

A Model of Bacteria Presence and Disinfectant Wipe Effectiveness in the Gym Setting

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Allegheny College
Department of Biology

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**A Senior Comprehensive Project in Partial Fulfillment of the Requirements
for a Bachelor of Science Degree from Allegheny College**

*I hereby recognize and pledge to fulfill my responsibilities as defined in the
Honor Code and to maintain the integrity of both myself and the College
community as a whole.*

Pledge

Approval by the Senior Thesis Committee

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Abstract

Bacteria can commonly be spread through contact as they survive on surfaces for differing amounts of time, depending on the type of bacteria and the condition of the surface. To stop the spread of bacteria, we can employ different disinfectant methods. This study aimed to understand the effectiveness of disinfectant wipes when looking at surfaces in the gym setting. The objective was to examine surfaces at the Wise Fitness Center on the Allegheny College campus to model the effectiveness of disinfectant wipe use. The goal was to examine how the wipes were being used, test if the wipes are effective, and to model their use on a gym setting. From the data, recommendations were made to ensure that the Wise Fitness Center was making the best decisions and following the most effective protocol for disinfection in this setting. In response to this research, we are able to know the effectiveness of the disinfectant wipes in a gym setting. Looking at these results is an important factor in examining how to better kill bacteria in the gym setting and therefore lower the spread of bacteria.

Introduction

Preventing the spread of disease can be understood by the prevention of bacteria transfer. Indirect contact is a common form of bacterial transfer that affects humans as a pathogen can survive on surfaces for varying durations of time. The majority of gram-positive bacteria, including *Staphylococcus aureus* and *Streptococcus pyogenes*, and many gram-negative bacteria, including *Escherichia coli*, *Pseudomonas aeruginosa* and *Serratia marcescens*, can survive on dry surfaces for upwards of seven months (Kramer et al., 2006). Many pathogens, including those in the *Staphylococcus* genera, that live on surfaces also cause harm to human health as they

are difficult to treat with antibiotics alone (Foster, 1996). Because these various pathogens can survive on surfaces for upwards of seven months, these surfaces can be a continuous source of transmission if no disinfection takes place (Kramer et al., 2006; Foster, 1996).

When looking at everyday settings, interactions between the skin and the surfaces contribute to the spread of bacteria. Surfaces, such as a mobile device which humans have high numbers of contact with, have contaminants that could potentially be transferred and infect humans (Egert et al., 2014). Similarly, eyeglasses swabbed for bacteria samples also show that eye glass pieces that were in close contact to the human skin, like the ear clips and nose pads, had higher cell densities comparable to that of the hands (Fritz et al., 2018). Surfaces with high amount of human activity and direct contact with the skin have higher bacterial loads (Fritz et al., 2018). Those surfaces that are regularly in contact with humans can become contaminated with microorganisms and can then be classified as a fomite, or an object that is likely to carry infection (Fritz et al., 2018). Skin bacteria are the most common type of bacteria found on dry surfaces and mostly include those from the *Staphylococcus* genera (Fritz et al., 2018; Young et al., 2017). The microbiome of the skin is dominated by *Staphylococcus* and *Propionibacterium* (Grice and Segre, 2011). What is on the human skin microbiome is what is being transferred to surfaces when they are in contact.

Communal surfaces show strong trends of an increased bacterial load correlating with increased activity level (Wood et al., 2015). Specifically at an athletic facility, surfaces that have highly dynamic bacterial community compositions are the surfaces that have the most primary contact with human skin (Wood et al., 2015). These surfaces that have high contact with the skin, such as the incline bench headrest area and floor mats, have higher levels of bacteria (Tam and Sidhu, 2014). Community associated *Staphylococcus aureus* (MRSA) is particularly at a high

risk of being transferred in physical fitness centers (Weissfeld, 2015; Cope, 2013; Markley et al., 2012; Ryan et al., 2011). Interactions are found between communal surfaces and multiple distinct bacteria, from the skin of different individuals, which leads to an increase in bacterial community turnover (Wood et al., 2015). Community settings are at increased risks for having exposure to many and various pathogens.

Another setting that is prone to disease transfer is college campuses. Since many people are living in such close proximities to each other and have multiple occurrences to be in close contact with another, there is an increase in the rate of bacteria spread (Prater et al., 2016). Having continuous contact with multiple people leads to highly variable microbial communities (Ross and Neufeld, 2015). Surfaces with high skin contact, like doorknobs are prime locations where bacteria can be spread in this environment (Ross and Neufeld, 2015). Employing an effective disinfectant method is needed to kill these bacteria and stop the transmission of them.

With bacteria that can be transferred from the human skin to surfaces and vice versa, there needs to be some mode of disinfection in place. Disinfection is a vital component when stopping infections and the spread of disease (Rutala and Weber, 2016). When done properly, disinfecting a surface will leave it free of pathogens therefore preventing the development and spread of disease in humans (Rutala and Weber, 2016). Disinfection can help prevent the disease from even spreading in the first place when done properly with effective products. There are a variety of disinfection products readily available from well-known Clorox wipes to different quaternary ammonium compounds (Rutala and Weber, 2016).

In order to combat bacteria on surfaces, a variety of disinfectant methods can be used. Common disinfectant methods include wiping with water, liquid soap, or 250-ppm free chlorine solution, as well as using an alcohol or non-alcohol impregnated wipe. All of these cleaning

methods have slight variations in their effectiveness in regard to killing bacteria from a designated surface (Fritz et al., 2018; Tuladhar et al., 2012). Median germ reduction with soap, chlorine, or wipes can be as effective as 99-100% of the bacteria being killed because of the ethanol content, isopropyl content or alkyl-dimethylamine oxides being used as the active ingredient (Fritz et al., 2018). Looking specifically at communal surfaces, using a residual disinfectant is the most effective method (Young et al., 2017). Residual disinfectants have long-term bacteria-killing action compared to non-residual cleaners, including a standard 10% bleach treatment (Young et al., 2017).

Disinfectant wipes have proven to be effective at cleaning surfaces. Alcohol based wipes, used as an alternative to various handwashing products, are effective at controlling bacteria and have comparable bacterial loads as when hands were washed with nonmedicated soap (Butz, 1990). Eyeglasses, which have high contact with the skin, saw a reduction in the amount of bacteria on the surfaces when using a cellulose-based alcoholic lens cleaning wipe, cellulose-based alcohol-free lens wipe, dry cellulose-tissue, and a microfabric cloth (Fritz et al., 2018). While all of the methods are effective, both of the wet wipes had less variation in their effectiveness (Fritz et al., 2018). Mobile phones, items that have high contact with human skin, saw that there was a significant lower amount of bacteria on the surface when an alcohol-impregnated lens wipe was used (Egert et al., 2014). Similar trends can be seen when disinfectant wipes are used in the gym setting. Disinfectant wipes do make a significant difference in the cleanliness levels of surfaces, as surfaces shown to have no cleaning methods employed have a much higher amount of contamination (Tam and Sidhu, 2014). Disinfectant wipes seem to be effective at removing bacteria from surfaces when used properly.

The cleaning and disinfection protocols in the fitness club and gym setting are not closely regulated. In fact, there are no federal health codes for gyms. The gyms are only inspected when there is a complaint filed or if there is an illness that is traced back to the gym (MacMillan, 2014). If an individual gym has a pool, hot tub, sauna, or a place that prepares food, they will fall under a separate guideline for inspections (MacMillan, 2014). The actual gym equipment (the weights, cardio machines, lifting machines, mats, other surfaces) are under no federal guideline of how they should be cleaned and disinfected. It is recommended that athletic equipment and gyms clean their most commonly touched surfaces with a detergent-based or Environmental Protection Agency registered disinfectant (CDC, 2019). Additionally, it is recommended that cleaning procedures and schedules are reviewed with gym staff and/or the janitorial staff (CDC, 2019). It is up to each individual gym to have in place a disinfection protocol and have disinfection products available to users.

In the Wise Fitness Center at Allegheny College, ERC Reliance wipes are used as a mode of disinfection. These wipes are advertised to “clean fitness equipment quickly and effectively” and that “wholesale Reliance gym wipes contain a hospital grade quaternary formula for disinfecting” (ERC, 2017). The wipes are stored in a larger storage container that is mounted to the wall for users to more easily have access to them. They are wet wipes that consist of more than 93% water, <2% quaternary ammonium chloride, <1% sodium carbonate, <1% tetrasodium salt of ethylenediaminetetraacetic acid, <1% nonionic surfactant, <1% perfume oil, and <1% dye (ERC, 2015). The wipes are advertised to be used for fifteen seconds and will kill 99.9% of bacteria and germs in that time (ERC, 2017). This would indicate that if these disinfectant wipes are used the proper way, they would kill 99.9% of the bacteria and germs in the gym setting. With this specific product, there is no information on if it kills common skin bacteria that are

found on gym surfaces, like MRSA. The ERC Reliance wipes are not including in the list of the EPA's registered products that are effective against Methicillin-resistant *Staphylococcus aureus* (MRSA) and/or Vancomycin-resistant *Enterococcus faecalis* or *faecium* (VRE) (EPA, 2018). Such products that are included on this list include products such as Clorox, Lysol's multipurpose cleaner and foaming disinfectant, and Johnson's cleaner to name a few (EPA, 2018). The Wise Fitness Center additionally has a cleaning schedule in place for the student employees to follow. While individuals are responsible for using a disinfectant wipe after use of any equipment, employees are responsible for ensuring that each individual cardio machine, mat, strengthening machines, and upholstered equipment in the weight room is disinfected by the employees (Wise Center Brochure, 2019). The schedule looks to ensure that each piece of equipment is wiped down daily.

Although other work has looked at the bacteria load on varying surfaces and the effectiveness of disinfection methods, the research could be extended into how effectiveness may change based on how the disinfectant product is used. The ability to address how and what disinfection methods are the most suitable is a vital step in stopping the spread of disease and keeping communities healthy. To look further into this issue, I have tested the effectiveness of disinfectant wipes in a communal environment based off of the users' cleaning procedures. Research included testing the effectiveness of the disinfectant wipes of gym surfaces in the Wise Fitness Center on the Allegheny College campus. With this research, I have hypothesized that there will be differences in the amount of bacteria present on the surface depending on how the disinfectant wipe was used.

From this research, we can better understand the effectiveness of disinfectant wipes in a fitness center and gym setting. This information is important in understanding and preventing the

spread of disease in this environment. With communal environments having high activity with human contact, it is vital to understand how to control the spread of bacteria in these environments. Disease spread can be prevented if it is known how and with what methods are the most effective in disinfecting. This project looks into the effectiveness of disinfectant wipes in regards to removing bacteria from a surface and how to better these practices.

Methods

Observational Study

We first needed to understand how the disinfectant wipes are being used in the Wise Fitness Center at Allegheny College. Because the effectiveness of the disinfectant wipes may be different under different cleaning conditions, observations are needed to see if and how individuals are using them. Understanding how the disinfectant wipes are being used, will help in recreating a model of how an average individual uses the disinfectant wipes.

This experiment was done by an observational study at Allegheny College. Observations were made in the Wise Fitness Center on how many people use the disinfectant wipes, the amount of time that a disinfectant wipe was used, the surface that the wipe was or was not used on, and how the wipe was used by the individual. Notes on how the wipe was used by the individual included statements like “wiped over the surface once in a circular motion” or “wiped once across part of the surface”. The descriptions of these cleaning methods are what was used in the coding process.

The observational study was done over a four-week period. For the first week, observations were made for one hour from 6:45am to 7:45am. For the second week, observations

were made for one hour from 12:15pm to 1:15pm. For the third week, observations were made for one hour from 5:00pm to 6:00pm. For the fourth week, observations were made from 7:30pm to 8:30pm. For each week, observations were made at the designated time from Monday through Friday. For the Friday trial in the time period of 7:30pm to 8:30pm, observations had to be made from 7:00pm to 8:00pm due to the Wise Fitness Center closing at 8:00pm on Fridays. Individual use of the disinfectant wipes was recorded based on the criteria shown in Table 2. The type of equipment used, if a disinfectant wipe was used or not, the time a disinfectant wipe was used, and the method of wipe use was recorded. Observations were made by sitting in the back corner of the former cardio room of the Wise Fitness Center where observations could be clearly made for each type of equipment.

Data from the observational study was coded to find the average cleaning method of the disinfectant wipes. While descriptions like “swiped once across handles only” or “wiped in a circular motion across the entire surface” were recorded, all the data were put into six categories. Data that fit into the designated categories were given a number (Table 1).

Code Number	Representation
0	n/a (they did not use a wipe)
1	Had a one swipe (one motion/wipe) across the surface
2	Went down and around the surface in a circular motion
3	Went down and back at least one (did not just swipe over the surface once)
4	Had a one swipe (one motion/wipe) across the surface but did not get the entire surface
5	Very thorough (wiped over surfaces more then once in a circular motion)
6	Wiped over part of the surface thoroughly, but not the entirety of the surface

Table 1. Shown is the coding system for the cleaning methods. Descriptions were given one of the six numerical codes depending on the description recorded when observations were made.

The data was used as a descriptive analysis. The average amount of time individuals use the disinfectant wipes on a given surface was recorded. Additionally, findings on any trends there are with the way individuals currently use the wipes was able to be concluded. The findings from the observational study helped with modeling the current cleaning methodologies and allowed us to model how the average individual uses the disinfectant wipes.

Wipe Effectiveness

Since the aim of this project is to see how effective the disinfectant wipes are, we needed to test the wipes on a gym surface. This was done by examining the amount of Glo-Germ on the stationary bikes in the spin room at the Wise Fitness Center. Glo-Germ was chosen because it is a model of bacteria and can easily be visualized under a black light (Glo-Germ). The bikes in the spin room were chosen specifically because the lights can be turned off in the room, aiding in the visualization of Glo-Germ.

Testing was done by adding a quarter size amount of Glo-Germ onto laboratory gloves. I put my hands on the handle and seat of the stationary bikes for twenty seconds to mimic an individual using the stationary bike. The application of Glo-Germ was done by myself in every trial to ensure consistency.

Different cleaning methods involved both time and the “method” of cleaning (Figure 1). The times used were fifteen seconds, the average amount of time found from the observational study (four seconds, see results), and no time as a control. The method of cleaning was broken up into two groups: “lazy” and “thorough”. The thorough cleaning method included cleaning the surface by wiping over the entire surface more than once in a circular motion. The lazy cleaning method included cleaning the surface by just wiping over the surface. The lazy cleaning method was also a representation of how the disinfectant wipes are most commonly used based off of the observational study (see results). Each time period was done with each method of cleaning for a total of nine groups. Each group was repeated three times for a total of 27 result points. The trials were done by myself to ensure consistency between trials.

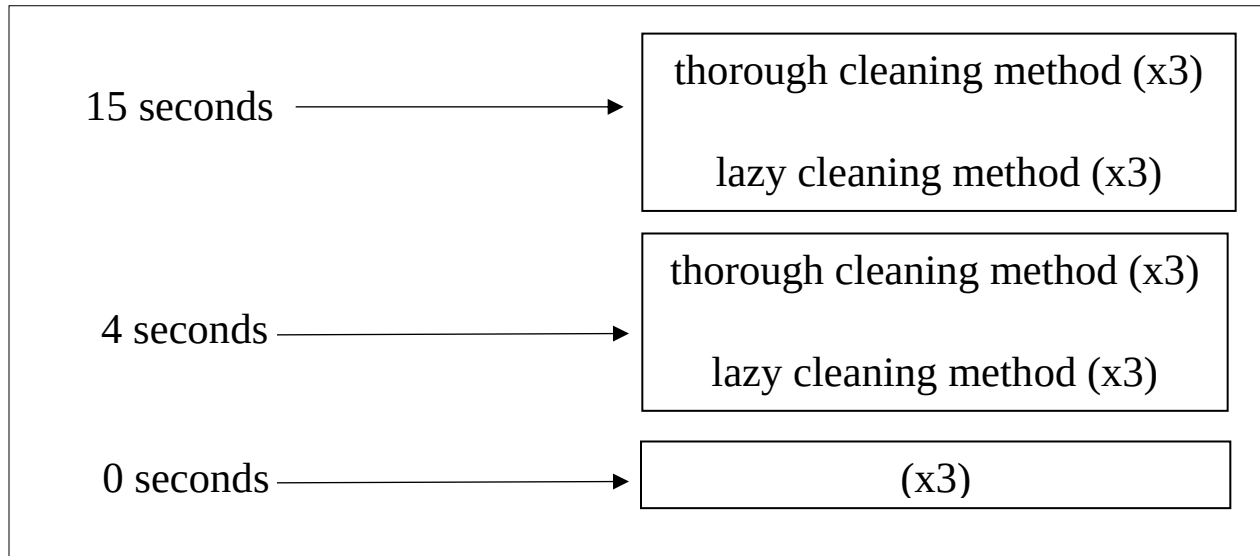


Figure 1. Diagram showing the methods that were used for cleaning. The amount of time the wipe was used is shown on the left and the type of cleaning method performed is shown on the right. The time of 4 seconds and the lazy cleaning method is representative of the most common type of disinfection method from the observational study.

Photographs were taken on an iPhone XS. Pictures of the handle and seat of each trial were taken separately. When taking pictures, the black light and iPhone were held in parallel approximately 16 inches above the surface. After photos were taken, the surface was completely wiped off with multiple disinfectant wipes and paper towels, ensuring that there was no remaining Glo-Germ on the surface. Pictures taken on the iPhone were transferred to a laptop and labeled with the date, method of cleaning, amount of time cleaned, and trial number (example- 1.15.20_lazy_4sec_2).

Pictures of the handles and seats of each trial were analyzed separately. While the seat and handle from the corresponding method and cleaning time are representative of one trial, the pictures are separate and were analyzed separately. The amount of Glo-Germ left on a surface in a picture was quantified using ImageJ. ImageJ was used to find CTCF (corrected total cell

fluorescence score). CTCF score is calculated in each picture by the integrated density minus the area times the mean fluorescence of the background readings.

T-tests were used to determine any statistical significance. A two-sided t-test found on the Social Science Statistics website found p-values for every given cleaning method and time versus the control (no cleaning). Mean values of the seat and handle from each grouping of both time and method were used.

Table 2. The table used in the observational study. Notes were taken on what equipment was being used, if that surface was being wiped with a disinfectant wipe, for how long the disinfectant wipes was being used and how the wiped was being used.

Results

Observational Study

Observations were made in the Wise Fitness Center at Allegheny College for a one-hour period for four weeks (Monday – Friday) at different times of the day. 25 individuals were observed from 6:45am – 7:45am, 49 individuals were observed from 12:15pm – 1:15pm, 81 individuals were observed from 5:00pm – 6:00pm, and 44 individuals were observed from 7:30pm – 8:30pm (Table 3). Three observations from the 7:30pm – 8:30pm category of time were taken from 7:00pm – 8:00pm due to the Wise Fitness Center closing on Fridays at 8:00pm. Observations were recorded on a word document based on the format shown in Table 2. The most frequently used piece of equipment was the treadmills (57 users), followed by the bikes (50 users), mats (49 users), and then ellipticals (43 users) (Table 4).

Time Period	Number of Observed Individuals (n=199)
6:45am – 7:45am	25 (12.6%)
12:15pm – 1:15pm	49 (24.6%)
5:00pm – 6:00pm	81 (40.7%)
7:30pm – 8:30pm	44 (22.1%)

Table 3. Observations about the number of users at different times is shown. The number and percentage of individual users that were present in the area of interest are calculated.

Observations found that out of the 199 observed users, 102 (51%) of them did not use a disinfectant wipe after use. 97 individuals did use a disinfectant wipe after use. Additionally, four individuals were found to have prewiped the surface before use. Of those four individuals, two of them used the same wipe after their use on the machine to wipe the surface down again. The average amount of time that a wipe is used on any given piece of equipment is 3.9 seconds.

Approximately 4.5% of individuals use the wipes for the advertised 15 seconds or more. The second most frequent time frame of using a wipe, behind zero seconds, was using a disinfectant wipe in the five to nine seconds time frame was the most frequent (Table 5).

Of the 57 individuals who used the treadmills, a wipe was used 49% of the time. 74% of the 37 individuals that used the bikes used a wipe. 12% of the 49 individuals that used the mats used a wipe. 60% of the 49 individuals that used the ellipticals used a wipe (Table 4).

Type of Equipment	Number of individuals that <i>did not</i> use a wipe (n=102)	Number of individuals that <i>did</i> use a wipe (n=97)	<i>Total</i> number of individuals use of equipment (n=199)
Elliptical	17 (16.7%)	26 (26.8%)	43 (21.6%)
Bike	13 (12.7%)	37 (38.1%)	50 (25.1%)
Treadmill	29 (28.4%)	28 (28.9%)	57 (28.6%)
Mat	43 (42.2%)	6 (6.2%)	49 (24.6%)

Table 4. Information about the amount of times a wipe is used based on the different surfaces is shown. The number and percentage of individual users that did or did not use a wipe on different surfaces is calculated. The percentages in the second column is representing the percentages that when a wipe was used, it was used on that surface. The percentages in the third column is representing the percentages that when a wipe was not used, it wasn't used on that surface. The far-right column is displaying how many total observed individuals used that piece of equipment. The percentage for the far-right column is calculated using the whole observed sample to display the percentages of the individual equipment use regardless of wipe use.

Time Frame a Wipe was Used	Number of Observed Individuals (n=199)
0 seconds	102 (51.2%)
1 – 4 seconds	20 (10.1%)
5 – 9 seconds	49 (24.6%)
10 – 14 seconds	19 (9.5%)
15 or more seconds	9 (4.5%)

Table 5. The number of times that a wipe was used is shown based off of the time frame that the disinfectant wipe was used.

Data was also collected on the method, the way in which an individual used the disinfectant wipe, that each individual used with the wipes. Of the 97 individuals that used a wipe, 60 of them wiped the surface by wiping over the main part of the surface in a linear motion once. 17 individuals wiped across the surface once but in a circular motion. 10 individuals wiped the surface by wiping in a linear motion down and back over the entirety of the surface. 4 individuals wiped the surface thoroughly, making sure to go over the surface more than once in a circular motion, but did not get the entire surface of the piece of equipment. 6 individuals used the wipe very thoroughly, making sure that all surfaces were cleaned by going over them multiple times in a circular motion (Table 6).

It was found that the most common type of disinfectant method that is employed by users is not using a wipe at all. Of those that used a wipe, the most common method of disinfectant method with the wipe was using it for 3.9 seconds by wiping in a linear motion over the main part of the equipment's surface once.

Method of Using the Disinfection Wipe	Number of Observed Individuals (n=199)
n/a (they did not use a wipe)	102 (51.3%)
Had a one swipe (one motion/wipe) across the surface	23 (11.6%)
Went down and around the surface in a circular motion	17 (8.5%)
Went down and back at least one (did not just swipe over the surface once)	10 (5.0%)
Had a one swipe (one motion/wipe) across the surface but did not get the entire surface	37 (18.6%)
Very thorough (wiped over surfaces more than once in a circular motion)	6 (3.0%)
Wiped over part of the surface thoroughly, but not the entirety of the surface	4 (2.0%)

Table 6. Information about the method in which an individuals used a wipe is shown. The cleaning method is shown on the left and the amount of individuals and calculated percentage of individuals that used that cleaning method is shown on the right.

Wipe Effectiveness

Corrected Total Cell Fluorescence (CTCF) scores were used to represent the amount of Glo-Germ present on surfaces under varying disinfectant methods. Scores were averaged for “lazy” cleaning method for 4 and 15 seconds, “thorough” cleaning method for 4 and 15 seconds, and no wipe being used. The “lazy” cleaning method is wiping over the surface once in a linear

motion. The “thorough” cleaning method is wiping of the entire surface in a circular motion, making sure that the wipe goes over the area of the surface more than once. If a wipe was used, the average cleaning method based on the observational study would be “Lazy (4 seconds)”. While seat and handle scores for the stationary bike are shown separately, each trial was done as one, but pictures of the seat and handle were analyzed separately (Figure 2).

Average CTCF score had a range of 1.45×10^7 – 3.57×10^7 . Using no wipe on the bike surface was found to be the least effective at removing Glo-Germ resulting in an average CTCF score of 3.19×10^7 for the handle and 3.57×10^7 for the seat. Thoroughly wiping for 15 seconds was found to be the most effect at removing Glo-Germ resulting in an average CTCF score of 1.45×10^7 for the handle and 1.61×10^7 for the seat. If a wipe was used, the average use of the wipe found from the observational study would be modeled as “Lazy (4 seconds)”. The average CTCF score for this cleaning method was found to be 3.13×10^7 for the handle and 3.02×10^7 for the seat (Figure 3).

Time that a wipe was used seemed to be more of a factor at altering CTCF score than method of cleaning. The average CTCF scores are more similar based off of time, 4 or 15 seconds then off of cleaning method, thorough or lazy (Figure 3). When comparing CTCF scores to the control of no wipe, scores that come from using a wipe for 4 seconds seem to be comparable to the control.

Statistical tests were run on the both the seat and handle scores from each cleaning method and time group. T-tests were run on all averages in comparison to the control. No p-values were greater than 0.05, indicating that there is not statistical significance and that there is no association between the amount of time a wipe was used and the method of cleaning that the

wipe was used and no cleaning at all (Table 7). Statistically, this would indicate that there was no one method of cleaning that was more effective than no cleaning.

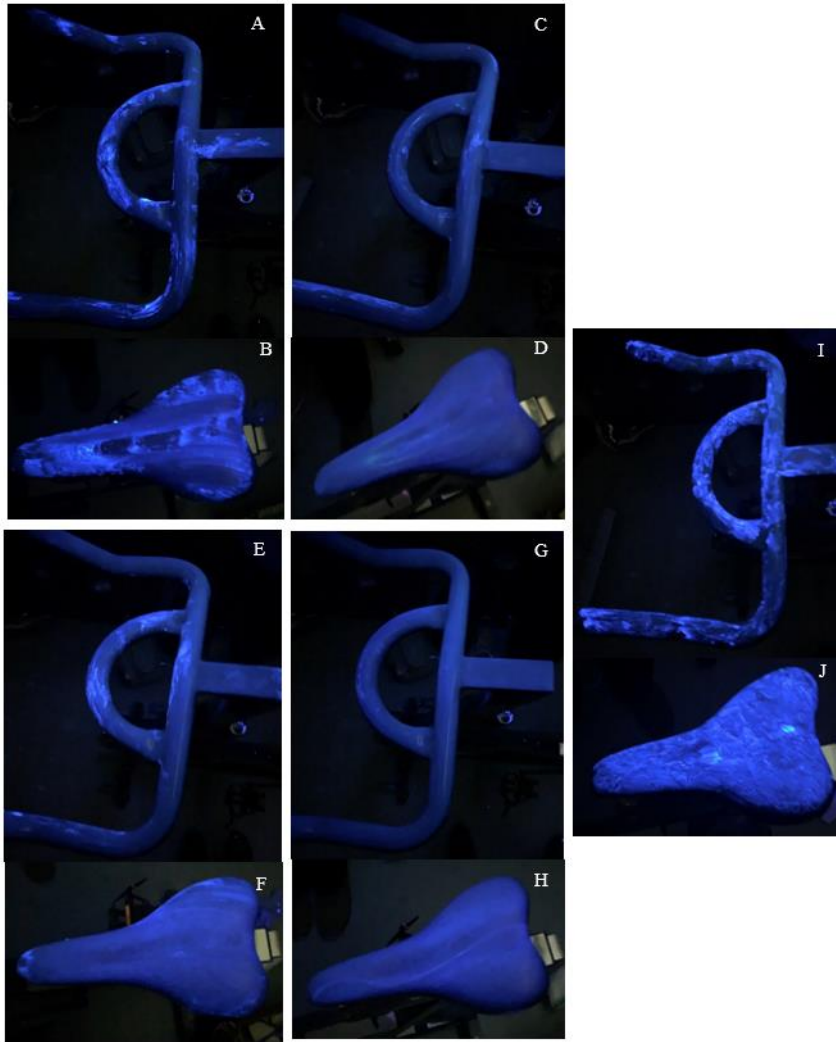


Figure 2. Pictures taken from the trials done on the stationary bikes. A black light was used to visualize the Glo-Germ on the equipment. Each handle and seat of a said cleaning method and time are from the same trial. A) The handle of a lazy cleaning method for 4 seconds. B) The seat of a lazy cleaning method for 4 seconds. C) The handle of a lazy cleaning method of 15 seconds. D) The seat of a lazy cleaning method for 15 seconds. E) The handle of a thorough cleaning method for 4 seconds. F) The seat of a thorough cleaning method for 4 seconds. G) The handle of a thorough cleaning method for 15 seconds. H) The seat of a thorough cleaning method for 15 seconds. I) The handle of no wiping. J) The seat of no wiping.

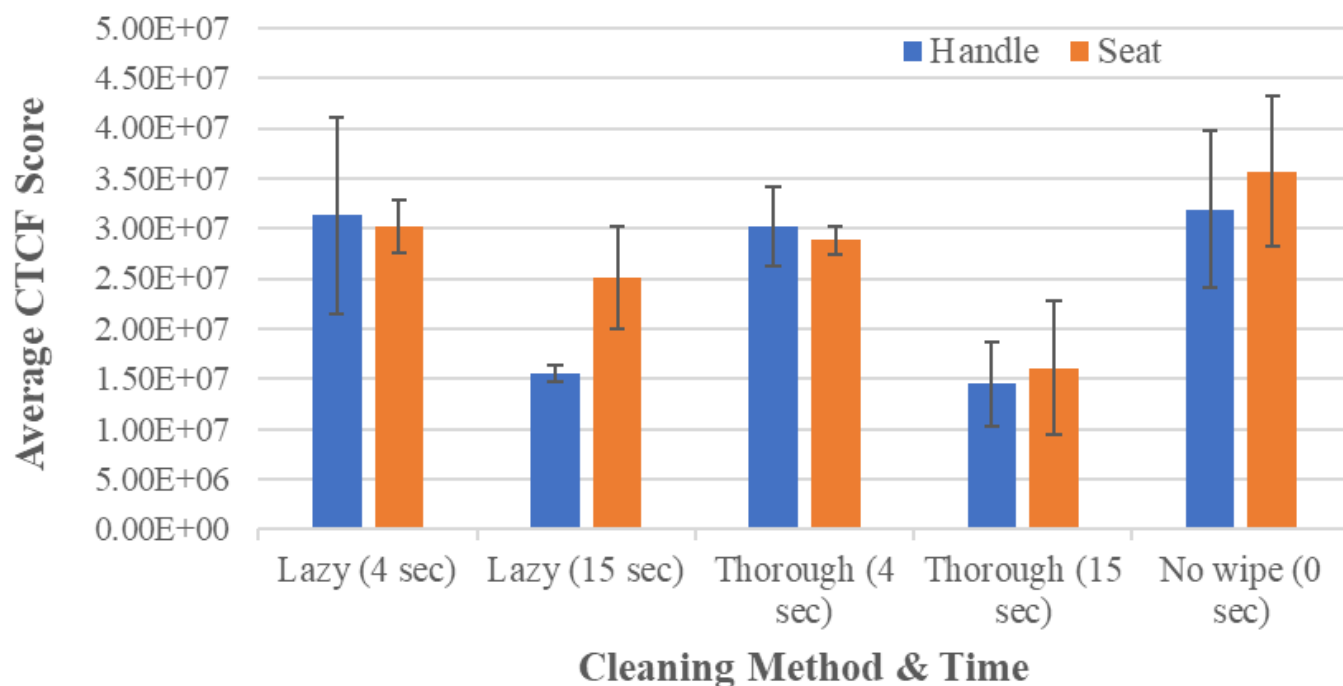


Figure 3. The average CTCF score for each of the cleaning methods and times is recorded. Each average is representative of three trials. Average CTCF score is represented on the y-axis. Average CTCF (Corrected Total Cell Fluorescence) is calculated using ImageJ by the integrated density – (selected area * mean fluorescence of background reading). The type of cleaning method and the amount of time a wipe was used is represented on the x-axis. Cleaning method can be described as lazy, wiping over the surface once in a linear motion, or thorough, wiping over the surface more than once in a circular motion. Handle and seat are shown to have a separate score, but both the seat and handle scores are representing one trial. Pictures of the handle and seat were taken and analyzed separately. Error bars represent standard error.

Type and Time of Cleaning Method	Average CTCF Score (seats)	Value from t-test (p-value)
Lazy (4 sec)	30198593	0.531969
Lazy (15 sec)	25086497	0.312889
Thorough (4 sec)	28760482	0.419750
Thorough (15 sec)	16117279	0.125411
No wipe	35658163	Control
Type and Time of Cleaning Method	Average CTCF Score (handles)	Value from t-test (p-value)
Lazy (4 sec)	31332277	0.963340
Lazy (15 sec)	15592148	0.107025
Thorough (4 sec)	30237905	0.854853
Thorough (15 sec)	14850610	0.127874
No wipe	31946734	Control

Discussion

Results showed that there are no significant ($p\text{-value} < 0.05$) differences between the cleaning groups when compared to the control (Table 7). The p-values given indicate that there are no associations between the type of cleaning method and no cleaning at all. These results

Table 7. Each cleaning method is shown with the average CTCF score. The top portion of the table represents the data taken from the seat pictures. The bottom portion of the table represents the data taken from the handle pictures. Average CTCF score is shown. The average was taken from three trials. CTCF score is calculated using the scores given from ImageJ by the integrated density – (selected area * mean fluorescence of background). T-tests were run with each group against the control to get the p-values.

indicate that under any cleaning method and any time, there is no significant difference in the amount of Glo-Germ pictured on a surface compared to no wiping at all (Table 7).

The average CTCF score does not seem to be determined by the method of cleaning, thorough or lazy. Looking at the average CTCF scores, the lazy (4 seconds) category is similar to the thorough (4 seconds) and the lazy (15 seconds) category is similar to the thorough (15 seconds) (Figure 3). Results from this would indicate that the method, thorough or lazy, doesn't play as important of a factor in the reduction of Glo-Germ as other variables.

Time that a wipe was used in a trial seemed to be more influential in lowering the amount of Glo-Germ present on the surfaces than method. Average CTCF scores for all trials done for four seconds, seemed to be similar to the average CTCF score of not wiping. Scores for both the lazy (4 seconds) and thorough (4 seconds) categories display similar trends to that of the no wipe category (Figure 3). Alternatively, trials that were done for fifteen seconds, both with the lazy cleaning method and thorough cleaning method, showed lower average CTCF scores than that of the no wipe trial. The p-values for the trials done for fifteen seconds, regardless of method, were lower than those trials in the four seconds trials (Table 7). Results show that the time seems to be an important component in reducing the amount of Glo-Germ on a surface.

If using a wipe for four seconds, regardless of cleaning method, seems to have no effect in the reduction of Glo-Germ, then using a wipe for this amount of time is just a waste of resources. It is less vital that users are wiping the surfaces by using the wipes with a thorough cleaning method and more vital that they are using them for a longer period of time. Having individuals use a wipe for at least fifteen seconds itself would almost ensure that they are wiping the surface completely and thoroughly as trying to "lazily" wipe over a surface is hard to do over a longer period of time. Likewise, studies have found that swiping across a surface with a

disinfectant wipe three or more times is an effective measure at killing bacteria on a surface (Berendt et al., 2011). Swiping across a surface for three or more times would likely indicate that the disinfectant wipe would be being used for a longer period of time than four seconds.

One component that is not taken into consideration when looking at the time needed for a disinfectant wipe to be effective is surface area. The EPA does not require that disinfectant towelettes put the maximum surface area wiped per towelette on their products. The amount of bacteria removed from the surface largely depends on the surface area wiped (West et al., 2018). There are a wide range of surface areas in the gym setting, so the wipes effectiveness and the recommended time that a wipe is used could be variable based on the surface that it is being used on.

While it would be ideal that disinfectant wipes in the Wise Fitness Center are being used for fifteen or more seconds, only 5% of individuals are using the disinfectant wipes for fifteen or more seconds. Additionally, more than half of individuals (51%) do not use a disinfectant wipe at all. With insufficient disinfectant techniques, there are a wide range of bacteria that are thriving on the gym surfaces (Weissfeld, 2015). The gym is a host to a wide range of microbial communities that are often the cause to mostly respiratory infections and skin infections (Weissfeld, 2015; Wood et al., 2015). Under the current cleaning practices in the Wise Fitness Center, individual wipe use is not sufficient at killing bacteria on the gym surfaces. Further disinfection measures or a change in the way the disinfectant wipes are being used is needed to help in stopping the spread of bacteria and disease.

Currently at the Wise Fitness Center it is individuals' responsibility to ensure that disinfectant wipes are being used. The Wise Center's policy states that, "users are required to wipe machines off after use" (Wise Center Brochure). With that in mind, much of the weights

and cardio equipment are not being wiped off with a disinfection wipe by the individual. This study did not look at the frequency of disinfectant wipe use on the weights, but other surfaces, like the mats, are often not wiped down after use (Table 4). The Wise Fitness Center does have a cleaning schedule in place that requires student employees to follow. Student employees are not required to go through training on how to clean the surfaces but are told that they are to make sure that every machine that is wiped down to look as if it is brand new. Rags and Proforce Lemon Fresh Disinfectant Cleaner are used as the disinfectant for cleaning the gym surfaces for student employees. The cleaning schedule is set up to ensure that all mats, benches, weight machines, spin room equipment, and cardio machine are wiped down once a day. There is not scheduled cleaning for the free weights in the weight room nor the equipment in the student athlete weight room. If there are users on the particular mat, bench, weight machine, spin room equipment, or cardio machine that is scheduled to be wiped down, it is skipped. This could indicate that even though machines are scheduled to be wiped, there is no real reassurance that they are being wiped down daily.

Having the combination cleaning of individuals using the disinfectant wipes and using the disinfectant cleaner with rags is a good strategy when looking into an ideal cleaning practice. It has been found that surfaces with a combination of cleaning practices is extremely effective at lowering the amount of bacteria. A surface that is wiped down with liquid soap followed by a chlorine solution is sufficient at reducing the contamination levels of pathogens below the targeted level for disinfectant products (Tuladhar et al., 2012). Additionally, communal gyms are recommended to have a wipe-down policy that ensures that all surfaces are sanitized at least once a day. Many gyms are sanitizing all of their equipment twice a day, once after the morning rush and again in the afternoon (Das). To further ensure that gym surfaces are as clean as

possible, users are even recommended to wipe down the surface themselves before and after use (Weissfeld, 2015). Ideally, individuals would use a disinfectant wipe before and after use to further ensure that the surface is sanitized.

Disinfectant wipes are not the only way to sanitize a surface in the gym setting. There are unique patented products that aim to lower bacteria on gym surfaces. Items like disposable single use gym workout gloves would help stop the spread of bacteria by blocking the hand's contact to the gym surface (Farago and Bog, 2010). Disposable covers for the hand grips and seats for most gym equipment would also act as a barrier between the individual and the gym surface (Del Sole, 2012). A non-disposable option could be the gym sports towel that is an antimicrobial towel that would be affixed to the gym surface, again being a barrier from the individual to the surface (Morris, 2009). These options seem to be unrealistic. Having to wear disposable gloves, changing out the cover on the seat and handles of equipment, or ensuring that there is an antimicrobial towel on the surface you are using seems inconvenient to users. Other gyms use spray bottles and towels as a disinfectant measure rather than wipes. Disinfectant sprays show low variability when compared to disinfectant wipes (Kenters et al., 2017). However, disinfectant sprays may be more likely to be used incorrectly because there are more variables that have to be accounted for than for disinfectant wipes. The spray method would have to ensure that users are spraying a right amount, spraying over the right amount of area, and are using the correct towel and wiping method. With the wipes, there are less variables that could be contributing to user error.

When looking into an ideal disinfectant, there are multiple things to consider. The best disinfectants have a broad spectrum, so they are able to kill a wide range of bacteria. They should additionally be rapid in their disinfection action and remain wet for the use of the product.

To ensure easy individual use, they should be in an easily accessible container. Disinfectants should also be nontoxic, have persistent disinfecting actions, are compatible to mostly all surfaces, have a low odor, and are economical (Rutala and Weber, 2016). When looking at the disinfection methods in the gym setting, they should also meet these recommendations. If one is looking at disinfection wipes in the gym setting, it would be important that individuals can easily access them, that they kill a wide range of bacteria in a short amount of time, be a wet wipe that is not toxic, has a low odor, works on all of the gym surfaces, and is economically friendly to buy (Rutala and Weber, 2016). The disinfection wipes in the Wise Fitness Center seem to adhere to these recommendations. The Reliance Wipes used are wet wipes and are stored in containers mounted to the wall to allow for individuals to pull and grab for use. They are advertised to be effective at killing a wide range of bacteria and are suitable for wiping down a variety of surfaces in gyms, fitness centers, health clubs, and athletic departments (ERC, 2017). They do not have any inherently toxic components, do not have much of an odor, and are advertised to be financially friendly and can save facilities money (ERC, 2017).

The disinfection wipes in the Wise Fitness Center seem to be valuable if they are being used and if they are being used for fifteen or more seconds. Looking at the gym setting, educating employees about bacteria that live on surfaces is shown to be an encouraging tool to have them develop good work practices. This in turn encouraged individuals to change their cleaning practices when using gym equipment (Cope, 2013). When looking at other ways to encourage individuals to use disinfectant wipes effectively, having signs and cleaning products readily accessible increase cleaning behavior (Elba and Ivy, 2018). Signs and the placement of cleaning products is more successful in increasing cleaning behavior in the gym setting than signs alone or having verbal announcements come on (Elba and Ivy, 2018). Posters have

additionally been found to be effective in the gym when using both descriptive and injunctive norms as well as subjective and university norms (Meade, 2015). Descriptive norms would entail what the typical patterns are and how people will then behave according to patterns. Injunctive norms would have the ideas that are approved and disapproved, so using a disinfectant wipe would be approved. Subjective norms would be having a group or person with power approving the behavior. Finally, university norms would involve what is the cleaning use norm at the Wise Fitness Center at Allegheny College. Having posters that display the “approved norm” of wiping down equipment after use will increase the amount of individuals that use the disinfectant wipes.

The IHRSA, International Health, Racquet and Sports club Association provides many guidelines for creating a healthy and clean gym facility. They advise that clubs keep a checklist of any cleaning that needs to be done daily and that a supervisor follows up to ensure that all tasks are done daily. Training is recommended for all employees working in the gym setting regularly to reinforce the important of ensuring that they are helping keep the facility clean and are aware of any new or altered procedures (IHRSA, 2008). They also recommend that the members of the gym are aware of their responsibilities as a user. Such recommendations could be done through postages, newsletters, or included in the contract upon getting membership (IHRSA, 2008).

Posters seem to be a strong and easy reminder to individuals about disinfection and wipe use. Mostly all of individuals know that disinfecting a gym surface is a desirable behavior, however many people still are not employing any disinfectant measures (Meade, 2015). Without intervention measures, the gym is a setting that will be an area that is a spot where much disease and bacteria transfer can happen. With the Wise Fitness Center being located on a college campus, it is at an even high risk for spreading infectious diseases (Prater et al., 2016). Just like it

is important that we teach and inform individuals of the proper handwashing techniques, it is also important that individuals are informed on proper wipe use (Prater et al., 2016). Without proper wipe use, the gym surfaces will continue to be a source of transmission for bacteria and disease. Communal gyms are particularly at risk for the transmission of certain disease such as MRSA (Cope, 2013). Fungal, viral, and bacterial infections thrive in environments like the gym (Brody, 2010). It is of importance that we look into the most effective way to disinfect surfaces in the gym setting to help stop the spread of disease transfer.

If I were to advise the most effective cleaning protocol, it would involve adding and altering current practices. To begin, I would advise that posters be used. Posters should be placed at convenient places, where individuals will be prone to look and respond to them. Such locations could be on the walls directly in front of users in the cardio room and doors that every individual must enter through to get to. Such posters should be attention grabbing and be distinctive from other posters. This could be done simply by making them slightly larger, using cardstock paper, or making them look more permanent, like being framed. They should also be attention grabbing, easily get to the point that they should use a disinfectant wipe, and support that using a disinfectant wipe is what the norm should be (Figure 4). In addition to the posters placed in these locations, it might additionally be useful to have smaller posters or reminders on the disinfectant wipe dispensers that instruct them to use the wipes for fifteen or more seconds (Figure 5). Since the posters on the walls and/or doors will remind individuals to use a wipe, the posters/graphics on the disinfectant wipe dispensers will remind them to use it for an effective amount of time.

It is a great start that the Wise Fitness Center has a cleaning protocol in place, but steps could be added to further improve the disinfectant measures. To begin, employees should be

given a hands-on training so they can visually be shown what it looks like to disinfect a surface completely. Such training could simply be a manager or supervisor showing them for five minutes how to properly clean the surfaces and briefly explain why it is important that they do such. It is important that this is not just a training done at the time of employment, but one that is done at the beginning of each school year, even if it is just a refresher for returning employees. The training would additionally teach employees how the different machines are labeled numerically and give them a general walkthrough of the cleaning schedule.

While the current cleaning schedule shows that all equipment be wiped down, if an individual is using a piece of equipment when it is supposed to be cleaned, it is skipped over. A revised cleaning protocol would require employees to write down and communicate that a certain piece of equipment wasn't wiped down, so it can be cleaned during the next shift. Such efforts will ensure that all equipment is cleaned daily. The final shift of the day should ensure that all surfaces were cleaned that day, and if not, they should address it by cleaning such surfaces (Table 8). Additionally, there needs to be a way that the free weights in the weight room are disinfected. A section in the newly revised cleaning protocol will help address this problem (Table 8). The disinfection of the surfaces in the athlete weight room is more complex as there are varying teams that are scheduled to be in the room at different times every day. There would need to be information available to employees and managers about when the room is unoccupied so there can be times when the surfaces are cleaned.

While the study was able to visualize the effectiveness of disinfectant wipes there were still limitations. Glo-Germ is an accurate visual representation, but bacteria itself was not tested on the surfaces. Additionally, only bikes in the spin room were examined in regard to wipe effectiveness. There could perhaps be differences in the disinfectant wipe effectiveness across

the surfaces in the gym setting. There was a small sample size in this study, so increasing this would further support or disprove the results shown here. The use of disinfectant wipes was only based on observations made on the users in the Wise Fitness Center on the campus of Allegheny College, which has a majority of college aged users. Additionally, this study only looked into presenting and proposing an improved disinfectant protocol but was never followed up in the protocol was put in place or worked.

Based off of this study, there are multiple directions that future research could go into examining further. There could perhaps be variations in wipe effectiveness depending on the surface composition. In the future, looking at the differences, if any, that there are in wipe effectiveness based on the surface that they are used on could be done. Another area that could be further explored is the time that the wipe is used. What could be done is looking at the wipe effectiveness over a wide range in times to see if there is a minimum and maximum time that the wipe could be used for maximum effectiveness. The disinfectant wipes in this study could also be tested in comparison to other disinfectant measures that are in place in the gym setting, like a spray and towel. There are often times that when users go to take one of these wipes in the Wise Fitness Center, that they end up taking more than one because the wall dispenser is not always consistent at making it completely user friendly to take only one wipe. It could further be looked into if there are any advantages or disadvantages to taking and using more than one wipe. Finally, it could be looked into if a disinfectant protocol, like the one presented, is successful or not in increasing proper disinfectant wipe use and cleaning procedures in the gym setting.

Having proper disinfection methods in place is a vital step in stopping bacteria transfer and therefore lowering the rate of the spread of disease. Communal surfaces, like the gym, are prone to be areas that have a high bacterial load (Ryan et al., 2011). Without proper disinfection

methods in place, the bacteria will continue to thrive and spread on these surfaces. The proper disinfection protocol is of importance when looking to keep communities healthy.



Figure 4. Example poster of what could be hung on the walls and/or doors.



Figure 5. Example poster of what could be placed on the disinfectant wipe dispensers.

<i>Building Monitor Checklist</i>					
	Upstairs Cardio Room	Downstairs Weight Room/ Blue Courts/ Spin Room		Initials of Employee	Anything not cleaned?
6:00am	Turn on lights; restock wipe dispensers; check equipment for any errors	Turn on lights; restock wipe dispensers; report any equipment left out from previous evening	Put hoops down and curtains up; restock wipe dispensers; report any equipment left out from previous evening		
7:00am	Wipe down cardio machines 1, 2, 3; return unused equipment to proper storage	Wipe down mats and benches; return unused equipment to proper storage	Wipe down Lifefitness strength machines 1, 2		
8:00am	Pick up and discarded trash; look for any items left behind and place in Lost & Found	Reorganize weights on Rack 1 (if not in use) and wipe the weights; return unused equipment to proper storage	Wipe down all Physio and Bosu Balls, Wipe down mats and return to holders		
9:00am	Wipe down cardio machines 4, 5, 6; return unused equipment to proper storage	Reorganize weights on Rack 2 (if not in use) and wipe the weights; return unused equipment to proper storage	Wipe down Lifefitness strength machines 3, 4		
10:00am	Return unused equipment to proper storage; wipe down blue mats	Reorganize weights on Rack 3 (if not in use) and wipe the weights; return unused equipment to proper storage	Wipe down all upholstered equipment (benches and plyo boxes) inside weight rooms		
11:00am	Wipe down cardio machines 7, 8, 9; return unused	Remove plate weights from machines; reorganize plate	Wipe down Lifefitness strength machines 5, 6;		

	equipment to proper storage	weight towers; wipe plate weights return unused equipment to proper storage	Wipe down equipment in spinning studio		
12:00pm	Pick up and discarded trash; look for any items left behind and place in Lost & Found	Reorganize dumbbell rack and wipe down; return unused equipment to proper storage	Go through the Blue Courts (including behind the curtains) and bring all the balls back to the bin by the front desk.		
1:00pm	Wipe down cardio machines 10, 11, 12; return unused equipment to proper storage	Wipe down mats and benches; return unused equipment to proper storage	Wipe down Lifefitness strength cable towers		
2:00pm	Return unused equipment to proper storage; wipe down blue mats	Reorganize weights on Rack 1 (if not in use) and wipe down; return unused equipment to proper storage	Wipe down all Physio and Bosu Balls, wipe down mats and return to holders		
3:00pm	Wipe down cardio machines 13, 14, 15; return unused equipment to proper storage	Reorganize weights on Rack 2 (if not in use) and wipe down; return unused equipment to proper storage	Wipe down Lifefitness strength machines 7, 8		
4:00pm	Pick up and discarded trash; look for any items left behind and place in Lost & Found	Reorganize weights on Rack 3 (if not in use) and wipe down; return unused equipment to proper storage	Wipe down all upholstered equipment (benches and plyo boxes) inside weight rooms		
5:00pm	Wipe down cardio machines 16, 17, 18; return unused equipment to proper storage;	Reorganize dumbbell rack and wipe down; return unused	Wipe down Lifefitness strength machines 9, 10		

	wipe down blue mats	equipment to proper storage			
6:00pm	Return unused equipment to proper storage; wipe down mats	Reorganize weights on Rack 1 (if not in use) and wipe down; return unused equipment to proper storage	Go through the blue courts (including behind the curtains) and bring all the balls back to the bin by the front desk.		
7:00pm	Wipe down cardio machines 19, 20, 21; return unused equipment to proper storage	Reorganize weights on Rack 2 (if not in use) and wipe down; return unused equipment to proper storage	Wipe down Lifefitness strength machine 11; reorganize tower handles and attachments		
8:00pm	Pick up and discarded trash; look for any items left behind and place in Lost & Found	Reorganize weights on Rack 3 (if not in use) and wipe down; return unused equipment to proper storage	Wipe down Lifefitness strength cable towers		
9:00pm	Wipe down cardio machines 21, 22, 23, 24; return unused equipment to proper storage	Remove plate weights from machines; reorganize plate weight towers; wipe down plate weights; return unused equipment to proper storage	Wipe down equipment in spinning studio; return unused equipment to proper storage; assess tidiness of dance studio and report incidents		
10:00pm	Return unused equipment to proper storage; wipe down mats; turn off lights; prepare for closing	Reorganize dumbbell rack and wipe down; return unused equipment to proper storage; turn off lights; prepare for closing	Check lockers by Blue Courts for left items and put in Lost & Found; return unused equipment to proper storage; prepare for closing		

Date		Checked by supervisor	
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Figure 8. Revised cleaning schedule and protocol from the current cleaning schedule in place in the Wise Fitness Center. Machines numbers and labels are able to be identified by employees via the map that they are given.

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