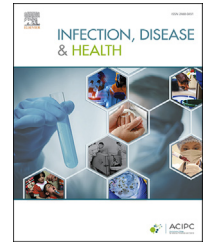




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Research paper

Mobile phones as fomites for pathogenic microbes: A cross-sectional survey of perceptions and sanitization habits of health care workers in Dubai, United Arab Emirates

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Abstract *Backgrounds:* In 2022, smartphone use continues to expand with the number of smartphone subscriptions surpassing 6 billion and forecasted to grow to 7.5 billion by 2026. The necessity of these 'high touch' devices as essential tools in professional healthcare settings carries great risks of cross-contamination between mobile phones and hands. Current research emphasises mobile phones as fomites enhancing the risk of nosocomial disease dissemination as phone sanitisation is often overlooked. To assess and report via a large-scale E-survey the handling practices and the use of phones by healthcare workers.

Methods: A total of 377 healthcare workers (HCWs) participated in this study to fill in an E-survey online consisting of 14 questions (including categorical, ordinal, and numerical data). Analysis of categorical data used non-parametric techniques such as Pearson's chi-squared test.

Results: During an 8-h shift, 92.8% (n/N = 350/377) use their phone at work with 84.6% (n/N = 319/377) considering mobile phones as an essential tool for their job. Almost all HCWs who participated in this survey believe their mobile phones could potentially harbour microorganisms (97.1%; n/N = 366/377). Fifty-seven respondents (15.1%) indicated that they use their phones while wearing gloves and 10.3% (n/N = 39/377) have never cleaned their phones. The majority of respondents (89.3%; n/N = 337/377) agreed that contaminated mobile phones

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could contribute to dissemination of SARS-CoV-2.

Conclusion: Mobile phone use is now almost universal and indispensable in healthcare. Medical staff believe mobile phones can act as fomites with a potential risk for dissemination of microbes including SARS-COV-2. There is an urgent call for the incorporation of mobile phone sanitisation in infection prevention protocol. Studies on the use of ultraviolet-C based phone sanitation devices in health care settings are needed.

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Highlights

- Current research emphasises mobile phones as fomites enhancing the risk of nosocomial disease dissemination.
 - A total of 377 health care workers participated in an e-survey on their perceptions and sanitization habits.
 - Majority (97.1%) of healthcare workers believe that their mobile phones harbour microorganisms.
 - 71.3% of healthcare workers clean their phone only once during an 8-h shift with the majority using a chemical cleaner.
 - Urgent need for modalities for sanitization and policies for utilization of mobile phones in healthcare settings.
-

Introduction

Two-thirds of the world's population has a mobile phone with roughly three-quarters of all mobile handsets being smartphone devices [1]. With this extensive availability of mobile phones globally, the healthcare sector has also adapted to using these devices as a work aid to increase productivity and quality of care. Most healthcare workers (HCWs) of all levels regularly use either their personal mobile phones or hospital working phones to communicate and provide efficient medical advice across departments in the healthcare setting [2]. In addition, medical applications and software can also be used via mobile phones and other personal digital devices including smart watches. Indeed, a feasibility study on a Smartwatch application to deliver laboratory results in emergency departments was reported recently [3]. Hospitals encourage the use of mobile phone applications to improve the uptake of point-of-care tools that can support improved and standardised clinical decision making that in turn leads to improved patient outcomes [4]. Whilst this seamless integration of mobile phones has enabled a high standard of quality of care, it has however also provided the perfect condition for these devices to act as potential fomites for microbes including pathogenic ones which are ubiquitous in the healthcare setting [5]. This is associated with the fact that mobile phones are high touch devices due to their constant use and interaction with the hands of the owner. Indeed, it is estimated that mobile phones are used for 3 h and 37 min on average per day [1], with individuals touching their devices between 2617 and 5400 times [6].

Nosocomial infections constitute an important health problem associated with significant morbidity and mortality

globally [7]. Multi-drug resistant (MDR) bacteria which are one of the most important threats to public health are typically associated with nosocomial infection. Despite their best intentions, HCWs may inadvertently act as vectors, disseminating infectious agents including MDR pathogens within the healthcare setting. In a recent report from Italy, 93% of health professions students used their mobile phones on the wards, and only 11% changed gloves after medical procedures/use of phone and just 3% reported cleaning their phones [8]. Similarly, in a study by Cavari et al. [9], 90% of participating HCWs kept their phones with them in the workplace, 37% utilized the phones at least once every hour and 13% disinfected their cell phone regularly. In 2021, a hospital-based survey of 165 healthcare staff in a tertiary care facility in Australia revealed that although most participants knew that mobile phones could potentially harbour pathogenic microorganisms, they rarely sanitised their devices [10]. These habits are of significant concern as they could reduce or nullify the impact of hand hygiene practices instituted to limit the spread of microbes in the healthcare setting [11].

The United Arab Emirates is a cosmopolitan setting and HCWs from across the globe are part of the healthcare system. However, there remains a lack of data on the utilization and sanitization of mobile phones among HCWs in the UAE and indeed in the wider Arabian Gulf region. Furthermore, the perceptions of this diverse population of HCWs on the role of these devices as "trojan horses" for microbes remains unknown. Therefore, to address this gap in the literature, a survey was carried out to obtain comprehensive information on the usage of mobile phones as well as the habits surrounding the use and sanitization of these devices among HCWs.

Methods

Setting and population

The study population comprised of HCWs working in Dubai Health Authority (DHA) healthcare facilities. All categories of HCWs including nursing staff, physicians, and ancillary staff who have contact with patients in the clinical setting e.g., radiographers, pharmacists, laboratory staff, physiotherapists were eligible to participate in the survey. Administrative staff were excluded. Data was collected as an electronic survey (E-survey) through self-completion of a computer-based questionnaire.

Study tool and implementation

The questionnaire consisted of 14 questions and 7 sub-questions relating to mobile phone usage and sanitization habits [10]. Most questions consisted of tick-box responses with binary yes/no answers, for example, 'do you consider your mobile phone to be an essential tool for your job?' and 'how often do you use your mobile phone during an 8-h shift?'. The sub-questions provided the respondent with a range of potential answers, for example, "if yes, for which purpose would you be most likely to be using on your device at this time? with potential responses being work/social, media/personal, phone calls/mobile, gaming/other. Additionally, participants were able to provide an alternative answer where the options did not include their preferred response.

The study was conducted from 14th March-20th May 2021 when the E-survey was available for participants to complete. The invitation link was shared with all clinical staff via the DHA email portal which is routinely used for dissemination and communication of information. The E-survey landing page stated the purpose of the project, and participants were assured that participation was anonymous and no personal information would be collected. Progression to viewing and completion of the questionnaire was contingent upon confirming that they had not completed the questionnaire and they gave consent by ticking "yes" in the provision of consent section. The E-survey took approximately 10–15 min to complete.

Statistical analysis

All data was exported to SPSS for analysis. Descriptive statistics for categorical variables are as numbers (percent). Associations between participant demographics and survey responses were analysed using Pearson's chi-square test of independence with p-value of ≤ 0.05 considered as statistically significant.

Results

Participant demographics

A total of 377 HCWs participated in the study. The majority of respondents (87.5%; n/N = 330/377) were between 26

and 55 years old while 11.7% (n/N = 44/377) were older than 55 years of age. There was a preponderance of females (76.4%; n/N = 288/377). Across the 377 participants, 17 unique occupational roles were identified (Table 1) comprising mostly of nursing staff (56%), followed by physicians (16%) and laboratory staff (14%).

Mobile phone use in healthcare

A high proportion of participants (84.6%; n/N = 319/377) considered mobile phones as essential tools for their job and majority of participants (92.8%; n/N = 350/377) used their mobile phones frequently whilst at work (Fig. 1). Most respondents (56%; n/N = 211/377) used mobile phones not more than 2–3 times during their shift, while 20.4% (n/N = 77/377) and 16.4% (n/N = 62/377) reported utilization at least once every hour and once every 2 h respectively. There was a significant association between gender and frequency of utilization of the phone during a shift (Pearson's chi-square test with $p = 0.00073$, $df = 3$, Chen's effect = 0.3532) with the females having a higher frequency of phone utilisation than the males. Only 7.2% (n/N = 27/377, comprising of 18 females and 9 males) indicated that they do not use their mobile phones during their shifts. When asked reason for usage of mobile phones at work, 83.5% (n/N = 315/377) indicated that it was for work-related and personal purposes.

Mobile phones as potential fomites and staff current existing mitigation strategies to prevent cross-contamination

A total of 97.1% (n/N = 366/377) of participants believe mobile phones could harbour micro-organisms while 2.7% (n/N = 10/377) are unsure. Additionally, 15.1% (n/N = 57/377) indicated they use their phones while wearing gloves.

Table 1 Total count of participant occupations.

Occupation	Total	Percentage (%)
Nursing Staff	213	56.5
Physician	62	16.5
Laboratory Staff	53	14
Administrative Staff	10	2.7
Radiology	9	2.4
Physiotherapist	8	2.1
Dietitian	7	1.9
Dentists	3	0.8
Pharmacist	3	0.8
Paramedic	2	0.5
Audiologist	1	0.3
ENGG (hospital engineering)	1	0.3
Health Education	1	0.3
Occupational Therapist	1	0.3
Psychology	1	0.3
Quality assurance	1	0.3
Respiratory therapist	1	0.3
Total	377	100

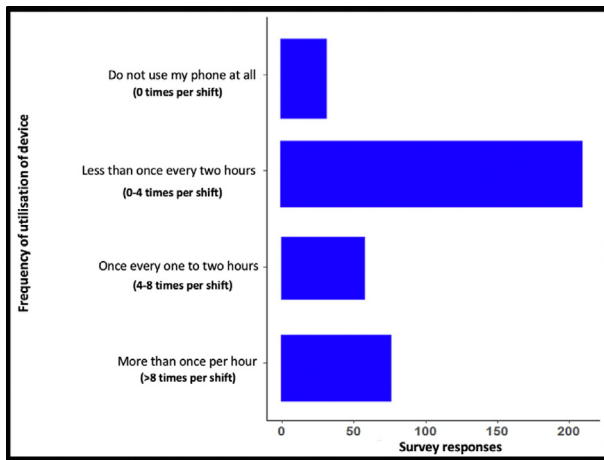


Figure 1 Frequency of utilization of mobile phones in the workplace.

Among those who use their mobile phones whilst wearing gloves about one-third do not change their gloves after handling their mobile phones (Table 2). The usage of mobile phones in the toilet was reported by 16.2% ($n/N = 65/377$), and almost all the respondents reported on practicing handwashing after using the toilet mostly with soap/water (Table 2). The practices of the HCWs with regards to cleaning their mobile phones are shown in Table 2.

Although 10.3% ($n/N = 39/377$) of participants indicated that they never clean their mobile phones at work, 89.7% ($n/N = 338/377$) reported cleaning with either alcohol swabs, other disinfectants wipes or non-disinfectant lint felt cloths. Among those who reported cleaning, (92.3%; $n/N = 312/338$) utilise alcohol wipes or sprays to clean and wipe down mobile phones at work. Cleaning frequency and cleaning method data are shown on Table 3. Overall, when phones were cleaned within an 8-h working shift, the disinfection method using wipes accounted for 92.3% (312/338) while non disinfectant lint felt wipes were used to clean phones by 7.7% (26/338) of participants.

Perception of mobile phones as fomites

A high proportion of HCWs agree that their mobile phones could harbour microorganisms (97.1%; $n/N = 366/377$).

Although most HCWs also indicated that mobile phones could spread SARS-CoV-2 (89.6%; $n/N = 335/377$), almost half (46.7%; $n/N = 176/377$) were unaware that the SARS-CoV-2 virus could remain viable on the surface of mobile phones for an extended period.

When dividing the whole cohort ($N = 377$) into two groups with staff role most likely in close/physical contacts with patients (Group A; $n/N = 291/377$) and staff role most likely without these contacts (Group B; $n/N = 86/377$) (Table 4), analysis showed that $n/N = 260/291$ (89.3%) of Group A and $n/N = 76/86$ (88.4%) of Group B considered with affirmation that mobile phones could contribute to the dissemination of SARS-COV-2.

Group A and B respondents that indicated "yes there is a likelihood that mobile phones are vectors for dissemination of SARS-CoV-2" were asked that following question: "If yes, kindly name one measure you think can be applied to stop this particularly in the healthcare setting? (You may tick more than one box)". Results for such question showed that the measures predominantly reported from both groups consisted of i) the use of disinfectants to sanitise mobile phones or/and ii) to sanitise phones with ultraviolet exposure or/and iii) to implement a policy to limit phone use at work. The use of disinfectants was the most reported measure by both groups (73.5% and 77.6% in group A and B respectively), followed by the ultraviolet phone sanitation (43.8% and 47.4% in group A and B respectively), and finally the requirement of a policy implementation (40.8% for both groups) (Table 5).

Three main measures were suggested to participants to limit mobile phones as possible fomite platforms responsible for viral dissemination as shown in Table 5 which included i) the use of disinfectant to clean phones ("Disinfectant") or/and ii) the implementation of a policy to limit the use of mobile phones in Health care settings ("Policy") or/and to conduct ultraviolet C sanitation of mobile phones at work ("Ultraviolet"). As the participants could choose either one or a combination of these measures, further analysis to see if there were differences between the two groups was carried out. For those in Group A, 72 participants suggested 'disinfectants' only; 39 suggested 'disinfectant' and 'Policy'; 50 participants suggested 'Disinfectant' and 'Ultraviolet'; 30 participants suggested 'Disinfectant' and 'Ultraviolet' and 'Policy'. The Venn diagrams shown in Fig. 2 illustrate the number of

Table 2 Mobile phone use and hand hygiene practice of participants.

Hygiene practices	Number of respondents (N = 377)	Percentage
Respondents who practice wearing of gloves when using their mobile phones in the workplace.	57	15.1
Respondents who don't change their gloves after touching their mobile phones with gloves on.	20	5.3
Respondents who practice hand hygiene after using the toilet.	376	99.7
Preferred method for hand hygiene after using the toilet.		
Water and soap	359	95.2
Hand sanitizer	13	3.5
NA	5	1.3

Table 3 Cleaning frequencies and materials of participants reporting cleaning their phones at work (89.7%; n/N = 338/377).

		Number of respondents	Types of Cleaning	
			Alcohol swabs/Disinfectants (wipes/spray)	Lint felt cloth
Cleaning Frequency	At least once during 8 h shift	269	249/269 (92.6%)	20/269 (7.4%)
	At least once every 2h	51	49/51 (96%)	2/51 (4%)
	At least once every hour	18	14/18 (78%)	4/18 (22%)
Total		338	312/338 (92.3%)	26/338 (7.7%)

Table 4 Staff role most likely with or without close/physical contacts with patients.

Group A		Group B	
Nurses	213/377 (56.5%)	Laboratory staff	53/377 (14.1%)
Physicians	62/377 (16.4%)	Administrators	10/377 (2.7%)
Physiotherapists	8/377 (2.1%)	Radiologists	9/377 (2.4%)
Dentists	3/377 (0.8%)	Dieticians	7/377 (1.9%)
Paramedics	2/377 (0.5%)	Pharmacists	3/377 (0.8%)
Audiologists	1/377 (0.3%)	Hospital Engineer	1/377 (0.3%)
Occupation therapist	1 (0.3%)	Psychology	1 (0.3%)
Respiratory therapist	1(0.3%)	Quality Assurance	1 (0.3%)
		Health Education	1 (0.3%)
Total	291 (77.2%)		86 (22.8%)

participants opting for a unique type of measure or for a combination of measures.

There is no association between the responses to possible methods of disinfecting mobile phones and the different groups (A and B), categorised by role (χ^2 test, $p = 0.9608$, $df = 2$ and Cohen's $d = 0.0042$) (Table 5).

Additionally, no association was found among the choice of responses (singular choice, a combination of two choices and a combination of all three of disinfection) and classification of respondents by roles (Group A and Group B) (χ^2 test, $p = 0.5377$, $df = 2$ and Cohen's $d = 0.0671$). Further no association was found among the choice of responses as combinations of two preferences only (i.e Disinfection/Policy, Disinfection/Ultraviolet C and Policy/Ultraviolet C) and the groups (Group A and Group B) categorised by role (χ^2 test, $p = 0.8353$, $df = 2$ and Cohen's $d = 0.0377$). Both groups had no differences in responses overall as to how to mitigate the contamination of the phones (Fig. 2).

Table 5 Participant's responses to suggested measures to limit mobile phones as possible fomite responsible for viral dissemination.

	Group A		Group B	
	Respondents	% (/260)	Respondents	% (/76)
Disinfectant	191	73.5	59	77.6
Ultraviolet	114	43.8	36	47.4
Policy to limit MP	106	40.8	31	40.8

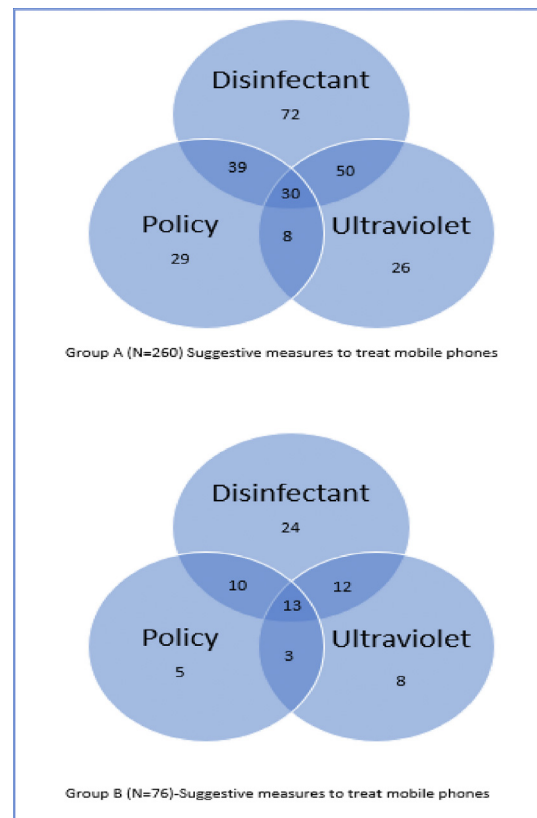


Figure 2 Venn diagram_ Suggested measures suggested by healthcare staff to address mobile phone as fomites.

Fig. 2. Health care staff suggested measures if mobile phones acted as platforms capable of contributing to the dissemination of SARS-CoV-2. Each Venn diagram denotes the participant's suggested measures [First diagram: responses from Group A (n = 260); Second diagram: responses from Group B (n = 76)]. Three main suggestions were i) the use of disinfectant to clean phones ("Disinfectant") or/and ii) the implementation of a policy to limit the use of mobile phones in Health care settings ("Policy") or/and to conduct ultraviolet C sanitation of mobile phones at work ("Ultraviolet").

Discussion

The results of this E-survey study provide a comprehensive overview of the attitudes and opinions of healthcare staff towards mobile phone hygiene at a time when infection control is heightened by the COVID-19 pandemic. The risks presented by mobile phones as potential fomites and the importance of maintaining sanitised devices are shared by healthcare workers since such devices are ubiquitously used in the professional healthcare setting. In this study, mobile phone use was close to universal (92%; n/N = 350/377) with these findings comparable to a study undertaken in 2021 by Leong [12], in which more than 90% of the HCWs respondents use their mobile phones regularly at work, be it for personal or work-related use. In our current study, 84.62% (n/N = 319/377) of healthcare staff considering their phones to be essential tools for work with 56% (n/N = 211/377) of the HCWs used their mobile phones at least 2–3 times during their shift, 20.4% (n/N = 77/377) used their phones at least once every hour and 16.4% (n/N = 62/377) at least once every 2 h.

It is essential to investigate the effects of altered human behaviour and tendencies when individuals are confronted to report about their personal hygiene. In this current study, 16.2% (n/N = 65/377) of participants admitted to using their mobile phones in the toilet. This is likely an under-representation as previous studies, in health care settings, have reported higher usage rates of 57% whilst in the toilet [10]. Mobile phone use is prominent in all areas of daily life, and it is likely that some participants may opt to not reveal their 'true' mobile hygiene habits regarding phone use in toilets. This is referred to as the Hawthorne effect and outlines that some participants of a study may alter or adjust disclosure of their habits and behaviour due to their awareness of being possibly observed or examined [13]. Due to the nature of the E-survey being online, as opposed to a survey delivered in person, individuals with a bias may be over-represented. The subject of whether a healthcare professional uses their mobile phone in an area of faecal driven fomite contamination while aware infection control protocols are in place in health care settings added to the importance of hand hygiene may create a preference for participants to answering "no" to the usage of mobile phones in bathrooms skewing the data. As there is no way of knowing the motives of survey respondents it is difficult to understand the extent of a bias in online surveys [14].

The psychological aspects of excessive mobile phone use in the professional healthcare setting become quite complex due to a variety of factors [15]. Doctors and healthcare

staff of all levels of seniority use mobile phones and encourage their peers to utilise medical apps and work-related tools. Smartphone devices enable healthcare staff to access important medical information as well as providing effective and continuous service to patients [16]. Additionally, staff members can use their phones to contact family and relatives which may reduce work-related stress and anxiety during long and continued overtime shifts. Due to the necessity of these devices, they become overlooked and even neglected when considering their role as 'trojan horses' bypassing fundamental hand hygiene procedures. The results of this study indicate that 97.1% (n/N = 366/377) of participants believe their phones can harbour microorganisms which coincides with previous studies of 98.7% [10].

Furthermore, greater emphasis is placed on mobile phones acting as vectors for SARS-CoV-2 transmission. In 2020, a study demonstrating the viability and longevity of SARS-CoV-2 on mobile phones was undertaken establishing that the virus can survive up to 28 days on mobile phones, compared to the previous estimation of 14 days [17]. In this study, 89.7% (n/N = 338/377) of respondents cleaned their phones with 92.3% (n/N = 312/338) using chemical cleaner to wipe down their mobile phones and 7.7% (n/N = 26/338) using a non-chemical lint felt cloth. Furthermore, cleaning frequency was mostly performed once during an 8-h shift [71.35% (n/N = 269/377)]. Using chemical cleaners could prove detrimental to phones. Yet despite such attempts at trying to maintain a sanitised mobile phone, studies have shown that contamination with microbes can occur instantaneously. Recently, our research team highlighted the presence of SARS-CoV-2 on the mobile phone of a HCW although the phone was wiped, within the preceding 24 h with 70% isopropyl [18].

More practical approaches for mobile phone sanitisation are urgently needed in the healthcare and community settings particularly in light of the ongoing pandemic. Studies have demonstrated that the spike protein, present on the SARS-CoV-2 virus, can bind and enable the virus to enter various human organs via the angiotensin-converting enzyme 2 (ACE2) receptor which is present in the gastrointestinal tract [19]. Additionally, individuals who are asymptomatic for COVID-19 can continuously shed virus particles in stool [20]. It is particularly concerning when considering that mobile phones are commonly used in toilets, as new research has revealed high amounts of viral RNA from the SARS-CoV-2 virus to be present in faeces of infected individuals [21].

The need to implement regulation on the sanitisation of mobile phones in health care setting is mounting. In 2006, the British Medical Association outlined the risks of doctor's ties acting as potential reservoirs for pathogens and released new guidelines to ban the use of ties on ward rounds. The main pathogens of concern were methicillin resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile*, which at the time contributed to up to 5000 patient deaths each year and resulting in up to £1bn in treatment costs [22]. In 2020, Olsen and colleagues presented a compressive assessment of mobile phone contamination of the last 15 years, highlighting the range of pathogens present on mobile phones including MRSA, *C. difficile* in addition to fungi and viral pathogens [5].

Furthermore, in 2021, the work performed by Tajouri and colleagues using next-generation sequencing approach revealed a much greater spectrum of viable pathogenic organisms on mobile phones [23]. The pathogenic microorganisms uncovered include nosocomial “ESKAPE” pathogens with high virulence; *Enterococcus faecium*, *S. aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* spp. The presence of viable protozoa was first reported to be present on community-derived mobile phones with the identification of *Entamoeba histolytica*, a parasite known to cause gastrointestinal bleeding and estimated to kill more than 55,000 individuals each year [24].

To ensure that HCWs are maintaining a high standard of patient care, mobile phones need to be sanitised and considered as potentially soiled and colonised platform [25,26]. The current survey of 377 participants is a low power study and may not capture all necessary data to pinpoint the issues associated with mobile phones use in healthcare settings. Additionally, this survey study has only few questions addressing mobile phones as fomites. Large scale studies with a more robust survey tool capturing data relating to other high touch digital devices is urgently warranted. The future of effective prevention and global infection control is technology driven. The existence of ultraviolet-C (UVC) sanitisation technologies provides an optimal practical and novel solution for sanitization of mobile phones in a relatively short amount of time. Identification of UVC sanitisers that are safe and certified will enable a practical and easy to use phone sanitisation modality. This will be an asset for any infection control procedures in the healthcare and community settings. In terms of practicality, fast and efficient phone sanitisers will be ideal for healthcare professionals on duty as the minimum amount of time of 10–20 s for phone sanitisation will also enable staff to simultaneously carry out hand hygiene protocols either by hand wash or use of hand gel sanitiser.

Conclusions

Our findings demonstrate a high utilization of mobile phones in the workplace by HCWs and despite recognising the potential for microbial contamination, cleaning of mobile phones remains infrequent. Therefore, the inclusion of mobile phone sanitization in infection control protocols is warranted globally. Studies on the deployment and impact of new technologies such as ultraviolet-C sanitisation devices for cleaning mobile phones in the healthcare setting are urgently needed.

Ethical considerations

Ethical approval for the study was granted by the Dubai Scientific Research Ethics Committee, Dubai Health Authority (REF#: DSREC-03/2021_22).

Author contribution statement

Development and set up of the E-survey was performed by AA, HA, AS, SB, LM, MAA, RAlm. Data analysis and

interpretation was performed by MO, LT, RA, AS, RN, BK, SM. Manuscript was prepared by AA, AS, MO, LT. All authors reviewed the manuscript.

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Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

Provenance and peer review

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.idh.2022.07.001>.

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