Introduction. It is recognized that mobile phones may play a role in microorganism transmission and that hand hygiene, is considered the most important action for preventing infections and the spread of pathogens. The objective of this study was to determine presence and circulation bacteria on hands and mobile phones capable of causing infections in people and also determine if disinfection with gel-alcohol is useful to reduce the bacterial colonization.

Methods. The bacterial evaluation included 596 hands of participants and 256 mobile phones. Isolated colonies were identified by biochemical test and confirmed by gene 16S rRNA sequencing. Antimicrobial susceptibility was performed using the automated instrument Vitek®2-Compact and disk-diffusion-method.

Results. In total, 92.9% of mobile phones and 98.3% of participants in study demonstrated evidence of bacterial contamination with different types of bacteria. Surprisingly, we observed that 18.6% plaques inoculated with disinfected fingers showed bacterial growth. In general, Gram negative isolates showed resistance to a higher number of antibiotics tested than Gram positive isolates.

Conclusions. Our results could help to raise awareness in our society about the importance of hand hygiene, as well as frequently used devices, reducing bacterial contamination and limiting the possibility of transmission of resistant multi-drug bacteria.
The fingers (two group: with or without disinfection) were supported onto plates for 5-7 seconds. Plates were incubated aerobically at 37°C for 48 h. Bacteria recovered from all plate were pooled and frozen in 20% medium glycerol.

**Bacterial Identification and Antibiotic Susceptibility**

Colonies obtained in each processed plate were screened by their resistances, using broad spectrum antibiotics-10 μg ampicillin, 4 μg gentamicin and 5 μg chloramphenicol (Britania SA, Argentina) placed separately on Muller–Hinton agar plates and incubated aerobically at 37°C for 18 hours. The number of colony forming units (CFU) for the sample pool was estimated by plaque count. Isolated microorganisms were identified using Gram stain, colony morphology, standard biochemical tests and confirmed by the automated ID/AST instrument Vitek® 2 Compact (Biomérieux) both Gram positive (GP ID card) and Gram negative (GN ID card) cards (Biomérieux, France) were used. Minimal inhibitory concentration (MIC) was performed using the automated ID/AST instrument Vitek® 2 Compact (Biomérieux) and the Gram positive and Gram negative susceptibility test cards (AST-P577; AST-N117; Biomérieux, France). Diffusion method according to Kirby-Bauer was used for the antibiotics aztreonam, minocycline and levofloxacin. The breakpoints were interpreted following CLSI guidelines [7].

**DNA Extraction, Amplification and Sequencing**

Culture of each isolate was suspended in sarcosil (0.01%) and DNA extracted using a combination of heating and centrifuged. Universal 16S rRNA bacterial (0.01%) and DNA extracted using a combination of sarcosil and sequencing using primers 27F and 1492R [8].

**Results**

Five hundred thirty-one (98.3%) out of 538 volunteers in study had hands contaminated with bacteria. Also, 238 (92.9%) out of 256 cell phones of volunteers were contaminated with bacteria. Surprisingly, we observed that 18.6% of the 38 plaques inoculated with disinfected fingers showed bacterial growth. Filamentous fungi were observed in 3% of the plates. Twenty one different appearance colonies were recovered on plates with antibiotic. The organisms identified with 96-100% probability belonged to seven species of Gram positive bacteria (Bacillus subtilis, B. pumilus, Lysinibacillus sphaericus, Staphylococcus cohnii spp aureus, S. warneri, S. saprophyticus and Enterococcus durans) and seven species of Gram negative bacteria (Serratia marcescens, Pseudomonas putida, Sphingomonas paucimobilis, Acinetobacter baumannii complex, Stenotrophomonas maltophilia, Klebsiella pneumoniae spp pneumoniae, and Ochrobactrum anthropi).

Results of antibiotic resistance of Gram positive and Gram negative bacterial isolates are listed in Table I (Antibiotic susceptibility results for all tested antibiotics are shown in supplementary data Table SI and Table SII, respectively). A strain S. cohnii was resistant to ERI and intermediate to NIT. S. warneri was resistant to ERI and GEN. S. saprophyticus resistant to OXA, ERI, GEN and STX, plus positive cefoxitin screen. E. durans was resistant and intermediate to SXT and NIT, respectively. Bacillus sp evidenced intermediate resistance to CLI. In general, Gram negative bacteria exhibit increased resistance to antibiotics. P. putida strains were resistant to AMP, SAM, CTX, NAL, NIT, SXT and intermediate to TZP. S. marcescens strains were resistant to AMP, SAM, CF, COL and NIT. S. paucimobilis was resistant to NAL, GEN and NIT. A. baumannii complex was resistant to AMP, CTX, NIT. S. maltophilia was resistant to GEN, IPM and AZT. K. pneumonia was resistant only to AMP. O. anthropi was resistant to AMP, SAM, NAL, NIT and SXT and intermediate to TZP and CTX. All the observed resistances respond to natural mechanisms of resistance.

**Discussion**

Our study – first of its kind in our region – carried out with aimed to determine presence and circulation of antibiotic-resistant bacteria on mobile phone and hands of healthy people. The most organisms recovered, do not typically cause infections in healthy people rather they have been known to cause significant infections in those with depressed immune systems, including those infected with HIV, patients undergoing cancer chemotherapy, or taking other medications that depress the immune system (transplanted) [9, 10]. However, other belong to species that have been protagonist in both nosocomial and community acquired infections [11, 12].

In recent years, dozens of publications report the presence of microorganisms on money, coins and mobile phones. While the studies can vary, due to the methods used, local community flora, environmental conditions, including the socio-cultural levels of the population, in general, Gram positive bacteria were the most predominant [13]. Staphylococci found in the mucous membranes and normal skin flora has recently got attention as a potential pathogen, specifically for hospital infections where are a major cause of septicemia and bacteremia, especially for the patients who have immune deficiency. Locally, Staphylococcus aureus (MRSA) emerged at the Pediatric Hospital, in 2003 as a cause of community-acquired (CA) infections [14]. In several studies, high resistance ratios against erythromycin, gentamicin and trimethoprim-sulphonamethoxazole, which is an alternative medicine in the treatment of methicillin-resistant staphylococci infections were reported [15]. Some species of genus Enterococcus have currently a particular medical significance, considering their notable ability of acquire and disseminate antimicrobial resistance de-
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-β-lactamase [23]. β-expression of an AmpC SMEA
naturally resistant to aminoglycosides, tetracycline, and quinolones due to the high level of expression of smeA

| Species - isolated | OXA | GEN | ERI | NIT | SXT | AMP | SAM | TZP | CF | CTX | CAZ | CEF | IPM | MEM | NAL | COL | AZT |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| S. cohnii N132    |     | 8   |     |     | 64* |     |     |     |     |     |     |     |     |     |     |     |     |
| S. warneri G62    | 4   | 8   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| S. saprophyticus N4 | ≥ 4 | 8   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| S. saprophyticus N3 | ≥ 4 | ≥ 320 | ≥ 32 | ≥ 32 | 32* | 16 |     |     |     |     |     |     |     |     |     |
| E. durans G152    | 64* | 10  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| E. durans G153    | 64* | 10  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| S. paucimobilis G61 | ≥ 16 | 256 | ≥ 32 | ≥ 16 |     |     |     |     |     |     |     |     |     |     |     |
| P. putida Ch7     | ≥ 512 | 80 | ≥ 32 | ≥ 32 | 32* | 16 |     |     |     |     |     |     |     |     |     |
| P. putida Ch8     | ≥ 512 | 80 | ≥ 32 | ≥ 32 | 32* | 16 |     |     |     |     |     |     |     |     |     |
| A. baumannii Ch16 | 512 | 16  | 8   |     |     |     |     |     |     |     |     |     |     |     |     |
| A. baumannii A108 | 256 | ≥ 32 | 4   | 8   | 16 |     |     |     |     |     |     |     |     |     |     |
| S. marcescens M2  | 256 | ≥ 32 | 16 | ≥ 64 |     |     |     |     |     |     |     |     |     |     |     |
| S. marcescens A12 | 256 | ≥ 32 | 16 | ≥ 64 |     |     |     |     |     |     |     |     |     |     |     |
| S. maltophilia G151 | ≥ 16 |     | ≥ 16 | ≥ 16 |     |     |     |     |     |     |     |     |     |     |
| K. pneumoniae M11 | 2   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| O. anthropi N13   | 256 | ≥ 32 | ≥ 32 | ≥ 128* | ≥ 64* | ≥ 64 | ≥ 64 |     |     |     |     |     |     |     |

OXA, oxolin; GEN, gentamicin; ERI, erythromycin; NIT, nitrofurantoin; SXT, trimethoprim/sulfamethoxazole; AMP, ampicillin; SAM, Ampicillin/Sulbactam; TZP, Piperacillin/Tazobactam; CF, cefalotin; CTX, cefotaxime; CAZ, ceftazidime; CEF, cefepime; IPM, imipenem; MEM, meropenem; NAL, nalidic acid; COL, colistin; AZT, azteronam. (-) no tested; * Intermed according to CLSI [7].

Tab. I. Minimum inhibitory concentration in bacteria antibiotic resistant recovered in this study.

-β-lactamases which is consistent with the reported expression of two β-lactamases that hydrolyzes all β-lactams with the exception of aztreonam [24]. Species of Acinetobacter exhibit mechanisms of resistance to all existing antibiotic classes as well as a prodigious capacity to acquire new determinants of resistance [12]. P. putida is usually susceptible to fluoroquinolones, aminoglycosides, monobactams, and extended-spectrum cephalosporins. However, acquisition metallo- β-lactamases that confer resistance to most β-lactams, including carbapenems, have been reported [25]. Our results revealed permanent colonization of bacteria on the mobile phones, which are very close to the hand of users. For this fact, contaminated phones can play a potential role in the spread of drug-resistant bacteria into the community. Food manipulators have been implicated in various outbreaks of food-borne diseases and human occupational activities could introduce the risk of food contamination. Food manipulators (workers) can be infected by pathogens from multiple sources and them in turn become potential sources of contamination in food processing and preparation facilities [26]. Equally important is way as parents tend to use their mobile phones at the bedside to communicate while touching, change diapers or holding their baby, increasing the risk of transmission [27].

Disinfection with gel-alcohol was effective in reducing bacterial colonization [4], however, it does not ensure complete disinfection, according to our results. We speculate the more likely explanation is related to the...
inadequate application of gel-alcohol. Developing active preventive strategies like routine decontamination of mobile phones with gel-alcohol containing disinfectant materials might reduce cross-infection. Another way of reducing bacterial contaminations on mobile phones might be the use of antimicrobial additive materials, today available for medical applications [28]. We could easily avoid dispersion of bacterial infections just by using regular cleaning agents, such as gel-alcohol and rearranging our habits. This could include educating to children in schools and parents on the risk that a contaminated mobile phone poses for their baby, mobile phone hygiene and proper hand antimicrobial-gel application before and after mobile phone usage at the baby’s bedside [27]. In the future mobile phones and devices could be produced by using protective material against the microbial contamination [29].

This activity was novel, Tecnopolis exhibition gave us the opportunity to interact with the community – especially students of initial and middle school levels to show the microscopic world we carry with itself. Highlighted the occurrence of pathogens bacteria on objects outside the health care environment in order to and raise awareness people on the necessity of improving the habit of washing their hands and employ appropriate disinfection methods to tactile electronic device in order to reduce microbial transmission. However, study presents some limitations. First of all we conducted a descriptive analysis, during an optional intervention, of sample obtained from non-probabilistic sampling thus no generalization of the results can be proposed. Questions to participants regarding the level of knowledge about microorganisms were not properly registered. Furthermore, the design not explore socio-demographic characteristics of the study sample. In future research, these variables should be considered for a more complete analysis of the thematic which allows identifying the determinants of health acting in hand washing adherence of the community to a more effectiveness intervention on specific population groups.

Conclusion

The present study shows that the mobile phones and hands of people even without symptoms of disease harbored a variety of pathogenic organisms with resistance to some of the therapeutic antibiotics used which can cause serious diseases. Our results could help to raise awareness in our society about the importance of hand hygiene and frequently used devices, decreasing bacterial contamination and limiting the transmission of pathogens.

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Conflict of interest statement

The authors declare no conflict of interest.

Authors’ contributions

PFM and JF designed and coordinated the design and data acquisition. CKC, PFM and JF collected, analyzed and interpreted the results. MM and MVS were responsible for the microbiology analysis. PFM and MM drafted the manuscript. All authors read and approved the manuscript.

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Tab. SI. Determination of minimal inhibition concentration in Gram positive bacteria recovered in this study.

| Antibiotic                  | S. cohnii N132 | S. cohnii N13M | S. warneri G62 | S. saprophyticus N3 | S. saprophyticus N4 | E. durans G152 | E. durans G153 | B. pumilus A10 | B. subtilis A9 | L. sphaericus Ci14 | L. sphaericus Ci5 |
|-----------------------------|----------------|----------------|----------------|---------------------|---------------------|----------------|----------------|----------------|----------------|----------------------|----------------------|
| Oxacillin                   | 0.5 S          | 0.5 S          | 0.25 S         | 4 R                 | 4 R                 | 2 S            | 2 S            | -              | -              | -                    | -                    |
| Gentamicin                  | 0.5 S          | 0.5 S          | 4 R            | 0.5 S               | 0.5 S               | -              | -              | -              | -              | -                    | -                    |
| Ciprofloxacin               | 0.5 S          | 0.5 S          | 0.5 S          | 0.5 S               | 0.5 S               | -              | -              | -              | -              | -                    | -                    |
| Levofloxacin                | 1 S            | 0.5 S          | 0.12 S         | 0.5 S               | 1 S                 | 0.5 S          | 0.5 S          | 0.5 S          | 0.5 S          | 0.5 S                | 0.5 S                |
| Moxifloxacin                | 0.25 S         | 0.25 S         | 0.25 S         | 0.25 S              | 0.25 S              | 0.5 S          | 0.5 S          | -              | -              | -                    | -                    |
| Erythromycin                | ≥ 8 R          | 0.5 S          | 8 R            | 0.5 S               | 8 R                 | 0.25 S         | 0.25 S         | -              | -              | -                    | -                    |
| Clindamycin                 | 0.25 S         | 0.25 S         | 0.25 S         | 0.25 S              | 0.25 S              | -              | -              | -              | 2 I            | 1 I                  | 0.5 S                |
| Quinupristin/ Dalfopristin  | 1 S            | 0.5 S          | 0.5 S          | 1 S                 | 0.5 S               | 1 S            | 1 S            | -              | -              | -                    | -                    |
| Linezolid                   | 4 S            | 2 S            | 2 S            | 4 S                 | 4 S                 | 2 S            | 2 S            | -              | -              | -                    | -                    |
| Telopenaxin                 | 4 S            | 4 S            | 0.5 S          | 4 S                 | 0.5 S               | 0.5 S          | 0.5 S          | -              | -              | -                    | -                    |
| Vancomycin                  | 1 S            | 1 S            | 1 S            | 1 S                 | 1 S                 | 0.5 S          | 0.5 S          | 0.5 S          | 0.5 S          | 0.25 S               | 0.25 S               |
| Minocycline                 | 0.5 S          | 0.5 S          | 0.5 S          | 0.5 S               | 0.5 S               | 0.5 S          | 0.5 S          | -              | -              | -                    | -                    |
| Tetracycline                | 2 S            | 1 S            | 1 S            | 1 S                 | 1 S                 | 1 S            | 1 S            | -              | -              | -                    | -                    |
| Nitrofurantoin              | 64 I           | 32 S           | 16 S           | 16 S                | 16 S                | 64 I           | 64 I           | -              | -              | -                    | -                    |
| Rifampicin                  | 0.5 S          | 0.5 S          | 0.5 S          | 0.5 S               | 0.5 S               | -              | -              | -              | -              | -                    | -                    |
| Trimethoprim/ Sulfamethoxazole | 10 S       | 10 S           | 10 S           | 320 R               | 10 S                | 10 R           | 10 R           | -              | -              | -                    | -                    |

(-) no tested. S, sensible. I, intermed. R, resistant according to CLSI [7].
Tab. SII. Determination of minimal inhibition concentration in Gram negative bacteria recovered in this study.

| Antibiotic          | S. paucimobilis G61 | P. putida Ch7 | P. putida Ch8 | A. baumannii Ch16 | A. baumannii A10B | S. marcescens M2 | S. marcescens A12 | S. maltophilia G151 | K. pneumoniae M11 | O. anthropi N13 |
|---------------------|---------------------|----------------|----------------|-------------------|-------------------|-----------------|-----------------|-------------------|-------------------|-----------------|
| Ampicillin          | 2                   | S              | ≥ 32           | R                 | 16                | R               | 32              | R                 | -                 | 2               |
| Ampicillin/Sulbactam| 2                   | S              | ≥ 32           | R                 | 2                 | S               | 16              | R                 | -                 | 2               |
| Piperaclillin/Tazobactam | 4           | S              | 32             | I                 | 4                 | S               | 4               | S                 | -                 | 4               |
| Cefalotin           |                    |                |                |                   |                   | 64              | R               | 64                | -                 | 2               |
| Cefotaxime          | 1                   | S              | 16             | R                 | 8                 | R               | 8               | R                 | 1                 | -               |
| Ceftriaxime         | 4                   | S              | 4              | S                 | 4                 | S               | 1               | S                 | 1                 | 4               |
| Cefepime            | 4                   | S              | 1              | S                 | 2                 | S               | 1               | S                 | 1                 | -               |
| Imipenem            | 1                   | S              | 1              | S                 | 0.25              | S               | 0.25            | S                 | 0.5               | R               |
| Meropenem           | 4                   | S              | 1              | S                 | 0.25              | S               | 0.25            | S                 | 0.25              | R               |
| Amikacin            | 2                   | S              | 2              | S                 | 2                 | S               | 2               | S                 | 2                 | -               |
| Gentamicin          | 16                  | R              | 1              | S                 | 1                 | S               | 1               | S                 | ≥ 16              | R               |
| Nalidixic acid      | 32                  | R              | ≥ 32           | R                 | 2                 | S               | 2               | S                 | 2                 | -               |
| Ciprofloxacin       | 1                   | S              | 0.25           | S                 | 0.25              | S               | 0.25            | S                 | 0.25              | -               |
| Nitrofurantoin      | 256                 | R              | 5               | 12                | R                 | 5               | 12              | R                 | 256               | -               |
| Colistin            | -                   | -              | 0.5            | S                 | 0.5               | S               | 0.5             | S                 | 16                | R               |
| Trimethoprim/Sulfamethoxazole | -     | -              | 0.5            | S                 | 0.25              | S               | 0.5             | S                 | 16                | R               |
| Levofloxacin        | -                   | -              | -              | -                 | -                 | -               | -               | -                 | 2                 | S               |
| Minocycline         | -                   | -              | -              | -                 | -                 | -               | -               | -                 | -                 | 2               |
| Aztreonam           | ≥ 16                 | R              | -              | -                 | -                 | -               | -               | -                 | -                 | ≥ 32           |

(-) no tested; ( ) no detected. S, sensitive; I, intermed. R, resistant according to CLSI [7].