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ORIGINAL RESEARCH

The unseen breeding ground for pathogens: a study on the spectrum and awareness of microorganisms on smartphones of university students in South Africa, Kwa-Zulu Natal

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Background: Smartphone use has increased exponentially, having formed an integral part of the COVID-19 pandemic era, especially in the academic arena. It has been established that fomites can harbour potentially pathogenic microorganisms, which pose health risks to humans, particularly to the immunocompromised. The purpose of this study was to determine which microorganisms were harboured on the surfaces of smartphones, document the device sanitisation and hand hygiene habits of students within a university cohort, and determine associations of these habits with microorganism colonisation on smartphones.

Methodology: This study prospectively sampled 168 randomly selected students from different departments at the Durban University of Technology (DUT). After informed consent, a swab sample from each participant's smartphone was collected and transported to the microbiology laboratory for culture following standard microbiological guidelines. Participants were also asked about device sanitisation and their awareness of smartphones harbouring microorganisms. IBM Statistical Package for Social Sciences (SPSS) Statistics V.27 was used for data analysis with the use of descriptive statistics, Pearson chi-square and Pearson's correlation tests.

Results: From the 168 participants, microorganisms were detected in 113 (67.3%) samples, from which 20 different microorganisms were isolated. The majority of microorganisms (n = 17; 73.7%) were opportunistic pathogens. Out of the 168 questionnaire responses, only 36 (21.4%) study participants sanitised their smartphones despite 97 (57.7%) stating that they were aware of smartphones harbouring microorganisms.

Conclusion: This study reports a high prevalence of microorganisms harboured on smartphones. The isolation of opportunistic pathogens, as well as the low frequency of smartphone sanitisation, raises a need for awareness of the contamination of smartphones and the potential risk of infection.

Keywords: phones, microorganisms, contamination, microbiology, sanitise

Introduction

Smartphone use has increased exponentially over the years with more than 3.5 billion smartphone users globally.[1] In South Africa, the number of smartphone users is estimated to be around 23.2 million.[1] The COVID-19 pandemic catapulted the higher education space into the virtual world. With the shutdown of all universities during the lockdown period, students and lecturers were forced to transition to online learning. However, due to various socio-economic factors, many students did not have access to computers and instead used their smartphones for learning and assessment activities.

Although smartphones are considered a necessity, there is a potential risk of contamination since it is established that the surface of these devices may harbour potentially pathogenic microorganisms.[2–4] Despite these risks of contamination, there are currently no general, national, or international guidelines for sanitising smartphones.[2] The Centre for Disease Control (CDC) defines sanitising as lowering the number of microorganisms on objects to a safe level by "cleaning or disinfecting".[5] Briefly, cleaning refers to using soap or detergents, with water, to physically remove organisms from surfaces. This process does not necessarily kill organisms, but by removing them it lowers their numbers and therefore reduces the risk of spreading infection. Disinfecting employs the use of chemicals to kill organisms on surfaces. This process does not clean the surface or remove the germs but kills them on the object's surface, thus also lowering the risk of infection.

Regular handwashing with soap and the use of hand sanitisers, as confirmed by the World Health Organisation (WHO), is the first line of defence against the spread of infections.[6] However, when there is a lack of adequate hand hygiene, transmission of microorganisms may occur to or from our smartphones, since hands are vectors of transmission.

Human skin, particularly the hands, is host to various types of microorganisms. Studies show that more than 150 unique microorganisms are harboured on the skin surface.[7,8] The constant exposure of human hands to the environment leads to contamination by opportunistic microorganisms, which may lead to diseases if these organisms are introduced to other parts of the body in larger numbers.[9] The continuous handling of smartphones together with the heat generated by these devices creates a favourable breeding condition for microorganisms.[4]

A review by Olsen et al.[2] reported that 68% of smartphones are contaminated. *Staphylococcus aureus* (*S. aureus*) and Coagulase-negative *Staphylococci* (CoNS) were found to be the most frequently identified microorganisms, and Gram-negative bacilli (GNB) were also identified.[10,11]

A search on Google Scholar, ScienceDirect and PubMed for publications up until December 2022 was performed to identify similar studies. Searches were limited to English language papers. The following keywords were used: "bacteria contamination" OR "microorganism contamination" AND "smartphones" OR "cell phones" OR "mobile devices" AND "students" OR "university" OR "college" AND "South Africa". The results yielded no publications on the contamination of smartphones in the South African university setting. The majority of studies in the literature focused on the healthcare sector or students from academic hospitals.[3,4,12,13] Therefore, given its importance and potential benefit, the purpose of this study was to determine which microorganisms were harboured on the surfaces of smartphones, document the device sanitisation and hand hygiene habits of students within the university, and determine the associations of these parameters with microorganism colonisation on smartphones.

Methodology

Study design

This study employed a positivist paradigm with a cross-sectional approach. The design was experimental and quantitative.

Study setting and participants

The DUT was selected as the study location because of the proximity to the researcher. The DUT has approximately 33 000 students, with five different campuses in the Durban area.

This study comprised 168 randomly selected students. Students were verbally informed of the research study, and those who were interested were given an information letter with further details as well as a consent form. Once participants signed the consent form, the researcher collected demographic information using the questionnaire and also asked each participant two questions (Table I). This information was captured on a separate datasheet containing no personal identifiers of the participants. Each datasheet was numbered (000-168).

Table I: Questions to participants

Questions
Year of study
Department
Age
Sex (male and female)
Q1: Are you aware that smartphones can harbour microorganisms?
Q2: Do you sanitise your smartphone after using it?

Sample collection

Samples were collected aseptically following the method used by Morubagal et al.[4] A sterile cotton swab was moistened with sterile, normal saline. The swab was rotated on the back, front and side surfaces of the smartphones. Each sample collected was labelled according to the given sample number from the datasheet. Swabs were placed in transport media into a cooler box and then taken to the laboratory for processing.

Sample processing

Per the WHO guidelines, all swabs were processed by inoculation on Chocolate, Blood and MacConkey agar plates.[14] The Chocolate and Blood plates were incubated in an anaerobic incubator at 37 °C, and the MacConkey plates in an aerobic incubator at 37 °C, both for 18–24 hours. After the incubation period, the plates were examined for growth. Agar plates with no visible growth were recorded as "No growth" and no further testing was performed. The plates that showed visible colonies were selected for identification using the Gram stain and various other biochemical testing.[15] These tests included: Catalase, Coagulase and DNase for Gram-positive cocci (GPC); GNB were identified using the Analytical Profile Index (API) 20E test; Gram-negative cocci (GNC) and Gram-positive bacilli (GPB) were identified using the VITEK® Mass Spectrometry (MS).[16,17]

Statistical analysis

IBM SPSS Statistics V.27 was used for data analysis. Descriptive statistics are presented as mean ± standard deviation (SD) for prevalence data. The chi-square test was used to compare the isolation of microorganisms. Pearson's correlation was used to determine the relationship between awareness of smartphones harbouring microorganisms and positive sanitising behaviour (participants' responses to Q1 & 2 respectively) with microbial growth outcome. A p-value less than 0.05 denoted statistical significance.

Responses to Q1 & 2 were divided according to growth and no growth (of microorganisms on smartphones). Those with growth of microorganisms were further grouped according to those with a single microbe isolated, those with two, and those with three microbes isolated.

Ethical consideration

Ethical approval was granted by the Ethics Committee at the DUT (Research Ethics Clearance Number: BIREC 026/21). All information was kept confidential by giving each swab a unique sample number according to the corresponding datasheet that contained no personal identifiers. This study has conformed to the Declaration of Helsinki.[18]

Results

A total of 168 students participated in the study (n = 168). From the 168 samples evaluated, microorganisms were isolated in n = 113 (67.3%) samples (Figure 1). Some media plates showed growth patterns of more than one type of microorganism

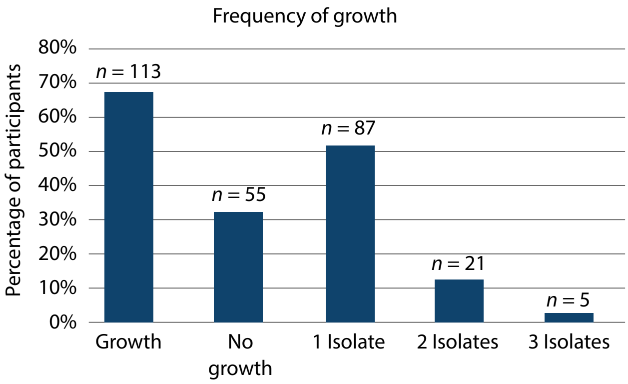

Figure 1: Bar graph showing the growth patterns of microorganisms

(Figures 2 & 3). These growth patterns were categorised as 1 isolate, 2 isolates, and 3 isolates (Figure 1).

From the 113 samples that showed growth of microorganisms, 20 different species were isolated (Table II), with a total of 144 individual microorganisms isolated, of which Coagulase-negative *Staphylococcus* was the most frequently isolated ($n = 83$).

Analysis of the binary questionnaire responses for Q1 (Are you aware that smartphones can harbour microorganisms?) showed that 57.7% ($n = 97$) of participants answered "Yes", and 42.3% ($n = 71$) answered "No" (Table III), with no statistical difference ($p = 0.081$) between these two responses.

When asked "Do you sanitise your smartphone after using it?", 21.4% ($n = 36$) of participants answered: "Yes", and 78.6% ($n = 132$) said "No" (Table III). There is a statistically significant difference between these two responses ($p = 0.007$), and a positive correlation (r = 0.205) between those who answered "Yes" and the number of isolates recorded. Conversely, there was no statistical difference between the growth/no growth for Q2 (Do you sanitise your smartphone after using it?) ($p = 0.098$). However, when the three groups were analysed, those categorised with a single microorganism isolated and who answered "No" to Q2 had a higher statistically significant number of pathogens present on their smartphones ($p = 0.021$; $r = 0.124$). A positive association between healthy sanitising behaviour and lower growth was observed, compared to those who did not sanitise.

Discussion

According to the knowledge of the researcher, this was the first study of its nature performed in South Africa to determine which microorganisms were harboured on smartphones, document the device sanitisation and hand hygiene habits within a subgroup of university students, and determine associations with microorganism colonisation on smartphones. This study found that 67.3% of swab samples showed growth of one or more microorganism types.

Similar results were found in several international studies.[19–21] A study by Dibetso compared 15 different studies that were

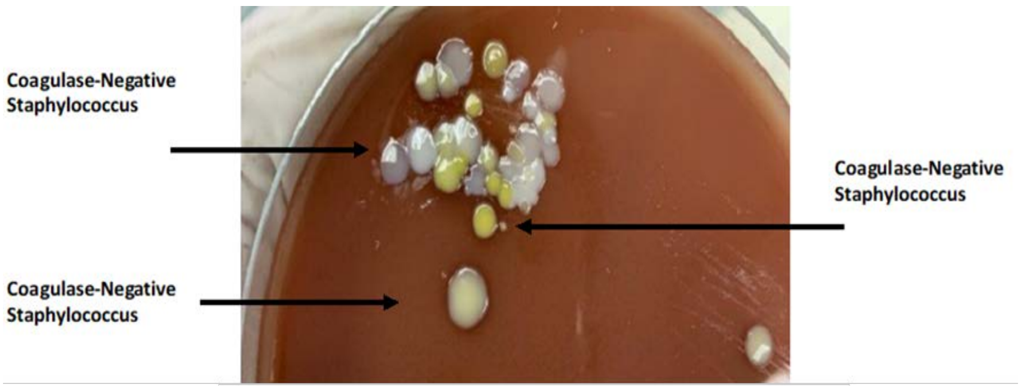

Figure 2: Chocolate agar plate with mixed growth (CoNS)

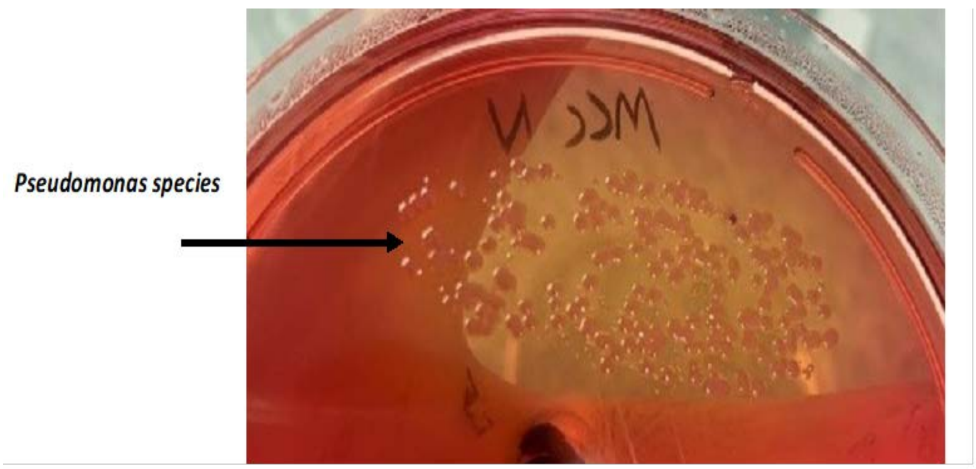

Figure 3: MacConkey agar plate with a gram negative bacilli (*Pseudomonas spp.*)

Table II: Microorganisms isolated from smartphones

Microorganism isolated	Number isolated	Percentage (%)	Pathogenicity
Acinetobacter baumannii	1	0.7	Opportunistic pathogen
Acinetobacter species	3	2.1	Opportunistic pathogen
Aeromonas salmonicida	4	2.8	Environmental contaminant
Bacillus cereus	1	0.7	Food-borne pathogen
Bacillus species	5	3.5	Environmental contaminant
Burkholderia cepacian	2	1.4	Opportunistic pathogen
Chryseomonas indologenes	1	0.7	Environmental contaminant
Coagulase-negative Staphylococcus	83	57.6	Opportunistic pathogen
Corynebacterium species	1	0.7	Opportunistic pathogen
Enterobacter cloacae	2	1.4	Opportunistic pathogen
Escherichia hermannii	1	0.7	Environmental contaminant
Moraxella species	4	2.8	Opportunistic pathogen
Ochrobactrum anthropic	3	2.1	Opportunistic pathogen
Pantoea species	4	2.8	Opportunistic pathogen
Pasteurella pneumotropica	2	1.4	Opportunistic pathogen
Pseudomonas aeruginosa	4	2.8	Opportunistic pathogen
Pseudomonas species	12	8.3	Opportunistic pathogen
Serratia species	2	1.4	Opportunistic pathogen
Stenotrophomonas maltophilia	2	1.4	Opportunistic pathogen
Unidentifiable GPB	6	4.2	Environmental contaminant
Total	**144**	**100**	

Table III: Analysis of questionnaire responses

Q1: Are you aware that smartphones can harbour microorganisms?			
	Yes	**No**	***p*-value**
	***n* = 97 (57.7%)**	***n* = 71 (42.3%)**	0.081
Total growth	*n* = 60	*n* = 53	0.09
1 isolate	*n* = 52 (86.7%)	*n* = 35 (66%)	0.131
2 isolates	*n* = 5 (8.3%)	*n* = 16 (30.2%)	0.022 (*r* = -0.230)*
3 isolates	*n* = 3 (5%)	*n* = 2 (3.8%)	0.33
Q2: Do you sanitise your smartphone after using it?			
	Yes	**No**	***p*-value**
	***n* = 36 (21.4%)**	***n* = 132 (78.6%)**	0.007 (*r* = 0.205)*
Total growth	*n* = 26	*n* = 87	0.098
1 isolate	*n* = 20 (76.9%)	*n* = 67 (77%)	0.021 (*r* = 0.124)*
2 isolates	*n* = 5 (19.2%)	*n* = 16 (18.4%)	0.865
3 isolates	*n* = 1 (3.8%)	*n* = 4 (4.6%)	0.671

*Indicates statistical significance ($p < 0.05$)

published between 2009 and 2016, of which most concluded a microbial contamination rate of mobile phones to be greater than 60%.[22] A retrospective study (pre-COVID-19 period) by Olsen et al.[2] reviewed 54 published works on the presence of microorganisms on smartphones. They reported that on average, 68% of smartphones show microorganism contamination. It is interesting to note that even though the current study was carried out during the COVID-19 pandemic period when sanitising had become a part of daily life, the study still achieved similar results to those of Olsen et al.[2] when sanitisation was not a mainstream practice.

Arora et al.[23] had a similar sample size to the present study, but a lower microbial contamination rate. This may be due to the different methods used for organism identification. The present study adapted methods for identification by selecting appropriate biochemical tests for all the Gram types. The use of Chocolate, Blood and MacConkey agar plates also allowed for a greater yield of microorganism growth compared to other studies, which used fewer media plates.[3,19,24,25]

A total of 20 different microorganism species were isolated, from which CoNS was the highest isolate with a prevalence of 57.6%. The results from the current study are supported by the findings of Zaman and Helmi, Akinyemi et al. and Heyba et al. who also found CoNS to be the most prevalent microorganism.[12,19,26] The high prevalence of CoNS could be attributed to this microorganism being normal commensal skin flora, and since our hands are used in operating smartphones, there is a possibility of transmission of microorganisms between hands and smartphones.

In the majority of similar studies, a high prevalence of *S. aureus* was isolated, however, *S. aureus* was not isolated in the present study.[11,24,27] A similar study investigating smartphone contamination also did not isolate *S. aureus*.[28]

The high prevalence of GNB (33.3%) isolated from smartphones in this study suggests contamination from faecal flora or microorganisms originating from soil, food, or skin.[25] This is suggestive of poor hand hygiene practices, especially after the use of the restroom. Zaman and Helmi found that 47.5% of participants reported using smartphones in the bathroom.[12] Zakai et al. reported that 59% of their participants also use their smartphones in the bathroom.[13] When hands are not effectively washed, they become vectors for transmitting microorganisms.

In the present study, *Pseudomonas aeruginosa* was a GNB that was isolated (n = 4) from smartphones. It was reported that *Pseudomonas aeruginosa* was a commonly isolated nosocomial microorganism.[29] Infections from this microorganism may cause various serious infections, such as meningitis, pneumonia, and septicaemia.

In this study, *Acinetobacter species* (n = 3) were also isolated. Although drug resistance was not determined in the present study, Pal et al. highlighted the concern of possible multi-drug resistant (MDR) pathogens.[30] A study by Borer supported this, reporting a significant number of MDR *Acinetobacter species* harbouring on smartphones.[31]

Burkholderia cepacian (n = 2) and *Stenotrophomonas maltophilia* (n = 2) were isolated from smartphones in the present study, which may show a high degree of resistance to antibiotics and often go undetected in routine culture.[32] Treating infections caused by these microorganisms may be difficult, especially for the immunocompromised.

Moraxella spp. (n = 4) were also identified. Schachat explained that *Moraxella spp.* are normal commensal microorganisms of the upper respiratory tract, skin, and urogenital tract, but may cause ocular infections, endocarditis, bacteraemia, septic arthritis, cellulitis, and meningitis.[33]

One isolate of *Bacillus cereus* was identified. McDowell et al. explained that *Bacillus cereus* is commonly found in the environment and can contaminate food, causing food poisoning symptoms and may cause serious infections such as septicaemia, especially in immunocompromised hosts.[34]

A few GPB (n = 6) were unidentifiable according to the Vitec® MS.[17] This could be due to a lack of reference spectra in the databases of the analyser. These GPB are thought to be normal environmental contaminants that are usually harmless to humans.

Overall, 73.7% of all the microorganisms isolated from smartphones in the present study were opportunistic pathogens which may cause disease if the host's immune system is suppressed or compromised.[35] Therefore, results from this study may suggest that immunocompromised individuals could be at risk of infection from smartphones.

Statistical significance was found between smartphones contaminated with two isolates and the participant's knowledge of microorganisms harbouring on smartphones (i.e. Q1) (p = 0.022, r = -0.230). This infers that those who lacked the awareness of smartphones having the potential to harbour microorganisms were more likely to have more than one microorganism isolated from their smartphone. This lack of awareness resulted in failure to take the necessary hygiene measures (sanitising of smartphones), allowing a larger number (two isolates) of microorganisms to thrive.

The present study found that only 21.4% of participants sanitise their smartphones after using them. In contrast, Zaman and Helmi stated that 8.8% of their participants did not sanitise their smartphones, whilst 52.5% only sanitised smartphones when visibly dirty.[12] A study by Heyba et al. reported that 33.5% of their participants also did not sanitise their smartphones.[26]

There was a statistical significance (p = 0.007) between those who answered "Yes" compared to those who answered "No" to Q2 (Do you sanitise your smartphone after using it?). The greater presence of microorganism growth by those who claimed to sanitise their smartphones could be attributed to the consistency of sanitising. These participants may only sanitise their smartphones once a day, which may leave the rest of the day open to exposure to microorganisms. This question was also open-ended and did not specify the frequency of sanitising.

No statistical significance was found between the two groups (Growth/No growth) for Q2 (p = 0.098). However, statistical significance (p = 0.021) was also found between those categorised with a single microorganism isolated and who answered "No" to sanitising their smartphone after using it, where a higher number of pathogens were present on the smartphones of those who neglected to take the proper hygiene measures. The inverse may be said about those who did take necessary hygiene measures as a lower number of isolated microorganisms was observed. The positive correlation (r = 0.124) suggests the benefit of disinfecting smartphones and that sanitising smartphones does inhibit microbial growth.

Alcohol sanitisers are effective against many microorganisms and with the emergence of viral infection outbreaks in South Africa, the latest being the measles outbreak, regular handwashing and use of sanitisers should be continued practice because it helps safeguard against possible infections. Currently, there are no studies that have investigated the prevalence of handwashing and the use of sanitisers after the lockdown regulations were relaxed in South Africa.

Recommendations and limitations

Smartphone users should be made aware in the form of awareness campaigns, which can be easily done at little cost. Some strategies include using social media or in the form of notices at wash basins, etc. on campus. An overall hand hygiene awareness may also be beneficial as the majority of smartphone contamination occurs from hands.

Further studies emanating from potential weaknesses of this study could include larger sample sizes to allow for a better and more substantive comparison of microorganisms, as well as open-ended questions to qualitatively determine handwashing habits and sanitising awareness of this cohort. Other groups of microorganisms such as fungi and viruses could also be included in future studies to get a better understanding of the microbiota contaminating the smartphone.

Conclusion

The smartphones of these study participants harboured a high prevalence of microorganisms, with a significant number of these being opportunistic pathogens. With the constant emergence of novel bacteria and viruses, there is a need for awareness of sources of contamination of smartphones, and the potential risk of infections to the general population. Any person, particularly those with a weakened immune system, should therefore be extra cautious about both hand- and smartphone hygiene.

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Conflict of interest

The authors declare no conflict of interest.

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The study was self-funded.

Ethical approval

Full ethical approval was granted by the Institutional Research Ethics Committee at DUT (BIREC 026/21). All information was kept confidential by giving each swab a sample number. This study conformed to the Declaration of Helsinki.[18]

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