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Exploring the Microbiome of Mobile Devices: Implications for Public Health and Hygiene

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved of the final manuscript.

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ABSTRACT

This study, which examined the diversity of microorganisms found on mobile phones, took a novel approach by identifying pathogenic microbes on phone users within different age groups. The study also aimed to test the effectiveness of a simple disinfection method using 70% sterile alcohol pads. Samples were collected using sterile cotton tip applicators and transport broth media before and after disinfection. The samples were cultured and incubated on Muller Hinton agar petri plates at 32 degrees Celsius for 48 hours. The isolated microbes were identified based on their morphological characteristics, gram-stain test, and biochemical analysis. The survey, conducted to determine the frequency of mobile phone usage and factors contributing to microbial contamination, revealed significant findings. Participants from two villages were surveyed using a structured questionnaire. The sample size of participants was generated using a sample size calculator. Two participants

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from each age group per village were selected randomly for microbial sample collection from their mobile phones using R Studio software. The results showed that older adults' mobile phones were more contaminated than younger adults and adolescents, providing valuable insights. The frequency of usage and hygiene did not determine the total viable count of pathogenic microbes found, challenging existing assumptions. The study also found that disinfection using 70% sterile alcohol pads was 76% effective in reducing microbial contamination.

Keywords: Microbes; pathogens; transmission; infectious; fomites; mobile phones.

1. INTRODUCTION

Mobile phones have become an essential part of our lives in today's digital age, serving as a constant companion [1]. However, they also serve as an environment that favors the growth and development of microorganisms [2,1]. Mobile phones can harbor many bacteria, many of which originate from our hands. This raises significant concerns about the potential health risks of transferring bacteria from our hands to our phones. The exact percentage of bacteria on your hands found on phones is difficult to determine, as it depends on a variety of factors, such as the type of phone, the cleanliness of the phone, the cleanliness of your hands, and the frequency of usage [3]. The surface of objects or materials with infectious agents, such as viruses or bacteria that can be transferred from one person to another is known as fomites, and mobile phones are major fomite platforms [4]. Meadow et al. [5] state that many people carry their phones everywhere they go, and it is therefore exposed to their environmental microbiota. According to Koscova [6], “mobile phone usage has a personal character” because of its proximity to the body. The rate at which people touch their mobile phones determines the shared microbiota composition of a particular environment [5]. For example, over eighty percent (80%) of bacteria that comprise our bacterial “fingerprints” were found on phone screens [7,8].

Mobile phone ownership has become very common among adolescents, dramatically changing how they communicate with their peers since it allows them to connect to the internet. Consequently, this changed the way and the number of times that they interact with their phones. Adolescents can send approximately one hundred text messages daily [9,10]. They are so attached to their mobile phones that they even feel emotional discomfort when they cannot access them [11]. The younger generations are more inclined towards mobile technology and rely heavily on their phones for various purposes such as communication, social media engagement, and entertainment. On the other hand, older adults may have different phone usage patterns, utilizing their phones primarily for communication purposes rather than engaging with other applications or online platforms. Additionally, during working hours for adults, their time spent on their mobile phones is limited [11,12].

According to Olsen et al. [4], bacteria were the most common microbe found on mobile phones, followed by fungi and RNA viruses. *Staphylococcus aureus* and *Coagulase-Negative Staphylococci w*ere the most numerous identified bacteria. Neglecting mobile phone hygiene can pose a significant health risk to individuals and even contribute to transmitting infectious diseases within communities. Therefore, regular cleaning and disinfection of mobile phones are essential to mitigate these risks and maintain personal hygiene. By adopting simple hygiene practices such as using alcohol-based wipes or cleaning solutions specifically designed for electronic devices, individuals can minimize the accumulation and transfer of harmful microorganisms on their mobile phones, reducing the likelihood of infections. According to a study conducted by Golin et al. [13], alcoholic pads are effective in reducing microbial contamination on mobile phones. The study demonstrated that using alcoholic pads significantly reduced the presence of various bacteria, including *S. aureus* and *Escherichia coli.* These findings suggest that alcoholic pads can be a valuable tool in maintaining the cleanliness and hygiene of mobile phones, potentially reducing the risk of pathogen transmission.

2. MATERIALS AND METHODS

2.1 Research Design

A mixed-method approach was used to determine, describe, and analyze the factors contributing to the number of pathogenic microbes on mobile phones within different age

groups. A survey and an experimental approach were used to collect qualitative and quantitative data.

2.2 Sample Size and Sample Site

The population for this study comprised ninety (90) respondents generated from a sample size calculator to participate in answering a questionnaire based on the frequency of usage and the factors that contribute to the presence of microbes found on mobile phones. The participants for this study were selected by snowball sampling from two villages on the East Coast of Demerara, Guyana: Village A (Cummings Lodge) and Village B (Industry). Forty-five (45) participants will be chosen from Area A, and forty-five (45) participants will be selected from Area B.

Fifteen (15) questionnaires were distributed to each age group in Village A, which was repeated in Village B. The ages were 14-19, 20-35, and 36-60. Microbial samples from mobile phone users within each village were randomly selected using the statistical software R Studio for each age group.

2.3 Study Tool - Questionnaire

A structured questionnaire was used to collect data. The questionnaire consisted of four sections: Section A: personal information, Section B: mobile phone use information, Section C: mobile phone hygiene information, and Section D: awareness of microbial growth on mobile phones. Additionally, the questionnaire consisted of twenty-five (25) closed-ended questions. The respondents were required to place a tick (√), which indicates their selected answers.

2.4 Sample Collection

Sterile gloves were used to avoid contaminating the microbial sample. A sterile swab was placed into the transport medium, moistened, and wiped by rolling the swab in a clockwise direction along the sample area (the front of the phone). The swab was then placed into the transport tube for a few seconds. The tube was closed and labeled with the appropriate information, such as the village, age group, and sample number. A 70% alcohol pad was used to clean the front of the phone. This procedure was repeated after the cleaning agent (alcohol pad) was used. The transport tube was taken to the laboratory and placed into an incubator at 32 degrees Celsius for 48 hours.

2.5 Preparation and Inoculation of Media for Microbial Analysis

To prepare the transport medium, 1.35 grams of nutrient broth powder was measured using a digital scale and placed into a conical flask containing 150 mL of water. The conical flask was then placed on an electric heater and brought to a boil to dissolve completely. 5mL of the solution was put into each transport tube. Twenty-four (24) transport tubes were prepared and sealed with cotton tops. 22.8 grams of Muller Hinton agar powder were measured, placed into a conical flask containing 600 mL of water, placed on an electric heater, and brought to a boil to dissolve completely. The Muller Hinton solution in the conical flask along the transport mediums was sterilized by autoclaving at 121°C for 15 minutes. They were removed from the autoclave with the use of heat-resistance gloves, and they were left to cool. The Muller Hinton solution was then poured into the petri plate about 25-30 ml per 90mm plate, with a depth of 4mm, and left for the medium to solidify. Sixty (60) petri plates were prepared. The petri plates were sterile under ultraviolet (UV) light for 20 minutes before the agar was added and another 20 minutes after the agar was added.

The prepared petri plates were inverted and stocked in rows in a plastic bag labeled with the researcher's initials, date, and type of medium. The plastic bag containing the plates, and the transport mediums was stored in a refrigerator. After the petri plates were removed from the fridge, they were placed into a Microbiology plate dryer at 32.7 degrees Celsius. The racks/shelves were sanitized with 70% alcohol, and the Muller Hinton agar petri plates were opened and placed downwards onto the two bottom shelves. As the plates from the bottom shelf dried, they were removed and replaced with plates from the top. Plates from the back were also replaced with plates at the front of the shelf.

The spread plate method was used to inoculate the petri plates in a laminar flow hood. A sterile cotton applicator swab was used as a spreader, placed into a 10^{-5} dilution, and then used to spread the inoculum over the surface of the Muller Hinton agar medium. This was repeated for the other sample dilutions. Moreover, each 10^{-5} dilution was cultured in duplicates. The petri plates were cultured in three groups, sixteen (16)

plates per age group. Forty-eight (48) petri plates were inoculated, and four (6) petri plates were used as a control for the sterile dilution blanks, the Muller Hinton agar, and the transport broth medium. The cultured plates were also inverted and placed into an incubator at 32 degrees Celsius for 48 hours.

2.6 Serial Dilution and Calculating the Number of Colony-Forming Units (CFU)

A series of sequential dilutions were used to reduce the density of microbial cells to a more usable concentration. This is known as serial dilution. The total dilution factor used was 10^{-5}, determined by a trial dilution factor. Each dilution reduced the concentration of microbes by a specific number. Each tube is referred to as a dilution blank. A total of 122 dilution blanks were prepared by adding 9 mL into each tube. These tubes were placed into an autoclave at 121°C for 15 minutes. The tubes were then removed from the autoclave and stored in a refrigerator. Each dilution blank was labeled with the total dilution that it contained. The transport medium was removed from the incubator, and the content was mixed by flicking the tube vigorously on the index finger. Using the aseptic technique, the cotton cover was removed, the mouth was flamed, and a sterile pipette transferred 1 mL of the medium to the first 9 mL dilution blank. The tube was flamed and recapped; this is 10^{-1} dilution since 1 mL of the inoculum was added to the 9 mL of sterile water. The tube was held at an angle, and the context was remixed by flicking the tube vigorously with the index finger. The aseptic technique transferred 1mL from the 10^{-1} dilution to the 10^{-2} dilution blank. This procedure was repeated to create the remaining dilutions. Note that a sterile pipette was used to make each subsequent transfer.

A 1 mL sample will be added to a 9 mL diluent for a 10 mL solution. The dilution factor equals the initial volume divided by the final volume. For example, 1mL/10mL is equal to 1/10. This is a 1:10 dilution. The dilution factor will be done two times; therefore, 1/10 x 1/10 equals 1/100. This is a 1:100 dilution. To calculate the number of CFU/ ml in the original sample, the CFU on a countable plate is multiplied by 1/FDF [14]. For example, each tube's dilution factor was calculated using the formula: the volume of solution divided by the volume of solution times the volume of the diluent.

Total dilution is equal to the current dilution times the previous dilution. Therefore, the total dilution factor used was $10^{-1} \times 10^{-1} \times 10^{-1} \times 10^{-1} \times 10^{-1} = 10^{-5}$. To estimate the number of viable bacteria in an original sample, concentration (CFU/mL or CFU/g) equals the number of colonies times the reciprocal of the dilution counted.

Identification of pathogenic microorganisms.

The colonies were identified based on their colony morphology and biochemical analysis (catalyst test, gram stain test).

2.7 Colony Morphology

Microbial colonies were observed and identified based on their morphological characteristics.

2.8 Gram Stain Test

One drop of distilled water was placed onto a glass slide, and a microbial colony was smeared onto it with a sterile metal loop to create a solution and achieve a thin, visible film. The metal loop was then flamed at an angle until red hot. The glass slide was passed slightly over an open flame to fix the cells in place, after which crystal violet was used to stain the fixed cells for approximately 40 seconds. The excess stain was removed by rinsing with cool water. A solution of gram's iodine was added and retained for 1 minute. The cells were then decolorized by washing with ethanol by adding one drop at a time to the slide tilted at an angle. The excess ethanol was washed off with water, and one to two drops of safranin was added for 1 minute. The glass slide was raised and passed gently, covering the flame to dry off the remaining water. Two drops of oil were added to the slide and viewed under a microscope at magnification 1000 times (Microbiology Resource Center, 2022). The above steps were repeated to identify and categorize the other colonies.

2.9 Biochemical Analysis

A catalase slide test was conducted to identify catalyst-positive colonies. A sterile cotton tip applicator swab was used to transfer a small amount of colony growth onto the surface of a clean, dry glass slide. One drop of 3% hydrogen peroxide was added to the glass slide, and observations of the rise of oxygen bubbles were recorded [15]. This method was repeated for all of the remaining colonies.

3. RESULTS AND DISCUSSION

3.1 Analysis of Findings from the Survey (Questionnaire)

The data collected from the questionnaire was qualitative, entered into an appropriate table on an Excel sheet, and represented on Bar graphs and Pie charts using Microsoft Excel.

3.2 Mobile Phone Usage among Different Age Groups

Fig. 1 shows the number of male and female respondents who participated in the survey. Forty-three percent (43%) of respondents were males, while fifty-seven percent (57%) were females. According to Rowntree [16], twenty percent (20%) of women are less likely than males to own a smartphone in low- and middle-income nations, indicating a considerable gender gap in smartphone ownership. Another study by Chen et al. [17] states that males used mobile smartphones more than females.

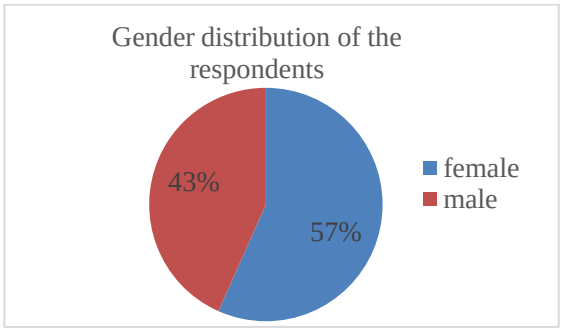


Fig. 1. Shows the gender distribution of the respondents.

Fig. 2 shows that a total of thirty-four percent (34%) of respondents were from the age group 14-19, thirty-three percent (33%) respondents from the age group 20-35, and thirty-three percent (33%) respondents from the age group 36-60.

Fig. 3 shows that a total of eighty-one percent (81%) of respondents had phone cases while nineteen percent (19%) of respondents did not have phone cases.

Fig. 4 shows that six percent (6%) of respondents had keypad mobile phones, while ninety-four percent (94%) had touchscreen mobile phones. According to Gratian [18], physical mobile phone keyboards are no longer widely used.

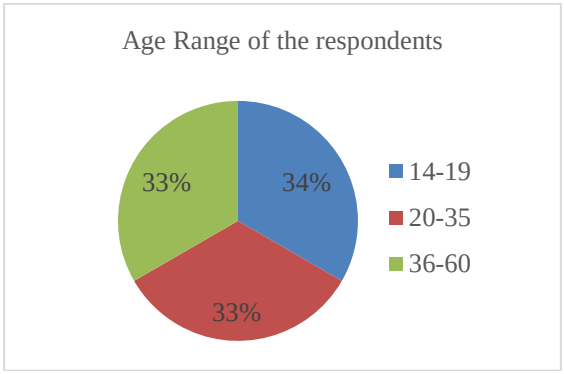


Fig. 2. Shows the age range of respondents.

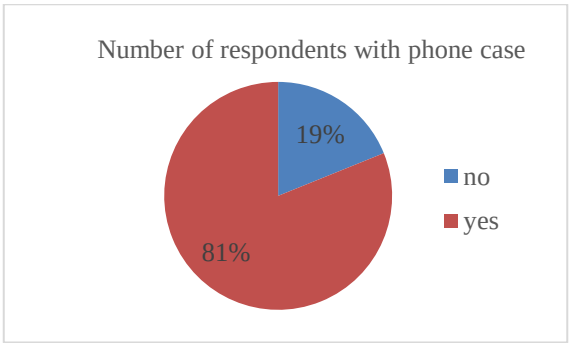


Fig. 3. Shows the number of respondents with phone cases

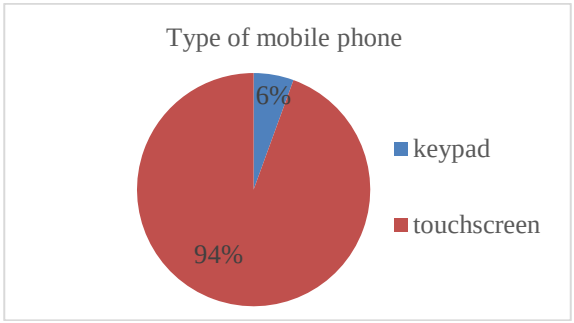


Fig. 4. Shows the type of mobile phone.

Fig. 5 shows the total daily usage time of mobile phones. Forty-one percent (41%) respondents spent 1-5 hours, twenty-six percent (26%) respondents spent 6-10 hours, nine percent (8%) respondents spent less than an hour, and twenty-four percent (24%) respondents spent more than 10 hours on their phones daily. Recent statistics show that the average person uses their phone for 3 hours and 15 minutes daily, while one in every five users spends more than five and a half hours daily on their mobile phone [19].

A Pearson's chi-square test was conducted to determine whether there is a relationship

between respondents' age groups and the frequency of daily usage time. The chi-square value is equal to 15.399; df is equal to NA, and the p-value is equal to 0.01649. The p-value is less than the significance level of 0.05, the null hypothesis that the two variables are independent is rejected, and it can be concluded that there is a relationship between age groups and the frequency of daily usage time. Hence, the two variables are dependent.

3.3 Factors that May Contribute to the Presence of Microbes Found on Mobile Phones

Fig. 6 shows that fifty-nine percent (59%) of respondents use their mobile phones in washrooms, while forty-one percent (41%) of respondents do not use their mobile phones in washrooms. According to Mendoza [20], eighty-eight percent (88%) of users use their smartphones in washrooms.

Fig. 7 shows that the age group 20-35 used their phones in the washroom the most, with thirty-eight percent (38%), followed by age groups 14-19 with thirty-six percent (36) and 36-60 with twenty-six percent, respectively. A study done by Beeton [21] proved that ninety-three percent (93%) of younger adults (ages 18 to 29) acknowledged using their phones while using the restroom.

A Pearson's chi-square test was conducted to test whether there is a relationship between respondents' age groups and washroom mobile phone usage. The chi-square value is equal to 1.1882; df is equal to 2, and the p-value is equal to 0.5521. The p-value is more than the significance level of 0.05, the null hypothesis that the two variables are independent is accepted, and it can be concluded that there is no relationship between age groups and mobile phone usage in washrooms. Hence, the two variables are independent.

Fig. 8 shows that sixty-four percent (64%) of respondents use their mobile phones while eating, and thirty-six percent (36%) of respondents do not use their mobile phones while eating.

Fig. 9 shows age groups 14-18 used their phones while eating the most, with thirty-six percent (36%), followed by age groups 20-35 with thirty-five percent (35%) and 36-60 with twenty-nine percent, respectively.

A Pearson's chi-square test was conducted to test if there is a relationship between respondents' age groups and mobile phone usage while eating. The chi-square value is equal to 1.7862; df is equal to 2, and the p-value is equal to 0.4094. The p-value is more than the significance level of 0.05, the null hypothesis that the two variables are independent is accepted, and it can be concluded that there is no relationship between age groups and mobile phone usage while eating. Hence, the two variables are independent.

Fig. 10 shows that most participants cleaned their mobile phones monthly with thirty percent (30%), followed by weekly with twenty-six percent (26%), daily and never. According to Beeton [21], seventy-five percent (75%) of people admitted to just wiping their phones once a day. In addition, one out of every four people admit they have never even cleaned their smartphones [20].

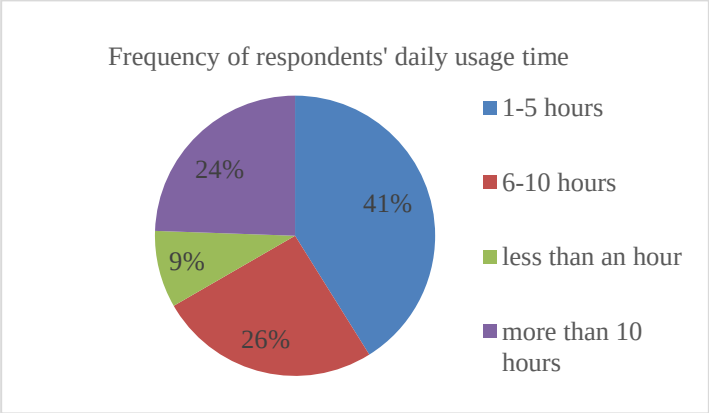


Fig. 5. Shows daily usage time

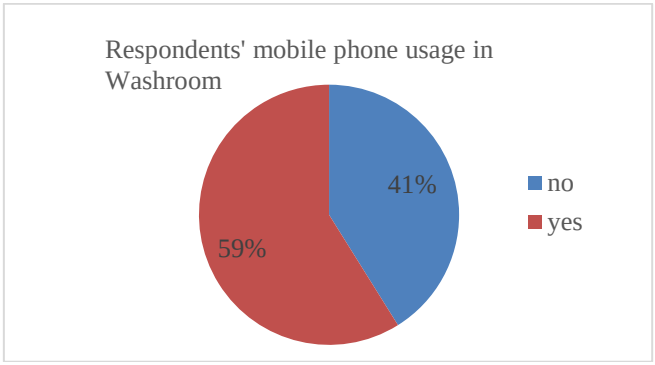


Fig. 6. Shows mobile phone usage in washrooms.

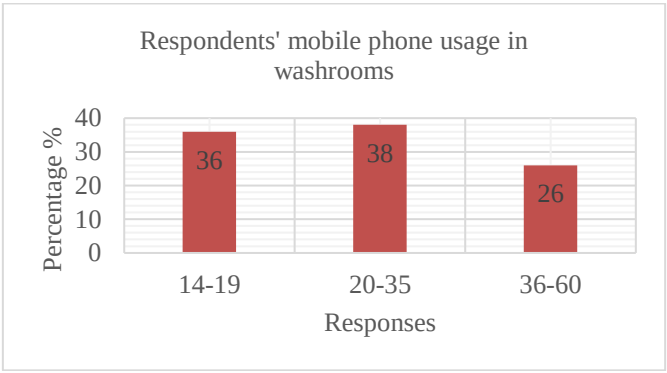


Fig. 7. Shows the use of mobile phones in washrooms per age group.

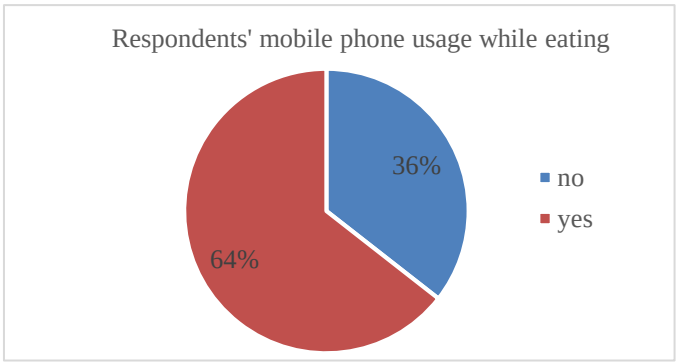


Fig. 8. Shows mobile phone usage while eating

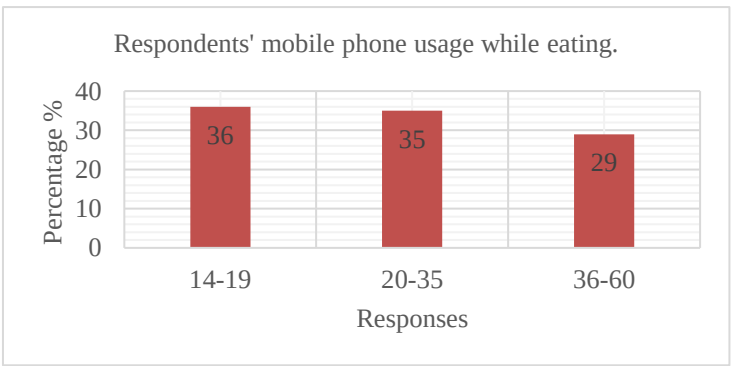


Fig. 9. Shows mobile phone usage while eating per age group.

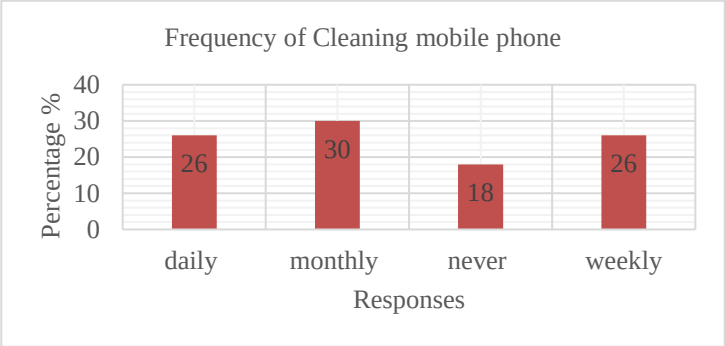


Fig. 10. Shows the frequency of cleaning mobile phones.

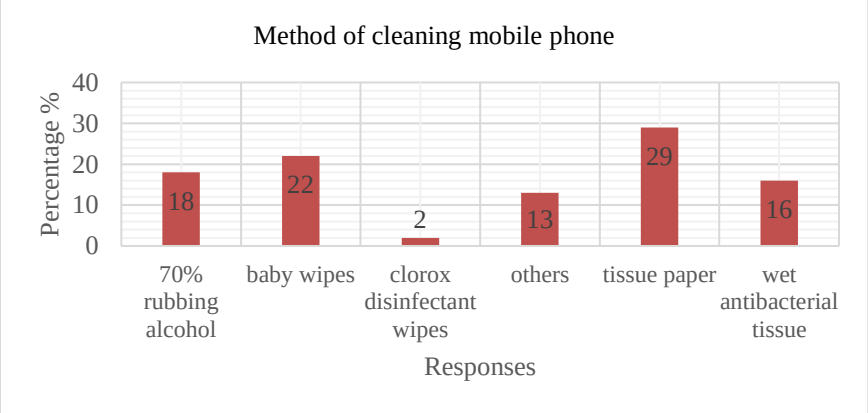


Fig. 11. Shows methods of cleaning mobile phones

A Pearson's chi-square test was conducted to test whether there is a relationship between respondents' age groups and the frequency of mobile phone cleaning. The chi-square value is equal to 7.2667; df is equal to NA, and the p-value is equal to 0.2974. The p-value is more than the significance level of 0.05, the null hypothesis that the two variables are independent is accepted, and it can be concluded that there is no correlation between age groups and the frequency of cleaning mobile phones. Hence, the two variables are independent.

Fig. 11 shows that most respondents used tissue paper to clean their mobile phones, with a total of twenty-nine percent (29%), followed by baby wipes with twenty-two percent (22%), 70% rubbing alcohol with eighteen percent (18%), wet antibacterial tissue with sixteen percent (16%), other methods with fourteen percent (13%) and Clorox disinfectant wipes with two percent (2%).

Fig. 12 shows that two percent (2%) of respondents always allowed others to use their phone, nineteen percent (19%) never allowed others to use their phone, ten percent (10%) often allowed others to use their phone, thirty-seven percent (37%) rarely allowed others to use their phone, and thirty-two percent (32%) sometimes allowed others to use their phone.

A Pearson's chi-square test was conducted to determine whether there is a relationship between age groups and the frequency of others using your phone. The chi-square value is equal to 21.045, df is equal to NA, and the p-value is equal to 0.007996. The p-value is less than the significance level of 0.05, the null hypothesis is rejected, and it can be concluded that there is a correlation between age groups and the frequency of others using your mobile phone. Hence, the two variables are dependent.

Fig. 13 shows that the primary source of transmission was hands with fifty-two percent (52%) of respondents, followed by dust with eighteen percent (18%) of respondents, environment with seventeen percent (17%) of respondents, and contaminated object/material with thirteen percent (13%) respondents. Several studies proved that hands were the primary mode of transmission of microbes from highly touched surfaces, including mobile phones [22,6], Mushabati et al., 2021).

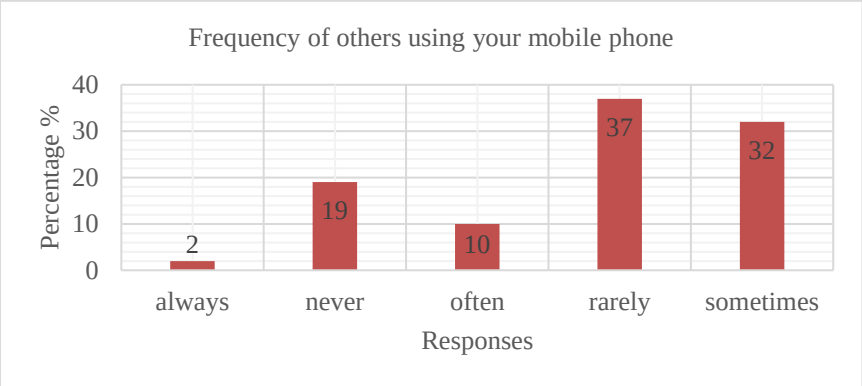


Fig. 12. Shows the frequency of others using your mobile phone

3.4 Data Analysis

The number of microbial colonies present on each petri plate based on their morphological characteristics and biochemical analysis was recorded in the appropriate tables in a Microsoft Excel sheet. However, statistical tests were conducted on the quantitative data to compare the number of colony-forming units (CFU/ml) present on mobile phones before and after using a cleaning agent (70% alcoholic pads) and to rank the mean number of CFU/ml based on the age groups. Further, the statistical tests were conducted using the statistical software R Studio. The Shapiro test was conducted to determine the normality of the data, which determined the following statistical tests.

The effectiveness of 70% alcoholic pads in reducing the concentration of pathogenic microbes found on mobile phones.

Using the Shapiro-Wilk Test, a normality test was done on the number of colonies before and after disinfection. The p-values were 1.153e-07 and 0.002696, respectively. Both values were less than the 0.05 significant level. Therefore, the null hypothesis that it is normally distributed can be rejected. A non-parametric test was used.

3.5 Wilcoxon Signed a Ranked Test

Null hypothesis - The median of the samples is the same at a significant level of 0.05.

Alternative hypothesis - The median of the samples is different at a significance level of 0.05.

Based on the results obtained from a Wilcoxon ranked test, the p-value was 0.008655, less than the significance level alpha = 0.05. Therefore, the median number of CFU/ml on the petri plates before disinfection significantly differed from that of CFU/ml on the petri plates after disinfection. The null hypothesis, which stated that the median of the samples was the same at a significance level of 0.05, was rejected.

Fig. 14 shows that the mobile phone samples were eight one percent (81%) contaminated before and ninety percent (19%) after disinfection.

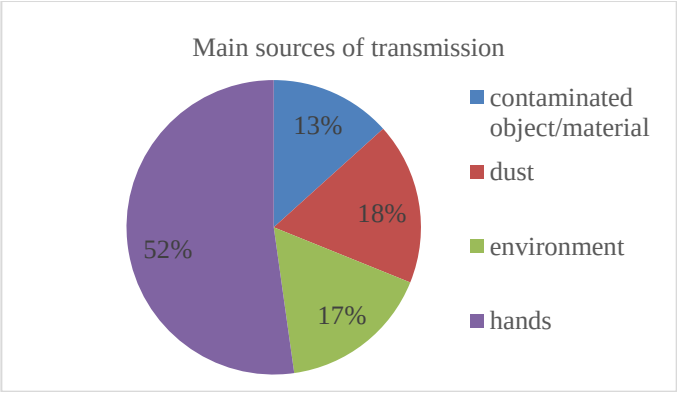


Fig. 13. Shows the primary sources of transmission

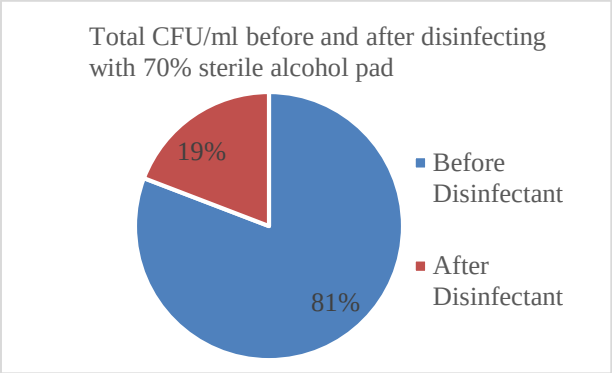


Fig. 14. Shows the total CFU/ml before and after disinfectant.

3.6 The Mean Ranks of the Concentration of Microbes Found on Mobile Phones with Different Age Groups

A Kruskal-Wallis Sum Test (Number of colonies by age groups)

The p-values were 0.2774, 1.935e-06, 0.000343. They were normally distributed and not normally distributed; Kruskal-Wallis test results were used.

Null hypothesis: the mean ranks of the groups are the same.

Alternative hypothesis: the mean ranks of the groups are not the same.

The chi-squared = 17.793, df = 3, p-value = 0.04124. If the p-value is less than 0.05, the null hypothesis is rejected. There is a significant difference between the numbers of colonies found per age group.

Fig. 15 shows that age group 36-60 mobile phones were the most contaminated with fifty percent (50%), followed by age groups 20-35 with forty-three percent (43%) and 14-19 with seven percent (7), respectively. The mean value of contamination was 72.

4. DISCUSSION

The microbial colonies on all the petri plates cultured before and after disinfection were Catalyst-positive. This was indicated by the immediate effervescence (bubble formation) after 3% hydrogen peroxide was added to each colony. Catalyst-positive bacteria demonstrate the presence of an enzyme called catalyst, which breaks down hydrogen peroxide (H_2O_2) and releases oxygen (O_2) and water (H2O) [24].

Identifying catalyst-positive bacteria on mobile phones is essential in understanding the potential health risks associated with these devices. Mobile phones have become an integral part of our daily lives and are frequently handled, accumulating various microorganisms on their surfaces. The catalyst test plays a vital role in identifying bacteria that produce the enzyme catalyst from those that do not. This test helps differentiate between genera, for example, *Aerococcus spp*. and *Campylobacter spp*. Additionally, it differentiates aerobic and obligate anaerobic bacteria and aerotolerant strains of *Clostridium,* which are catalyst-negative, from *Bacillus* species, which are catalyst-positive [24]. Catalyst-positive bacteria are known to be opportunistic pathogens. They can cause various infections, including skin and soft tissue infections, and they have been implicated in hospital-acquired infections, making their identification on mobile phones even more concerning. By identifying catalyst-positive bacteria on mobile phones, healthcare professionals can gain insights into the potential transmission routes of these bacteria and develop strategies to mitigate the risks associated with their presence. Moreover, understanding the prevalence and types of bacteria on mobile phones can also aid in developing effective cleaning and disinfection protocols to reduce the spread of these pathogens. Therefore, identifying catalyst-positive bacteria on mobile phones is crucial in ensuring the safety and well-being of individuals who frequently use these devices [25].

Seven species of pathogenic microbes were observed across all the cultured petri plates. Three types were gram-positive, while the other four types were gram-negative. Gram-negative and Gram-positive bacteria are two major classes of bacteria that differ in their cell wall

structure and composition. Gram-negative bacteria have a thin peptidoglycan cell wall surrounded by an outer lipopolysaccharide membrane. In contrast, Gram-positive bacteria lack an outer membrane but are surrounded by thick layers of peptidoglycan [26]. The color of the gram stain is purple. When the stain is placed on a bacteria sample, it remains purple for a Gram-positive result and changes to pink or red for a Gram-negative result. Gram-negative bacteria, such as *E. coli* and *P. aeruginosa*, cause various infections, including urinary and respiratory tract infections [27]. These bacteria can quickly transfer from contaminated mobile phone surfaces to the hands of users and subsequently to their mucous membranes, leading to the colonization and potential infection of the individual. On the other hand, Gram-positive bacteria, including *S. aureus* and *Streptococcus pyogenes*, are also commonly found on mobile phones and can cause a range of infections, including skin and soft tissue infections [27]. By understanding and differentiating between these bacteria, we can implement effective cleaning and hygiene practices to minimize the risks associated with mobile phone usage. Additionally, this knowledge can aid in developing innovative solutions to combat bacterial contamination in the future. As the use of mobile phones continues to be an integral part of our daily lives, it is crucial to prioritize identifying and managing gram-negative and gram-positive bacteria to ensure a safe and healthy environment for all.

The samples obtained from the older adults in the age group 36-60 had the most significant number of microbial colonies, followed by the younger adults in the age group 20-35 and adolescents in the age group 14-19, respectively. The total number of colonies in older adults was 865, with a mean value of 108; 753 colonies were found for younger adults, with a mean value of 94, and 144 colonies were found for adolescents, with a mean value of 14. The number of bacteria found in each age group did not coincide with the factors that contributed to the presence of microbes found on mobile phones. These factors were using phones in washrooms, using phones while eating, the frequency of others holding your mobile phones, the number of times mobile phones are cleaned, the cleaning method used, and the primary transmission sources [28].

Fifty-nine percent (59%) of respondents used their mobile phones in washrooms. However, the age group 20-35 spent more time using their phones in the washroom, followed by the age group 14-19 and 36-60, respectively. The age group 14-19 spent the most time on their mobile phones when eating, while those aged 36-60 spent the last time. The frequency of mobile phone usage did not determine the number of present microbes. The age group 36-60 spends 1-5 hours the most on their phones daily, the age group 20-35 spends 6-10 hours daily, and the age group 14-19 spends more than 10 hours on their phones daily. Therefore, the older adults spent the last time on their phones while the adolescents spent the most time on them.

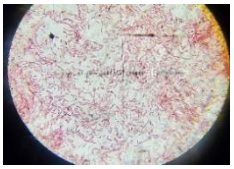
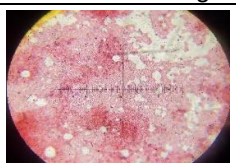
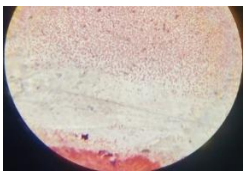
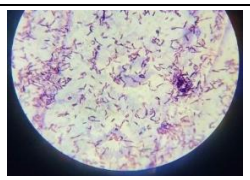
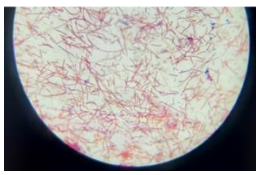
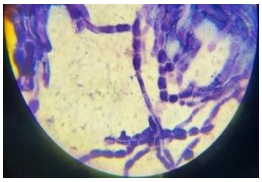
According to the results obtained from this study, the phones used more frequently had a lower bacterial load than phones used more regularly. This finding did not suggest that the more often individuals use their mobile phones, the greater the likelihood of bacterial colonization on the device. Various factors can influence bacterial presence on mobile phones. For instance, the method of cleaning the device effectively and the frequency of cleaning (Qureshi et al., 2020). Mobile phones are constantly exposed to various environments and surfaces, making them susceptible to bacterial contamination. Failure to clean the devices regularly and effectively can contribute to the accumulation of bacteria. Another factor is personal hygiene. Qureshi et al. (2020) suggest that individuals who do not practice good hand hygiene are more likely to transfer bacteria onto their mobile phones. This can occur when people handle their phones after touching contaminated surfaces or without washing their hands.

The survey proved that the primary source of transmission was hands. Fifty-two percent (52%) of respondents selected hands, followed by dust with eighteen percent (18%), environment with seventeen percent (17%), and contaminated object/material with thirteen percent (13%) of respondents. Additionally, the majority of respondents used tissue paper to clean their mobile phones, with a total of twenty-nine percent (29%), followed by baby wipes with twenty-two percent (22%), 70% rubbing alcohol with eighteen percent (18%), wet antibacterial tissue with sixteen percent (16%), other methods with fourteen percent (14%) and Clorox disinfectant wipes with two percent (2%).

Table 1. The summary of morphological characteristics of the microbial colonies found on mobile phones

Species	CFU/mL	Morphological Characteristics of Microbial Colonies						
		Shape	Size	Elevation	Margin	Surface	Opacity	Pigmentation
1	359	Circular	Medium	Flat	Even	Smooth	Translucent	White
2	1011	Circular	Small	Umbonate	Even	Smooth	Opaque	White
3	592	Circular	Small	Convex	Even	Smooth	Opaque	Yellow
4	7	Circular	small	Convex	Even	Smooth	Opaque	Orange
5	11	Circular	Large	Umbonate	Wavy	Rough	Translucent	White
6	45	Filamentous	Large	Raised	Filamentous	Rough	Translucent	White
7	118	Irregular	Medium	Flat	Wavy	Wrinkled	Translucent	White

Table 2. Results obtained from the Morphology, Gram stain and Biochemical (catalase test)

Total No. of CFU/mL.	Description	Gram Stain Test	Catalyst Test	Suspected Bacteria Krieg et al., [23] Magnification 1000X
359	Rod shape	Negative	Positive	 *Pseudomonas aerognosa*
1011	Cocci	Negative	Positive	 *Klebsiella pneumoniae*
592	Cocci	Positive	Positive	 *Staphylococcus aureus*
7	Cocci	Negative	Positive	 *Serratia marcescens*
11	Rod shape	Positive	Positive	 *Bacillus subtilis*
45	Filamentous	Negative	Positive	 *Pseudomonas fluorescens*
118	Rod shape	Positive	Positive	 *Listeria monocytogenes*

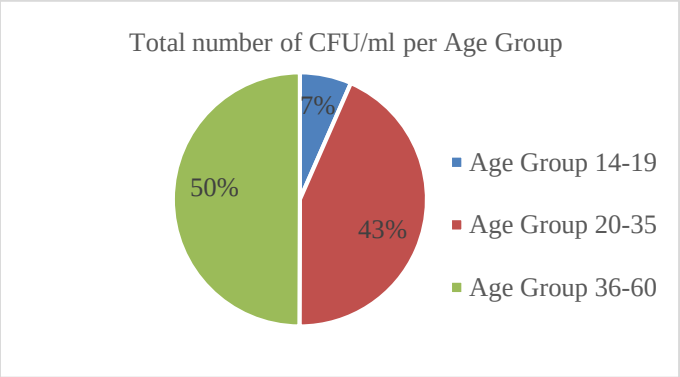


Fig. 15. Shows the total CFU/ml per age group.

Table 3. The effect of using alcohol pads to disinfect mobile phones

Age Group	Samples	Before cleaning with 70% (CFU/ml)	Serial dilution 10^5 (CFU/ml)	After cleaning with 70% (CFU/mL)	Serial dilution 10^5 (CFU/ml)
14-19	Village 1A Sample 1(plate 1)	25	2500000	14	1400000
	Village 1A Sample 1(plate 2)	32	3200000	20	2000000
	Village 1A Sample 2 (plate 1)	12	1200000	9	900000
	Village 1A Sample 2 (plate 2)	9	900000	3	300000
	Village 2D Sample 1(plate 1)	3	300000	1	100000
	Village 2D Sample 1(plate 2)	5	500000	1	100000
	Village 2D Sample 2 (plate 1)	18	1800000	1	100000
	Village 2D Sample 2 (plate 2)	10	1000000	10	1000000
	Total Number of CFU/ml	114	11400000	59	5900000
	Mean value of CFU/ml	14	1425000	7	737500
20-35	Village 1B Sample 1(plate 1)	77	7700000	26	2600000
	Village 1B Sample 1(plate 2)	564	56400000	21	2100000
	Village 1B Sample 2 (plate 1)	22	2200000	20	2000000
	Village 1B Sample 2 (plate 2)	20	2000000	20	2000000
	Village 2E Sample 1(plate 1)	7	700000	7	700000
	Village 2E Sample 1(plate 2)	11	1100000	3	300000
	Village 2E Sample 2 (plate 1)	20	2000000	38	3800000
	Village 2E Sample 2	32	3200000	43	4300000

Age Group	Samples	Before cleaning with 70% (CFU/ml)	Serial dilution 10^5 (CFU/ml)	After cleaning with 70% (CFU/mL)	Serial dilution 10^5 (CFU/ml)
	(plate 2)				
	Total Number of CFU/ml	753	75300000	178	17800000
	Mean value of CFU/ml	94	9412500	22	2225000
36-60	Village 1C Sample 1(plate 1)	57	5700000	12	1200000
	Village 1C Sample 1(plate 2)	15	1500000	18	1800000
	Village 1C Sample 2 (plate 1)	24	2400000	36	3600000
	Village 1C Sample 2 (plate 2)	99	9900000	65	6500000
	Village 2F Sample 1(plate 1)	310	31000000	11	1100000
	Village 2F Sample 1(plate 2)	317	31700000	15	1500000
	Village 2F Sample 2 (plate 1)	26	2600000	9	900000
	Village 2F Sample 2 (plate 2)	17	1700000	8	800000
	Total Number of CFU/ml	865	86500000	174	17400000
	Mean value of CFU/ml	108	7325000	22	2175000
Overall Total number of CFU/ml		1732	173200000	411	41100000
Overall Total mean value of CFU/ml		72	6054167	17	1787500

The total number of colonies (CFU/ml) that were present on the petri plates before disinfection was 1732, with a mean value of 72, while the average total number of colonies (CFU/ml) that were present on the petri plates after disinfection with 70% alcoholic pad was 411 with a mean value of 17. This proved that the total number of colonies present before disinfection reduced significantly by 1321 colonies (76%) after disinfection.

5. CONCLUSION

Based on the findings from this study, 100% of mobile phone samples collected were contaminated with at least two pathogenic microbes. The number of microbes on users' mobile phones within three different age groups was significantly different. Age group 36-60 had the most microbes, followed by age groups 20-35 and 14-19, respectively. The frequency of usage did not determine the number of microbes on mobile phones. Moreover, there was a 76% effectiveness of a simple disinfection method using 70% alcohol pads to reduce microbial contamination of mobile phones.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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