Are Computers Affecting Your Health?

A study of the extent of sickness attributable to bacteria found on personal computers.

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by

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Abstract

This study is intended to examine possible correlations between bacterial concentrations obtained by sampling personal computer keyboards and assessing the overall wellbeing of participants. The objective is to detect changes in bacterial concentration by use of an aerosol sterilizer and correlate these concentrations with a health score obtained from daily surveys filled out by the participant. This research evaluates two hypotheses—the first deals with changes in overall estimated bacterial concentration between the groups, and the second deals with a correlation between the estimated concentrations and health score. Peer-Reviewed scientific literature has shown that many surfaces can act as fomites and transfer bacteria from object to object, person to person, or object to person. Pathogenic bacteria can be transferred onto these objects and may cause disease when people are infected. A blinded cross-over study using aerosol sterilizer and a placebo cleaner was conducted to test if computer users are healthier when their computers have fewer bacteria. This study showed no statistical evidence to support that cleaning a personal computer has any affect on the health of the user. However, this study only analyzed personal computers; other public fomites may play a more important role in the transfer of pathogenic microorganisms.

Introduction

Everyday unsuspecting people come into contact with numerous fomites. Microorganisms are picked up and transferred from fomite to fomite. Fomites are any object or surface that can be contaminated and act as a reservoir of microorganisms and play a part in the transfer of bacteria[2]. Fomites have been studied for decades as scientists discover new means of bacteria transfer from object to object. When pathogenic microorganisms are transferred into one of the orifices of the body in high enough quantities, they can cause disease. People are constantly touching objects and most the time are unaware of the potential dangers. Without thinking, hands are brought to the face, microorganisms are transferred, and risk of infection increases. Researchers find themselves questioning, what is on the computers people constantly touch without a second thought?

The spread of disease is a popular topic of research, and experiments to determine the vector for transmission are high priority. All people appreciate knowing more about how sickness is spread in order to avoid getting sick. In addition, the health field is interested in preventing sickness and stopping the spread of disease. From determining what caused the Black Plague to analyzing the spread of Norovirus[1], almost every new sickness or disease has been studied in hopes of finding the transmission pathway and preventing the spread of each disease.

Fomites such as writing pens and even paper at hospitals have been analyzed and shown to contain viable microorganisms for hours and sometimes even days[1,3-7]. The amount of time the microorganism is viable depends on the type of surface and the strain of bacteria or virus. Those microbes that have been studied and associated with fomites include rhinoviruses, *E. coli*,

staphylococcal infections, *Giardia*, influenza virus, *Neisseria meningitidis*, *Rotavirus*, MRSA, Norovirus, etc. [1, 5-6 , 8-12]. Surfaces can contain *Staphyloccocus* microorganisms, such as MRSA[9], up to 11 days[5] after initial contamination. Norovirus can be present and viable for up to 3-4 weeks[1]. Many viruses that cause gastrointestinal outbreaks can be present on computer keyboards or mice for 1-2 days[6]. Bacteria found on pens used by doctors were viable for hours[3].

In recent studies, researchers analyzed the transfer of bacteria when it comes to computers [3,5,11]. These studies are of interest to most civilians as well as people in the health profession. Almost all Americans use some form of computer everyday between smart phones, tablets, and laptops.

Also while attending college, students are in close quarters with other students and faculty. Rates of direct and indirect contact are increased dramatically in these sorts of settings[11], the same as in hospitals and doctors' offices[3, 5]. With 1600 students on the Spring Arbor University campus, if one student or faculty member gets sick, it is easy to spread that pathogenic microorganism on to numerous people in a relatively short amount of time[1,6] due to the length of viability and transfer of microorganisms from fomites. On a college campus, the majority of students use the library computers, as well as their personal computers. These public computers can transmit microorganisms from person to person. With the switch to electronic records, hospital personnel share computers in order to document patients' charts. In both these situations, computers (touch screens, keyboards, and mice) can act as reservoirs for microbial growth and facilitate the spread of infection and disease [8,9].

Review of Literature

Numerous experiments have dealt with the transfer of bacteria from an object to a person and the effects it has on humans. Different experiments have identified reservoirs of MRSA in public schools, and analyzed different fomites, such as the pens of doctors and public computers, and the transfer of microorganism from them to people.

Bacterial colonization on doctors' pens. One interesting experiment examined bacterial colonization on writing pens; these pens were touched by healthcare professionals, and hospitalized patients with and without cleaning the pen with alcohol-based hand sanitizing agent[3]. This study found that the microorganisms on pens are commonly carried for several days without the thought of sanitation[3]. Pens are a potential source of transmission of healthcare-associated pathogens, this is important when dealing with hospital infection control practices like antibiotic-associated diarrhea[3]. These pens are reservoir for fomites because every patient that a doctor comes into contact with has the potential of carrying a different microorganism that has the ability to attach to the fomite[10].

There were three groups of participants, along with control pens: one did not clean their pen at all, one was given a new pen every day, and the last group had to sanitize their pen between each patient[3]. At the conclusion of each day the pens were collected and sent to the lab to be placed in nutrient broth media and then sonicated[3]. Sonication is a specially designed ultrasound bath that uses low frequency and low intensity ultrasound at the threshold of microbubble formation[13]. After microbubble formation, the sonicator amplitude was reduced to a level where no significant cell destruction occurs in order to dislodge the microorganisms from the pen without destroying them.[13] Following sonication 0.5 mL aliquots were placed onto agar plates and were incubated for 48-72 hours[3]. Tests that were done to identify the pathogens were colony morphology, gram staining, motility and biochemical characteristics[3, 14]. Later, the

Fisher's exact test was used to compare the specific organisms in the control and intervention groups[3]. The Fisher extract is a test that is used when two members of two independent groups can be placed into one of two mutually exclusive categories[15]. There was an average of 370 colony forming units; the most commonly found bacteria on the intervention group were skin particles, presumptively *Micrococcus* species, and there were no Gram-negative bacilli identified in either the non-intervention and intervention groups[3].

By wiping down the pens with sanitizer it greatly decreased the number of viable growth on the pens and reduced the amount of Gram-positive cocci for both *Staphylococcus* and *Enterococcus* species[3]. Based on these findings it is important that we are intentional about cleaning equipment after patient contact with alcohol-based sanitizing agents[3]. The results of this experiment inform us that a non-intervention pen, otherwise known as pens that were not wiped down with alcohol-based sanitizer, resulted in 12 out of the 13 pens having growth on them[3]. Intervention pens, referring to those swabbed with alcohol-based sanitizer only resulted in 4 out of the 10 pens contained growth[3]. The following table shows the amount of bacterial growth on both pens in the non-intervention and intervention study groups[3].

	Non-intervention	Intervention	p-value
Total pens with growth	12/13	4/10	0.019
Medium colony forming units/plate	370	130	0.090
Pens with catalase-positive Gram-positive cocci in irregular clusters (presumptively staphylococci)	5/13	0/10	0.046
Pens with catalase-negative cocci in short chain (presumptively enterococci)	5/13	0/10	0.046
Pens with catalase-positive cocci in quarters or octets (presumptively micrococci)	8/13	3/10	0.214

Pens with oxidase-negative, non-motile, Gram-negative cocco bacilli organisms (presumptively acinetobacters)	4/13	1/10	0.339
Pens with yeast (presumptively *Candida* spp)	3/13	1/10	0.604
Pens with aerobic spore bearers (airborn contaminants)	1/13	1/10	1.000

This table of bacteriological profile shows that pens used in non-intervention and intervention groups of the study breaks down the microbial organisms found on each sample, along with what environment they were exposed to[3]. This experiment is just one example of how bacteria can be transferred for one person to another, and how it can affect our health without even consciously realizing.

MRSA studies of secondary and post secondary schools. Methicillin-resistant *Staphylococcus aureus*[9] research is of high importance to the medical field due to the health threat of these outbreaks within the community. Studies have been done to identify reservoirs of MRSA and one such study identified the prevalence of MRSA on computers located in secondary and postsecondary schools[9]. This study analyzed specimens taken from high-traffic and low-traffic computers in a university and two high schools[9].

These computers were randomly swabbed wiping over the entire keyboard with sterile cotton-tipped swabs that were wet with sterile phosphate buffered saline[9]. The cotton swab was then cut to fit into a test tube containing tryptic soy broth (TSB) and allowed to incubate with agitation overnight in a 37ºC incubator[9]. The tubes were then sub-cultured onto mannitol salt agar medium to isolate species of *Staphylococcus* which were incubated for 48 hours in a 37 ºC incubator[9]. Some of the TSB (100 µL) was inoculated into new TSB tubes made with oxacillin[9] and incubated with agitation overnight. These oxacillin TSB inoculated tubes were then plated

onto mannitol salt agar medium[9]. Colonies on these plates that had the morphology of *Staphylococcus areus* were analyzed using gram staining, catalase tests, and coagulase tests[14], and then positive isolates were then plated onto MRSA select medium and oxacillin screen agar medium[9]. Any isolates that grew on these media were sent into a disease control laboratory for identification[9].

The colonies of *Staphylococcus aureus* that grew on the plates were analyzed and the three schools were compared[9]. Each school showed different levels of contamination. The following chart from the published study displays this[9]:

Location	Growth on Tryptic Soy Agar	Growth in Tryptic Soy Agar Oxacillin	Coagulase Positive
Low Traffic University Computers	70 (100%)	29 (56%)	9 (13%)
High Traffic University Computers	77 (100%)	17 (61%)	17 (22%)
High School #1	50 (100%)	50 (100%)	32 (60%)
High School #2	71 (100%)	66 (92%)	27 (38%)

As shown above, the random sampling taken from the high school had higher percentages of *Staphylococcus aureus* than the random samples taken from the university setting[9]. The counts of oxacillin-resistant bacteria were found to be relatively high for both the high school and the

university[9]. Two strains of MRSA were isolated and identified during this procedure. One was found in high school #1 and one from a high traffic university computer[9].

This study showed the degree of contamination of *Staphylococcus aureus* and discovered two reservoirs of MRSA on school library computers[9]. Many studies have recognized that computer keyboards can be important vectors in the transmittance of MRSA, rather than the direct skin to skin contact that is believed to be the main mode of transmission[9]. Before this study, most of the studies that analyzed computers for MRSA contamination were in hospital settings[5] so this study was an important confirmation that there could be reservoirs of MRSA in public settings as well[9]. This illustrates the importance of understanding the mode of transmission for MRSA bacterial strains, and discovering methods of disinfecting public computer keyboards routinely in order to slow or prevent the spread of this disease.

Computer Keyboard and Mouse: Etiological Agents for Microbial Infection.

Surface bio-contamination is a problem that has caused many outbreaks through intermittent fomites transformation of disease and persistent fomitic reservoirs[8]. It is thought that fomites play the same role in transferring pathogenic bacteria and causing diseases[8]. Surface contamination of publically used boundary systems in the spread of disease raises many questions, and there has been a lot of evidence in their support of the role that they play[8]. Pathogens are transferred via the hands of a user to other users of the same computer which leads to infection[8].

This experiment took place at National Veterinary Research Institute's Cyber Café which is located in Vom, Plateau State in the African nation of Nigeria[8]. Computer keyboards and mice are considered reservoirs because of the frequent dermal contact they have; computer keyboards have shown evidence of methicillin resistant *Staphylococcus aureus* (MRSA)[8]. When there are

breaches in the skin of the host microbes are able to invade the host; although, microorganisms must be present in a minimum dose that is sufficient to cause an infection that will cause a dormant infection[8]. This is one reason there is a continual increase of bacterial infections[8].

The purpose of this study is to examine the microbial colonization of computer keyboard and mouse, along with components of the computers which serve as public user interfaces in a cyber café [8]. There were two different sample groups used in this experiment; there were a total of 50 swabs taken, 22 were taken from both keyboards and mice that were used in areas of multiple user computers, and three that were taken from the keyboard and mouse of the Café manager's single user computers[8].

Each swab taken was first placed into a Tryptic Soy Broth and then was used to swab the surface of either the computer or the mouse[8]. Each of the keyboards and mice used in this experiment were swabbed with 70% alcohol[8]. After each swab reached the lab the tip of cotton was cut off and placed into another test tube that contained 5 ml of TSB; these samples were then incubated for 24 hours at a temperature of 37 ºC and after 24 hours the samples are sub-cultured on both blood agar (BA), and McConkey agar (MCA)[8]. After a total of 48 hours the cultures were sub-cultured onto sabouraud dextrose agar (SDA) slope[8]. Both the BA and MCA were incubated at 37ºC for a length of 24 hours while the SDA was incubated at a temperature of 25 ºC for a length of 21 days[8]. If there was any bacterial growth on the cultures gathered there were sub-cultured to further purification on another set of BA and MCA plates; this was also done with any fungal growth[8].

Bacteria were isolated and characterized based on different characteristics that they contained; some of these characteristics were the colony size, consistency, and colony pigmentation[8]. Many different identification materials were used during this experiment in order

to identify discrete colonies[8]. Some of the tests used during this process were gram staining, catalase tests, coagulant tests, biochemical tests, and citrate and urease activity and sugar fermentation tests to aid with isolates[8,14]. At the completion of the experiment there was a large amount of bacteria isolated, these bacteria's were *Bacillus* species, *Escherichia coli, Coagulase positive, Staphylococcus, Coagulase negative Staphylococcus, Streptococcus species* and diptheroids[8]. In terms of fungi/ molds *Trichophyton* species, *Aspergillus* species and *Candida albicans* were successfully isolated[8].

Bacillus species were the most isolated with 84% detection on both the keyboards and mice in the experiment[8]. Results for the single user keyboards and mice were *Bacillus* species (100%, 100%) and *Coagulase positive Stphylococcus* (33.3%, 33.3%)[8]. After reviewing the fungi tests the fungus that was the most prevalent was *Trichophyton* species with reference to the single user keyboard and mouse it appeared 33.3% on the keyboard and 0% on the mouse[8].

After isolation was completed it was determined that most of the contaminants were skin flora and dust that were combined with the organisms, in particular the ones from the keyboards[8]. From this study it was determined that the sources of the microbes on the keyboards and mice are unknown[8]. It is important to remember that the spread of staphylococci through the nasal cavities of humans results from the colonization of bacteria from hand to mouth or hand to nose contact, or even poor hand sanitation[8].

Based off the information retrieved appliances that have multiple users should be more hygiene conscious to prevent the possibility of cross infection[8]. Even though *Bacillus* species were found 100% on single user computers it does not mean that they are more exposed, it could be because they do not clean their keyboard and mouse often allowing the dust in the air to pick

up the bacteria and transfer it onto the fomites[8]. *Trichophyton* species could be transmitted through *Tinea* infections which could cause issues of infection in children; although many areas do not have to be extremely concerned because this is more common in low economical societies, but they are transmitted through fomites[8].

At the conclusion of the study it was found that there were high colonization rates of computers where people had had hand to mouth or hand to nose interaction[8]. As a result of these findings it is suggested that there should be regular cleaning of keyboards and mice[8]. Hand washing is also something that is very important to do after coming into contact with a keyboard or mouse to help reduce the chances of causing cross-spread of the bacteria[8].

Research Question (1)

Is the estimated concentration of bacteria discovered by sampling personal computer keyboards affected by the use of an aerosol sterilizer (staphene) compared to a placebo cleaner (water)?

Hypothesis (1)

H_0 (1): There is no effect on the estimated concentration of bacteria discovered by sampling personal computer keyboards affected by the use of an aerosol sterilizer (staphene) compared to a placebo cleaner (water).

H_1 (1): There is an effect on the estimated concentration of bacteria discovered by sampling personal computer keyboards affected by the use of an aerosol sterilizer (staphene) compared to a placebo cleaner (water).

Research Question (2)

Is there a correlation between the estimated concentration of bacteria discovered by sampling personal computer keyboards and the overall health of the user determined by a general health survey?

Hypothesis (2)

H_0 (2): There is no correlation between the estimated concentration of bacteria discovered by sampling personal computer keyboards and the overall health of the user determined by a general health survey.

H_1 (2): There is a correlation between the estimated concentration of bacteria discovered by sampling personal computer keyboards and the overall health of the user determined by a general health survey.

Materials and Methods

Preliminary work for this study was done in December of 2012. The data collection, in which the participant involvement occurred, took place from January 6, 2013 to March 4, 2013. The total data collection was eight weeks. Most of the procedures done in this study were inspired by a previous study done by Quri Daniels-Witt, a 2011 Spring Arbor University graduate in the biology department. The materials used during this experiment are listed below.

- Sheep's Blood Agar bacterial culture plates
- Sterile cotton swabs
- Staphene (an aerosol sterilizer)
- Deionized Water
- 10% Bleach Solution (used for cleaning laboratory countertops)
- Nitrile gloves (used for sanitary purposes)
- An autoclave (provided through Spring Arbor University)
- An incubator (provided through Spring Arbor University)
- Personal computer keyboards/laptops (provided by Spring Arbor University student participants)

Twenty-five Spring Arbor University students were recruited to participate in this study. The participants were given a number for their keyboard to stick on it for the whole study. Using these numbers, the participants were split into two groups (odd and even) without knowledge of which group they were in. Each participant was given disposable thermometers and the web

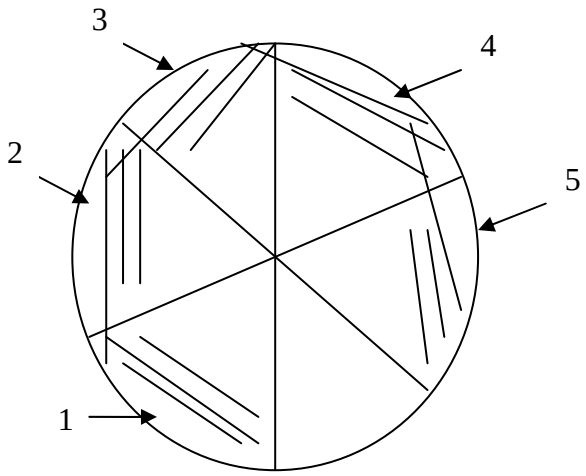
address to an online survey. They were requested to fill out the survey every day. Questions included: name, date, temperature, symptoms, and a rank of how they were feeling that day.

Participants provided their personal computer keyboards for cleaning and sampling purposes weekly throughout the study. During the first half of the study (4 weeks), the even numbered keyboards were cleaned with Staphene, while the odd were not cleaned. During the cleaning procedure, the research assistant wore clean Nitrile gloves (changed in between each computer). The even-numbered computers were sprayed generously with Staphene and the odd computers were wiped gently with deionized water to create an appearance of being cleaned. The computers were allowed to air dry for an hour. This was done so participants were not able to know what group they were in based on the smell of the computers. At the end of the first section of the study, samples were collected from both participants' throats and keyboards. This process was repeated over again for the second half of the study (4 weeks) except the odd numbered keyboards were cleaned and the even numbered keyboards were not.

At the end of both sections of the study, samples were collected from the keyboards and throats of the participants. The sampling process utilized a standard cotton-swab streak. The examiner wore Nitrile gloves that were changed in between each participant or new keyboard to reduce the risk of contamination. A sterile cotton swab was used to swipe the tonsils and back of throat of each participant and then immediately streaked onto a Sheep's Blood Agar plate. When sampling the keyboards, a sterile cotton swab was wiped over the surface of each keyboard especially the space bar, enter key and home position keys. When the keyboard was on a laptop, the touch mouse was wiped as well. This cotton swab was also immediately streaked onto a Sheep's Blood Agar plate.

The streak process used was a medical microbiological streak. This model consists of creating growth zones labeled 1-5 on the outer edge of the plate and utilizes a concentration gradient where higher concentrations of bacteria will allow for growth at higher zones. The original cotton swab was used to streak zone 1. Then a new sterile cotton swab was used to streak zone 2, crossing over onto the streaks from zone 1 during the first streak. A new swab was used for each zone following the same pattern. A model of this procedure is shown below.

Model 1



Streaked plates were incubated for about 48 hours to allow for moderate bacterial growth. They were then analyzed by a researcher wearing Nitrile gloves on a laboratory bench top that had been previously cleaned with 10% bleach solution. Colonies were counted and furthest growth zones were recorded on a data sheet along with keyboard number/participants name, and sample collection date. Then plates were stored in a refrigerator to use for comparison later.

On the first day of the study participants brought their computers in for cleaning. Each participant was given a sticky label with a number (1-25) to put somewhere on their laptop or keyboard so that the researcher and research assistants could easily know which computers to

clean without the researchers or participants being aware of which participants were in which group. The laptops were then taken into another room, where the counters had been sprayed down prior with 10% bleach solution to avoid contamination, and the even computers were generously sprayed down with Staphene while the odd were only wiped off gently with Deionized water. While participants waited to pick up their computers, they were informed about how to take their temperatures with the disposable thermometers and fill out the online survey. They were requested to take their temperatures at the same time each day to avoid changes in temperature due to the natural circadian rhythm. They were also beseeched to fill out the survey every day in order to have accurate data results.

Every following week, participants dropped off their laptops or keyboards and picked them up an hour later. The keyboards were cleaned in the same manner described above, and allowed to air dry to disburse the 'cleaner' smell in order that the groups remained blind. Computers and keyboards were collected once a week for 4 weeks. On the fourth week after the initial start of the survey, participants came in with their computers again. In separate rooms, the participants' throats and keyboards were swabbed following the method described in detail above. The keyboards then began the second round of cleaning where the odd keyboards were cleaned with Staphene and the even keyboards were gently wiped down with Deionized water. Computers were collected and cleaned for another 3 weeks. On the fourth week after swabbing, participants came once again and keyboards and throats were swabbed for a final time.

Throughout the whole study, participants were continuously encouraged to take their temperatures regularly and fill out the survey every day. They were expected to go about life as normal, using their computers the same amount they normally would.

At the end of the study, all data from the samples and online survey was collected and recorded in an Excel spreadsheet. Once this data was gathered and organized, it was analyzed using statistical methods listed below.

Statistical Tests

Tests used in data analysis of Research Question/Hypothesis (1) include:

A two-sample t-test (assuming equal variance) was used to compare data from the samples collected from each keyboard during their 'cleaned' and 'not cleaned' sections of the study.

This test used the following data: the furthest growth zones found with the samples collected from each keyboard during their 'cleaned' section of the study and the furthest growth zones found with the samples collected from each keyboard during their 'not cleaned' section of the study. A 0.05 level of significance was assumed.

A two-sample t-test (assuming equal variance) was used to compare data from the samples collected from the odd keyboards during their 'cleaned' and 'not cleaned' sections of the study.

This test used the following data: the furthest growth zones found with the samples collected from the odd numbered keyboards during their 'cleaned' section of the study and the furthest growth zones found with the samples collected from the odd numbered keyboards during their 'not cleaned' section of the study. A 0.05 level of significance was assumed.

A two-sample t-test (assuming equal variance) was used to compare data from the samples collected from the even keyboards during their 'cleaned' and 'not cleaned' sections of the study.

This test used the following data: the furthest growth zones found with the samples collected from the even numbered keyboards during their 'cleaned' section of the study and the furthest growth zones found with the samples collected from the even numbered keyboards during their 'not cleaned' section of the study. A 0.05 level of significance was assumed.

Tests used in data analysis of Research Question/Hypothesis (2) include:

A Correlation Analysis was used to investigate the relationship of the data from the samples collected from all the keyboards during both their 'cleaned' and 'not cleaned' sections of the study with the data from the daily health survey.

This test used the following data: the furthest growth zones found with the samples collected from all keyboards during their 'cleaned' and 'not cleaned sections of the study and the health score for the specific participant formulated with the data from the daily health survey. A correlation coefficient with a 0.05 significance was assumed.

A Correlation Analysis was used to investigate the relationship of the data from the samples collected from all the odd numbered keyboards during both their 'cleaned' and 'not cleaned' sections of the study with the data from the daily health survey.

This test used the following data: the furthest growth zones found with the samples collected from all the odd numbered keyboards during their 'cleaned' and 'not cleaned sections of the study and the health score for the specific participant formulated with the data from the daily health survey. A correlation coefficient with a 0.05 significance was assumed.

A Correlation Analysis was used to investigate the relationship of the data from the samples collected from all the even numbered keyboards during both their ‘cleaned’ and ‘not cleaned’ sections of the study with the data from the daily health survey.

This test used the following data: the furthest growth zones found with the samples collected from all the even numbered keyboards during their ‘cleaned’ and ‘not cleaned sections of the study and the health score for the specific participant formulated with the data from the daily health survey. A correlation coefficient with a 0.05 significance was assumed.

Results and Discussion

Research Question/Hypothesis (1)

For this research question, the primary data used in the statistical analysis was obtained from the furthest growth zones observed on the streaked Sheep's Blood Agar plates. Using the medical microbiological plating method allowed for a relative distinction to be made about the concentration of bacteria on each keyboard. The theory behind this procedure was discussed previously in the Materials and Methods section; Model 1 showed an example of this method. With this method, the greater the concentration of bacteria located on a keyboard provides a higher likelihood of bacteria making it further in the growth zones. Sterilization techniques should inhibit growth, which in turn should cause smaller concentrations of bacteria on a surface, and the bacteria will travel less in the growth zones.

Table 1

Data for Furthest Growth Zones from all keyboards studied over the course of the entire cross-over study.

Computer Number	***Not Cleaned (Furthest Growth Zone)***	***Cleaned (Furthest Growth Zone)***	***Difference***
1	2	3	-1
2	2	4	-2
3	2	0	2
4	2	1	1
5	1	3	-2
6	4	2	2
7	1	3	-2
8	3	2	1
9	1	3	-2
10	3	2	1
11	2	2	0
13	0	3	-3
14	2	1	1
15	2	3	-1
16	4	2	2
18	4	2	2
19	2	2	0
21	2	3	-1
22	3	2	1
23	2	1	1
24	1	2	-1
Mean	2.142857	2.190476	
Standard Deviation	1.128571	0.861905	

Table 2

t-Test: Paired Two Sample for Means
All Keyboards

	Not Cleaned	*Cleaned*
Mean	2.142857	2.190476
Variance	1.128571	0.861905
Observations	21	21
Pearson Correlation	-0.2825	
Hypothesized Mean Difference	0	
df	20	
t Stat	-0.1367	
P(T<=t) two-tail	0.8926	
t Critical two-tail	2.0860	

Table 3

Data for Furthest Growth Zones from the odd keyboards studied. These keyboards were not cleaned during the first section and cleaned during the second section of the cross-over study.

Computer Number	***Research Section 1 Not Cleaned (Furthest Growth Zone)***	***Research Section 2 Cleaned (Furthest Growth Zone)***	***Difference***
1	2	3	-1
3	2	0	2
5	1	3	-2
7	1	3	-2
9	1	3	-2
11	2	2	0
13	0	3	-3
15	2	3	-1
19	2	2	0
21	2	3	-1
23	2	1	1
Mean	1.545455	2.363636	
Standard Deviation	0.472727	1.054545	

Table 4

t-Test: Paired Two Sample for Means
Odd Keyboards

	Not Cleaned	*Cleaned*
Mean	1.545455	2.363636
Variance	0.472727	1.054545
Observations	11	11
Pearson Correlation	-0.4507	
Hypothesized Mean Difference	0	
df	10	
t Stat	-1.8448	
P(T<=t) two-tail	0.0948	
t Critical two-tail	2.2281	

Table 5

Data for Furthest Growth Zones from the even keyboards studied. These keyboards were cleaned during the first section and not cleaned during the second section of the cross-over study.

Computer Number	***Research Section 1 Cleaned (Furthest Growth Zone)***	***Research Section 2 Not Cleaned (Furthest Growth Zone)***	***Difference***
2	4	2	-2
4	1	2	1
6	2	4	2
8	2	3	1
10	2	3	1
14	1	2	1
16	2	4	2
18	2	4	2
22	2	3	1
24	2	1	-1
Mean	2	2.8	
Standard Deviation	0.666667	1.066667	

Table 6

t-Test: Paired Two Sample for Means
Even Keyboards

	Not Cleaned	*Cleaned*
Mean	2.8	2
Variance	1.0666667	0.66667
Observations	10	10
Pearson Correlation	0	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.9215	
P(T<=t) two-tail	0.0868	
t Critical two-tail	2.2622	

Research Question/Hypothesis (2)

The data for this research question was obtained from the furthest growth zones observed on the streaked Sheep's Blood Agar plates and analysis of the daily health survey. The furthest growth zone on each plate was considered the **Bacteria Score**. The daily health reports were analyzed in all three responses (temperature, personal assessment, and symptoms). If a participant's temperature was outside of an average range (analyzed for each participant), they reported to be less than a 8 in their personal assessment, and/or reported significant symptoms (more than just runny nose, headache, or tired), they were given a -1 for that day. If none of these were true, they were given a +1 for that day. The **Health Score** was an average of these daily scores for that section of the study.

Table 7

Keyboard	*Cleaned*		Not Cleaned	
	Bacteria Score	**Health Score**	**Bacteria Score**	**Health Score**
1	3	0.5	2	0.642857
2	4	0.6	2	0.428571
3	0	0.285714	2	0.642857
4	1	-0.04348	2	0.478261
5	3	0.538462	1	-0.54545
6	2	0.3333	4	0.7037
7	3	0.130435	1	0.478261
8	2	0.8261	3	0.913
9	3	0.454545	1	0.111111
10	2	0.5	3	0.5
11	2	-0.08333	2	-0.41667
13	3	-0.06667	0	0.583333
14	1	0.2593	2	0.4815
15	3	0.461538	2	0.538462
16	2	0.5556	4	0.5556
21	3	-0.3913	2	0.555556
22	2	0.1429	3	-0.714
23	1	-0.34783	2	0.230769
24	2	-0.1	1	0

Graph 1

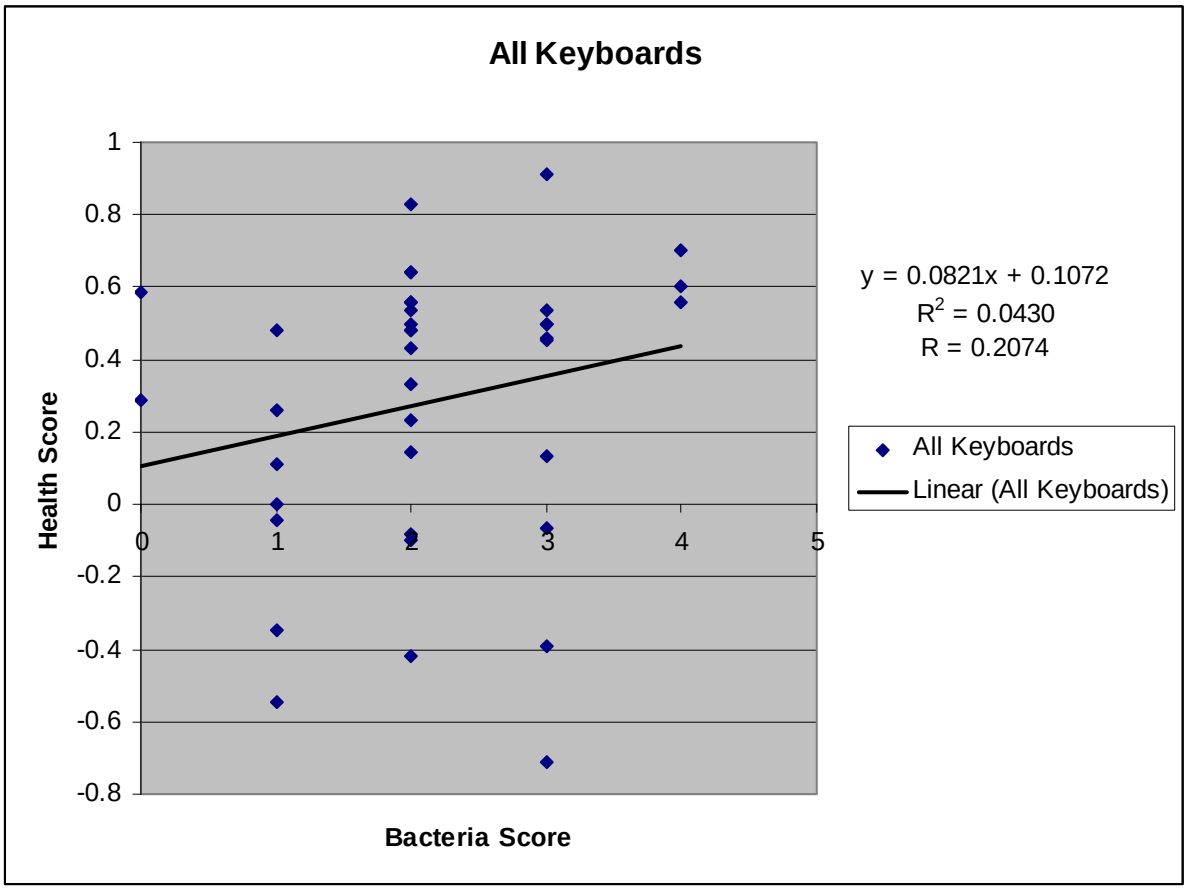

All Keyboards
Health Score
Bacteria Score
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
5
y = 0.0821x + 0.1072
R2 = 0.0430
R = 0.2074
All Keyboards
Linear (All Keyboards)

Table 8

Keyboard	*Cleaned*		Not Cleaned	
	Bacteria Score	**Health Score**	**Bacteria Score**	**Health Score**
1	3	0.5	2	0.642857
3	0	0.285714	2	0.642857
5	3	0.538462	1	-0.54545
7	3	0.130435	1	0.478261
9	3	0.454545	1	0.111111
11	2	-0.08333	2	-0.41667
13	3	-0.06667	0	0.583333
15	3	0.461538	2	0.538462
21	3	-0.3913	2	0.555556
23	1	-0.34783	2	0.230769

Graph 2

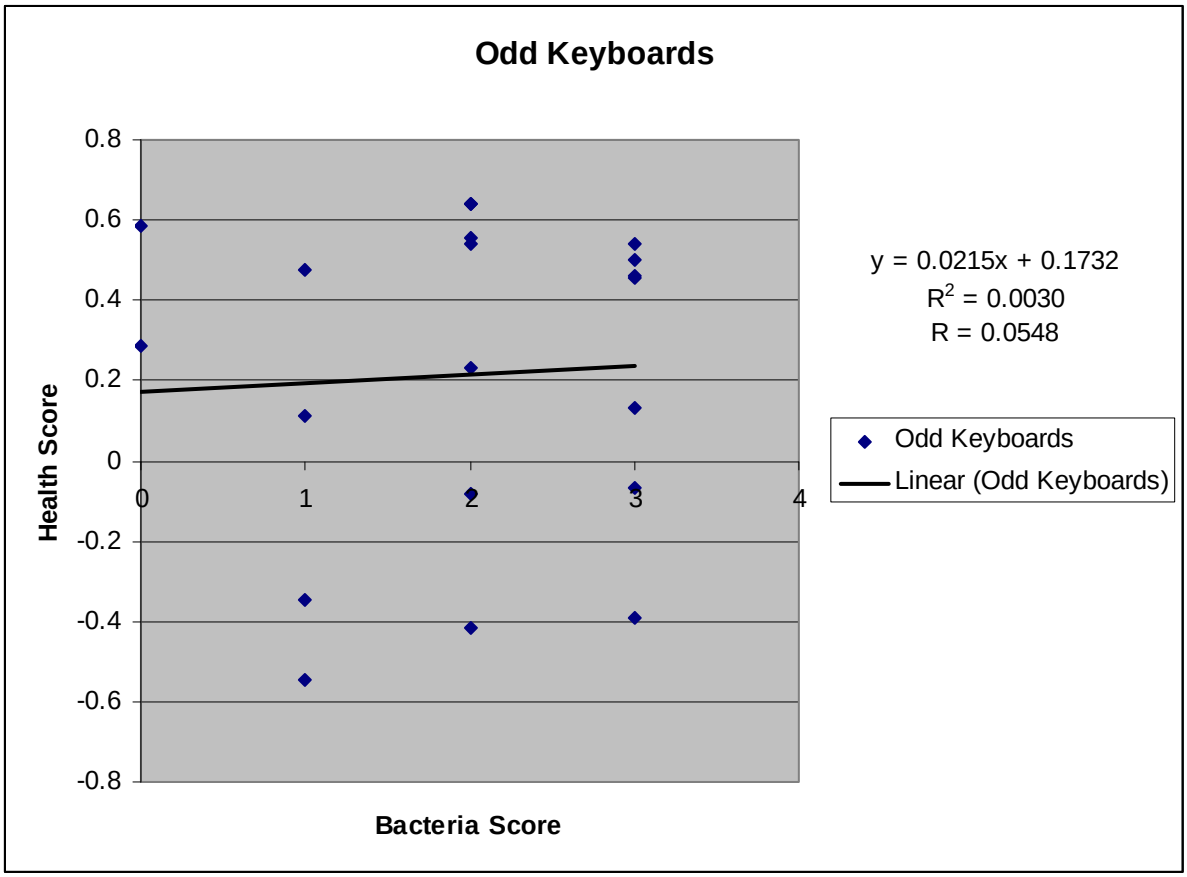
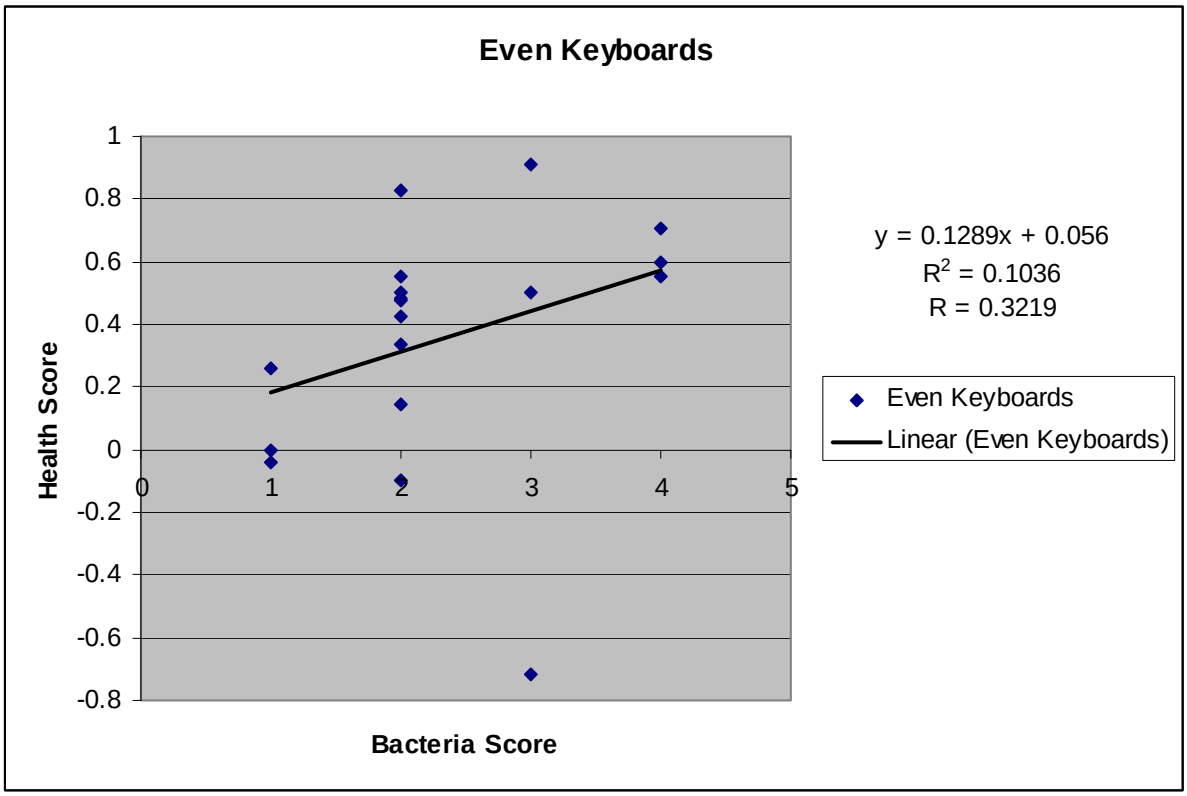

Odd Keyboards
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
Health Score
Bacteria Score
y = 0.0215x + 0.1732
R2 = 0.0030
R = 0.0548
Odd Keyboards
Linear (Odd Keyboards)

Table 9

Keyboard	*Cleaned*		Not Cleaned	
	Bacteria Score	**Health Score**	**Bacteria Score**	**Health Score**
2	4	0.6	2	0.428571
4	1	-0.04348	2	0.478261
6	2	0.3333	4	0.7037
8	2	0.8261	3	0.913
10	2	0.5	3	0.5
14	1	0.2593	2	0.4815
16	2	0.5556	4	0.5556
22	2	0.1429	3	-0.714
24	2	-0.1	1	0

Graph 3


Even Keyboards
Health Score
Bacteria Score
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
1
2
3
4
5
y = 0.1289x + 0.056
R2 = 0.1036
R = 0.3219
Even Keyboards
Linear (Even Keyboards)

Analysis: Research Question/Hypothesis (1)

The first statistical test performed during data analysis was a two-sample t-test (assuming equal varience) comparing the data from all the keyboards during their **cleaned** phase with their **not cleaned** phase. A total of 21 keyboards were tested (11 Not Cleaned then Cleaned and 10 Cleaned then Not Cleaned). The test assumed a level of significance at 0.05, meaning that if the calculated p-value is less than 0.05 the Null Hypothesis (H_0 (1)) can be rejected because a statistical difference exists between the two phases of cleaned and not cleaned, and if the calculated p-value is greater than 0.05 the Null Hypothesis cannot be rejected because there is not a statistical difference between the two phases. The t-test preformed for this analysis was a two-tailed test because the hypothesis was to find any difference between the two phases. The null hypothesis (H_0 (1)) and alternate hypothesis (H_1 (1)) are listed below:

> H_0 (1): There is no effect on the estimated concentration of bacteria discovered by sampling personal computer keyboards affected by the use of an aerosol sterilizer (staphene) compared to a placebo cleaner (water).
>
> H_1 (1): There is an effect on the estimated concentration of bacteria discovered by sampling personal computer keyboards affected by the use of an aerosol sterilizer (staphene) compared to a placebo cleaner (water).

The p-value provided in the Table 2 is 0.8926. As stated above in order to reject H_0 (1) and accept H_1 (1), the p-value must be less than 0.05. Therefore there is not enough statistical significance to reject H_0 (1) for this set of data. Other numbers in the table also help to confirm this analysis. In order to reject H_0 (1), the Critical t value must be greater than 2.0860 while the

actual t-value (t stat) was -0.1367. This supports the assumption that we cannot reject H_0 (1). Thus for this set of data, H_0 (1) must be accepted.

The next statistical analysis is a two-sample t-test (assuming equal varience) comparing the data from the odd keyboards during their **cleaned** and **not cleaned** phase. This group of keyboards were not cleaned during the first half of the study and cleaned during the second half. A total of 11 keyboards were analyzed. The level of significance assumed for this test was also 0.05. Using the same criteria as the first statistical analysis, the calculated p-value, provided in table 4, was found to be 0.0948. The value is greater than the level of significance (0.05) causing H_0 (1) to be accepted. In addition, the t stat value was -1.8448 which is less than the 2.2281 critical t-value. These prove that there is not statistical difference between the two phases and thus H_0 (1) must be accepted for this set of data.

The last statistical analysis for Research Question (1) is a two-sample t-test (assuming equal varience) comparing the data from the even keyboards during their **cleaned** and **not cleaned** phase. This group of keyboards were cleaned during the first half of the study and not cleaned during the second half. A total of 10 keyboards were analyzed. The level of significance assumed for this test was also 0.05. Using the same criteria as the first statistical analysis, the calculated p-value, provided in table 5, was found to be 0.0868. The value is greater than the level of significance (0.05) causing H_0 (1) to be accepted. In addition, the t stat value was 1.9215 which is less than the 2.2622 critical t-value. These prove that there is not statistical difference between the two phases and thus H_0 (1) must be accepted for this set of data.

Analysis: Research Question/Hypothesis (2)

The first statistical test performed during data analysis of Research Question (2) is a correlation analysis of the relationship between all the keyboards' bacteria score and health score during the phase in which they were cleaned and the phase in which they were not cleaned. In the correlation analysis, the correlation coefficient (R) by finding a linear relation between the bacteria score and the health score. The level of significance assumed is 0.05 meaning that if the correlation coefficient is greater than the number found on the Critical Values table the Null Hypothesis (H_0 (2)) can be rejected because a statistical relationship between the two scores exists, and if the correlation coefficient is less than the number found on the Critical Values table the Null Hypothesis cannot be rejected because a statistical relationship does not exist. The correlation analysis performed was a two-tailed test because the hypothesis was to find any relationship between the two scores (not specifically positive or negative). The null hypothesis (H_0 (2)) and alternate hypothesis (H_1 (2)) are listed below:

> H_0 (2): There is no correlation between the estimated concentration of bacteria discovered by sampling personal computer keyboards and the overall health of the user determined by a general health survey.
>
> H_1 (2): There is a correlation between the estimated concentration of bacteria discovered by sampling personal computer keyboards and the overall health of the user determined by a general health survey.

In this analysis 19 keyboards were studied with 38 data entries (19 cleaned, 19 not cleaned), making the degree of freedom 36. The Correlation Coefficient found in Graph 1 for all the

keyboards was 0.2074 which is less than the critical value of 0.325; this means that there is not a statistical relationship and we therefore must accept H_0 (2) for this set of data.

The next statistical analysis is a correlation analysis of the relationship between the odd keyboards' bacteria score and health score during the phase in which they were cleaned and the phase in which they were not cleaned. This group of keyboards were not cleaned during the first half of the study and cleaned during the second half. A total of 10 keyboards were analyzed with 20 data points (10 cleaned, 10 not cleaned) with a degree of freedom of 18. The level of significance assumed for this test was also 0.05. Using the same criteria as the first statistical analysis for Research Question (2), the calculated correlation coefficient, provided in graph 2, was found to be 0.0548. The value is less than the critical value of 0.444 causing H_0 (1) to be accepted for this set of data.

The last statistical analysis is a correlation analysis of the relationship between the even keyboards' bacteria score and health score during the phase in which they were cleaned and the phase in which they were not cleaned. This group of keyboards were cleaned during the first half of the study and not cleaned during the second half. A total of 9 keyboards were analyzed with 18 data points (9 cleaned, 9 not cleaned) with a degree of freedom of 16. The level of significance assumed for this test was also 0.05. Using the same criteria as the first statistical analysis for Research Question (2), the calculated correlation coefficient, provided in graph 3, was found to be 0.3219. The value is less than the critical value of 0.468 causing H_0 (1) to be accepted for this set of data.

Conclusions

While the previous section discussed the results of a study from a statistical perspective, this section will discuss the general conclusions that can be drawn from those analyses. To start, Table 2 shows the results of the two-sample t-test of all the keyboards assuming equal variance at a 0.05 level of significance. This test was used to compare data from the samples collected from each keyboard during their 'cleaned' and 'not cleaned' sections of the study. The results showed no statistical significance between the not cleaned and cleaned phases of the study. This allows the following conclusions to be made: there is no effect produced from sterilizing the keyboards compared to just wiping them down with water; the growth of bacteria on all the plates, however, does confirm that the keyboards did in fact serve as fomites. This lack of difference could have potentially been due to different levels of microorganisms in the environment during the different phases. So the different groups were split for testing the cleaned and not cleaned of the odd keyboards separated from the even keyboards.

Table 4 shows the results of the two-sample t-test of the odd keyboards assuming equal variance at a 0.05 level of significance. This test was used to compare data from the samples collected from the odd keyboards during their 'cleaned' and 'not cleaned' sections of the study. The results showed no statistical significance between the not cleaned and cleaned phases of the study. Table 6 shows the results of the two-sample t-test of the even keyboards assuming equal variance at a 0.05 level of significance. This test was used to compare data from the samples collected from the even keyboards during their 'cleaned' and 'not cleaned' sections of the study. The results showed no statistical significance between the not cleaned and cleaned phases of the study.

In this study the keyboards were cleaned or not cleaned weekly for 4 weeks. The cleaned group, the group that was sterilized with the aerosol sterilizer, is the group that was conjectured to produce change in the bacteria concentration. The testing method used was a two-tailed test because the hypothesis, H_1 (1), was concerned with any change between the two test groups. A decrease or increase in bacterial concentration from the aerosol sanitizer would be considered a change and would result in a rejection of the null hypothesis, H_0 (1), and accepting the alternative hypothesis, H_1 (1). The data sets collected during the study provide the following conclusion. Because H_0 (1) was accepted, there is no statistical difference between the cleaned and the not cleaned keyboards. This confirms that after 4 weeks of weekly sterilization, there is no statistically significant effect generated by sterilizing the keyboards weekly. Ideally there would have been a change in the overall bacterial concentration between the test groups after each section of the study. Due to the results not being ideal, this suggests that improvements need to be made for future studies.

Graph 1 shows the results of the correlation analysis of all keyboards at a 0.05 level of significance. This test was to compare data from the samples collected from the even keyboards during their ‘cleaned’ and ‘not cleaned’ sections of the study. The results show no statistical relationship between the bacteria count and the health of the participant. The two groups of keyboards were then split to analyze other potential relationships. Graph 2 shows the results of the correlation analysis of the odd keyboards at a 0.05 level of significance. The test was used to investigate the relationship of the data from the samples collected from all the odd numbered keyboards during both their ‘cleaned’ and ‘not cleaned’ sections of the study with the data from the daily health survey. The results show no statistical relationship. Graph 3 shows the results of the correlation analysis of the even keyboards at a 0.05 level of significance. The test was

used to investigate the relationship of the data from the samples collected from all the even numbered keyboards during both their ‘cleaned’ and ‘not cleaned’ sections of the study with the data from the daily health survey. The results show no statistical relationship.

In this study while the keyboards were cleaned or not cleaned weekly for 4 weeks, the participants were told to take their temperatures at the same time every day and fill out a daily health survey. The bacteria concentration was expected to have a correlation with the extent of sickness a participant experienced. H_1 (1) was again concerned with any change between the two test groups. A decrease or increase in bacterial concentration associated with a decrease or increase in the health score would be considered a change and would result in a rejection of the null hypothesis, H_0 (1), and accepting the alternative hypothesis, H_1 (1). The data sets collected during the study provide the following conclusion. Because H_0 (1) was accepted, there is no statistical difference between the cleaned and the not cleaned keyboards. This confirms that after 4 weeks of weekly sterilization and daily health reports, there is no statistically significant correlation found. Ideally there would have been a connection between the amount of bacteria and the health score. Due to the results not being ideal, this suggests that improvements need to be made for future studies.

An explanation for why projected outcomes were not seen can be provided with the analysis of the daily health reports. While participants were requested to fill out the survey every day, very few actually accomplished this task. Also, in order for the temperature to be relevant, it needed to be taken at the same time every day, and with the lacking health reports, there was not always enough information to create an accurate baseline temperature. The gaps in the daily survey could be a possible factor contributing to not ideal results.

Overall, the data analyses used in this study, including all two-sample t-tests and correlation analyses, allow the following conclusions to be made. In regards to Research Question/Hypothesis (1), no statistical difference was produced by sterilizing the keyboards weekly. Potential reasons why there was no difference will be discussed in the next section. In order to investigate a change in bacteria concentration from sterilizing keyboards more than once a week, another hypothesis would have to be tested with further study. Suggestions such as this are discussed in the Suggestions for Improvement section. In regards to Research Question/Hypothesis (2), no statistical relationship was concluded from the bacterial amounts and the daily health score. Potential reasons why there was no relationship concluded will be discussed in the next section. In order to investigate a correlation with a statistical relationship, an improved study would have to be implemented to test a new hypothesis. These ideas are discussed in the Suggestions for Improvement section.

Reasons for Error

The medical microbiological streak method used for collecting the bacterial samples is a method of analyzing relative concentration of bacteria. It utilizes the fact that higher concentrations of bacteria will account for growth in higher growth zones. A plate with growth in Zone 2 accounts for higher concentrations of bacteria than a plate with growth only in Zone 1, a plate with growth in Zone 3 accounts for higher concentrations than a plate with Growth only until Zone 2, and so on. This method uses relative concentrations as apposed to counting colonies. The main reason to avoid counting colonies is that many times plates contain too many colonies to count accurately. The medical microbiological streak method avoids this problem. However one of the issues with relative concentration methods such as this is contamination. Contamination can account for a large source of error using this method. Contamination is likely due to less than ideal sterile conditions in the laboratory. Even taking all the necessary precautions—such as cleaning the countertops with 10% bleach solution, wearing a sterile pair of nitrile gloves for each swab done, and allowing limited exposure of the sterile cotton swab and sheep's Blood Agar plate to the environment—there is still the risk of contaminates.

Another one of the crucial sources of error is due to the sample size. Finding volunteers willing to bring their computer in every week and fill out a survey every day was not an easy task and the group size dwindled throughout the study. At the end of the study, the group sizes were 10 in the odd numbered group and 9 in the even numbered group. An ideal sample size would have been around 30 or more participants. A larger sample size would have been more of an advantage for this study and may have revealed more statistical significance in the hypotheses.

Suggestions for Improvement

Looking back on this study, there are several ways it could have been improved. A more controlled study would hopefully provide more accurate data. Some additional controls that would benefit the study would be cleaning the keyboards daily, a more detailed health report, and a third group for control where the keyboards are never cleaned. Cleaning the keyboards daily would hopefully keep the group of cleaned keyboards cleaner to affect Research Question 1-that the keyboards cleaned with a sterilizer contain less microbes than the keyboards cleaned with just a placebo cleaner (water). A more detailed health report would provide more accurate data to use for trying to make the correlation between microorganisms on the keyboard and health of the participant. Having a control group would account for the airborne sicknesses going around in order to examine those sicknesses spread by contact. By implementing these changes, the study would hopefully be more likely to prove the hypotheses one way or another.

Suggestions for Further Study

There are numerous directions for research to progress in the area of fomites. Viability tests need to be run on different strains of microorganisms. Methods of maintaining clean surfaces or sterilizing surfaces need to be assessed. Correlations between bio-contamination (contamination of an object or surface by biological organisms such as bacteria and viruses that can potentially be harmful to humans or cause disease[16]) and outbreaks can be discovered. Correlations between amount of contact with microorganisms and a person's health need to be evaluated.

The viability of different microorganisms depends on the strain of bacteria or virus and the environment it comes in contact with when it is on a fomite. There are several different ways

to go about analyzing this. One of the most common methods is inoculating a surface or object with a specific strain of bacteria or virus, letting this surface or object sit in a sterile environment, swabbing a surface every [specific allotment of time], and plating the swab to see if there is still growth[4]. This method will show growth when the microorganisms are still viable and no growth after the microorganisms have died. This method can be modified to produce different results: various strains of microorganisms can be used; different surfaces or objects can be used, etc. This method can be used to analyze all types of microorganisms such as new strains of flu that have recently been discovered. This will help people understand how necessary it is to clean a fomite. One possible procedure for this is as follows. A specific strain of flu can be inoculated onto a fomite such as a door handle. The fomite would be swabbed[14] every few hours. These plates would be incubated, and then the colonies would be counted. As the viability of this strain decreased, the number of colonies would decrease. These counts can be graphed and the data can be analyzed to find a half life and other statistical information[17].

This method can also be utilized to help evaluate methods of cleaning or sterilizing a surface and maintaining a semi-sterile environment. An object can be inoculated with a bacteria or virus, cleaned/sterilized, and then swabbed and grown to check for any viable microorganisms, or an object can be left out in a specific environment for a designated period of time and swabbed checking for growth[14]. This method can allow analysis of different materials and how well they maintain sterility. It can also allow for examination of different cleaning products or methods and how well they actually work. Quri Daniels-Witt, a Spring Arbor alumnus, did a similar study and found that participants who used an alcohol based hand sanitizer routinely had less bacteria growth on their cell phones and iPods than participants who only washed their hands with soap and water[18]. She had one group of participants regularly

sanitize their hands every time they used their cell phone or iPod and one group go about as normal. She then swabbed each cell phone and iPod with a quadrant streak method[15] to make an estimation about the concentration of microorganisms by seeing how many quadrants colonies formed on. Comparing with a t-test she showed that the hand sanitizing group had statistically significantly fewer microorganisms than the control group[18].

Discovering correlations between outbreaks of sickness or disease and the source of bio-contamination is a really interesting topic of study that needs to be further pursued. Similar studies have been done in Hospitals finding the source of MRSA outbreaks[5]. Studies can be done to find the source of outbreaks of a specific bacterial or viral strain on college campuses, hospitals, etc. These studies can be done by swabbing different theoretical fomites[16] and finding the reservoir(s) of that pathogenic strain. These studies can then be evaluated by finding connections between the people who got sick and at least one of the reservoirs[6, 12]. A theoretical procedure for this would be as follows. After an outbreak on a college campus has been discovered, swabs are taken of many potential fomites around campus[14]. These swabs were plated, incubated, and streaked out again to isolate specific strains if needed[14]. These colonies would then be analyzed using tests and staining techniques to compare to the known infection strain[14]. Plates that contained this strain showed that the fomites where the swabs were taken from are sources of bio-contamination. Proving a connection between the infected people and the contaminated fomites is a little bit more difficult, but could potentially be accomplished with a survey. Data from the survey could be statistically analyzed to prove a correlation[17].

Still another type of study could be done to correlate the amount of contact with microorganisms and the health of a person. These can be done by regularly swabbing a theoretical fomite[14] that a person often contact throughout their daily activities such as a

computer, cell phone, iPod, doorknob, keys, etc. The correlation can be made by analyzing the pathogenic material on these fomites and the health of the person. Even better connections can be made, if you can show specific strains of a bacteria actually contaminated the person from that fomite[14]. That is what this study sought to do. It looked into making a correlation between the bacteria on a personal computer keyboard and the health of the user. However the data in this study could not prove any correlation.

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