2) working in specific care areas (*i.e.* intensive care, surgery, anesthesiology, emergency medicine); 3) understaffing and overcrowding; and 4) wearing gowns and/or gloves [4]. The above-mentioned factors of HH observed in hospitals were consistent with the established factors of HH. Implementing effective infection prevention and control measures is central to providing quality care to patients and healthcare workers in hospitals. Ensuring that health care workers understand the importance of each moment (such as the WHO five moments of hand hygiene) in preventing the spread of infection within a health care facility is critical. Unfortunately, hand hygiene indications at higher

risk of being neglected are the ones that prevent pathogen transmission to the patient. There have been many studies proposing measures to improve hand hygiene adherence rates, for example, more education programs, demonstrations of correct technique of HH, regular monitoring and feedback, posters containing educational messages and demonstrating correct techniques to be displayed at various places, mutual supervision and goodwill reminders among colleagues, the role model effect and active involvement of the administration [37]. Firstly, the compliance of HH in wards should be paid more attention, and the HH behaviors of trainees, medical technicians, cleaning workers, and nursing workers should be improved urgently. Secondly, the management of HH behaviors should be strengthened for doctors, trainees, and medical technicians after touching patient surroundings, and the education of HH should be concentrated on the moment before touching a patient for nurses, cleaning workers, and nursing workers. Thirdly, according to our observations, HH compliance rates were the highest at the end of the weekdays (Friday), and then, fell off a cliff when entering the non-weekday (Saturday), which may be related to the psychological factors of HCWs. The hospital infection management is relatively relaxed on non-weekdays, inspiring HCWs with the feeling of less attention on these days [24]. After entering the weekdays, as HCWs gradually entered the working state and hospital infection control measures were carried out, the HH compliance rate increased gradually (Table 1). Therefore, hospital infection control departments should more concentrate on strengthening the management and education of HH behaviors during non-weekdays [20] [32] [38], especially during the connecting period between weekdays and non-weekdays (Saturday). In response to the problems identified in this observational study and in light of the actual situation of our hospital, we have proposed some innovative and feasible improvement programs. For example, we can create a cultural atmosphere of hand hygiene in the whole hospital and raise awareness of the importance of hand hygiene by increasing the frequency of publicity activities and improving the fun of the activities; use the Internet and artificial intelligence technology in specific areas (e.g., scenarios with low hand hygiene adherence rates) to remind the personnel present to perform hand hygiene, and to provide effective supervision and feedback; set up training and education for the staff of cleaning and nursing care models to make it easier for them to understand and effectively implement hand hygiene; and make recommendations for deficiencies based on observations. Establish a training and education model for cleaning, nursing and other personnel to make it easier for them to understand and effectively implement hand hygiene; conduct face-to-face feedback and communication with departments and personnel with deficiencies based on observations, and collect their opinions and ideas for effective intervention and continuous improvement in the future to improve hand hygiene compliance.

This study is an analytical study using work data. In our daily work, we spend a lot of efforts to promote HH behavior, but the actual observed HH compliance was still not ideal. Observational research was the norm of our actual work

activities rather than experimental research, so although we consciously tried to avoid the Hawthorne effect, it cannot be eliminated, because observation is a powerful tool for examining adherence and techniques in the field. In fact, one of the goals of our HH monitoring campaign itself was to improve HH compliance at the HCWs. On the other hand, the improvement measures we have proposed in the discussion, such as the artificial intelligence reminder technology, have not yet been implemented, and some of the measures have only been in place for a short period of time, so the effects of these improvement measures have yet to be examined and observed in our subsequent studies. This study was limited to a public tertiary hospital with more Chinese medicine skills, which is one of the features of this study. Future studies could investigate hand hygiene practices in a wider sample of public tertiary hospitals to uncover more factors that may influence hand hygiene and to explore and promote the applicability of the “Five Moments of Hand Hygiene” in more public settings.

5. Conclusion

In conclusion, it is highly vital to enhance individuals’ awareness towards infectious diseases, through publicity, learning and training activities, the awareness of HH’s importance was enhanced among medical staff, leading to the active adoption of protective measures. Meanwhile, it is particularly important to enhance hygiene training for advanced students, interns, and cleaning staff, as well as to reinforce supervision during non-working hours to improve HH compliance rate. Our findings highlighted the influences of departments, professions, COVID-19 and weekdays (time) on HH behaviors, which may be important for the control of possible outbreaks of infection.

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Authors’ Contributions

T.E.G. and M.F.W. conceived the project. T.E.G. and M.F.W. recruited and trained volunteers. J.H.M. and Y.X.Z. aggregated and managed data. T.E.G. and M.F.W. analyzed the data and wrote the manuscript.

Ethics Statement

This study was approved by the Ethics Committee of the First Affiliated Hospital

of Zhejiang Chinese Medical University (Approval No. 2021-KL-38-01).

Availability of Data and Materials

The data and materials used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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List of Abbreviations

HAI: healthcare-associated infections;

HH: hand hygiene;

WHO: World Health Organization;

HCWs: health care workers;

CI: confidence interval;

COVID-19: coronavirus disease 2019;

ICU: intensive care unit;

OR: odds ratio.