The Healthy Workplace Project: Reduced Viral Exposure in an Office Setting

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Abstract

Viral illnesses like gastroenteritis and the common cold create a substantial burden in the workplace due to reduced productivity, increased absenteeism, and increased health care costs. Behaviors in the workplace contribute to the spread of human viruses via direct contact between hands, contaminated surfaces and the mouth, eyes, and/or nose. This study assessed whether implementation of the Healthy Workplace Project (HWP) (providing hand sanitizers, disinfecting wipes, facial tissues, and use instructions) would reduce viral loads in an office setting of approximately 80 employees after seeding fomites and the hands of volunteer participants with an MS-2 phage tracer. The HWP significantly reduced viable phage detected on participants' hands, communal fomites, and personal fomites (p 0.010) in office environments and presents a cost-effective method for reducing the health and economic burden associated with viral illnesses in the workplace.

Introduction

Common illnesses such as colds, influenza, and gastroenteritis significantly impact health care costs, absenteeism, and productivity among workers.[1,2] Adult influenza infections alone result in approximately $87 billion per year in healthcare costs, projected lost earnings and loss of life.[3] These infections result in an average of <1 to 5.9 lost working days, with higher losses in older and hourly workers.[4,5] Even if an employee is not absent, significant losses in productivity can occur, accounting for as much as 64% of the overall economic impact of worker illnesses.[2] Although emerging infectious disease models frequently target the workplace as an important source of transmission, little information is available on pathogen spread and mitigation strategies in the workplace.[6,7]

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According to the National Occupational Research Agenda (NORA), developed by the National Institute for Occupational Safety and Health (NIOSH) and more than 500 stakeholders, one of the top research priority areas for reducing work-related illnesses is reduction of communicable infections in indoor working environments.[8] Annual influenza vaccination has been an effective intervention promoted by many businesses to reduce economic costs associated with illness.[9] However, vaccine interventions are not available for the common cold and many other enteric maladies. Thus, alternative mitigation strategies aimed at preventing pathogen transmission and persistence in the workplace need to be evaluated.

Office environments include many common areas and shared resources (i.e., break rooms, photocopying machines, conference rooms and restrooms) that may serve as sites for the spread of infectious diseases. Pathogens are spread by infected individuals touching surfaces or by the settling of droplets disseminated through sneezing or coughing.[10] Once deposited onto surfaces, they may persist for hours to months and spread to other individuals via contact with contaminated surfaces and infection sites (i.e., nose, mouth, or eyes).[11–13]

Although fomite contamination and hygiene interventions have been evaluated in school, hotel and hospital environments,[14–17] few studies have focused on the public health impact of office hygiene practices.[18–20] The purpose of the current study was to quantitate the effectiveness of a hygiene program, known as the Healthy Workplace Project (HWP), in reducing transmission of viruses in the office environment. Phage tracers were used to monitor changes in virus transmission through the workplace before and after implementation of the HWP.

Materials and Methods

Two baseline and two post-intervention studies were conducted in a 30,000 square foot office building with 80 active employees, 41 individual offices and 116 cubicles. The building has one main and two side entrances and one shared kitchen and conference room. Workers were selected based on their consent to participate. At baseline, the subjects conducted their standard office hygiene practices. For the Healthy Workplace Project (HWP), subjects were provided with facial tissues (Kleenex® Anti-Viral Facial Tissue; Kimberly-Clark Worldwide, Neenah, WI), hand sanitizer (Kleenex® Moisturizing Instant Hand Sanitizer, with desktop and electronic floor dispensers; Kimberly-Clark Professional, Roswell, GA), surface disinfectant wipes (Scott® Disinfectant Wipes; Kimberly-Clark Professional, Roswell, GA) and written instructions (Table 1). The HWP promoted the use of disinfectant wipes in communal areas and personal workspaces, using hand sanitizer periodically to disinfect hands, and using tissues when blowing/wiping the nose in addition to proper hand washing practices.

During one baseline and one post-intervention study, the office entrance door push plate was seeded with 6×10^9 PFU (plaque forming units)/cm^2 of MS-2. During another baseline and post-intervention study, one randomly selected, blinded participant's hand was seeded with 3×10^8 PFU/cm^2 of MS-2 virus while nine other participants' hands were wetted with a placebo solution (1X phosphate buffered saline pH 7.4). Participants were asked to rub the

palms of their hands together until the solution dried. The seeded surface (hands or push plate) was re-inoculated after two hours, and designated fomites and volunteers' hands were sampled after four hours. Measurement of MS-2 from the seeded volunteer's hands was excluded from the analysis.

During the course of this study, 36 communal fomites, and 18 personal fomites were selected for sampling before and after implementation of the HWP (pre-intervention and post-intervention). Targeted fomites included communal (i.e., doorknobs, toilet handles, and light switches) and commonly-contacted surfaces (i.e., personal telephones, computer mice, and desk chair armrests).

Of the 80 potential site employees, 25 (50 hands) were selected for sampling during each baseline study and 22 (44 hands) participated in the HWP and were sampled during each post-intervention study. Other employees were present but did not directly participate in the intervention. Fomite and hand samples were collected using sterile 3M™ Swab-Samplers with 1 mL of Letheen broth (RS9601LET; 3M Corporation, St. Paul, MN). Separate swabs were used to sample each hand. All 10 fingertips were sampled, representing a total area of approximately 10.0 cm^2.

MS-2 (ATCC 15597-B1 bacteriophage) was analyzed using the double-layer agar technique with *Escherichia coli* C-3000 (ATCC 15597; American Type Culture Collection, Manassas, VA) host.[15] Samples were diluted and plated for analysis with a detection limit of 10 PFU per area sampled.

Data analysis was performed using STATA® 11 (StatCorp, College Station, TX). An odds ratio was computed to assess whether the intervention significantly reduced the detection of phage on fomites and hands. Because the data were not normally or log-normally distributed, a Wilcoxon signed-rank test for paired samples was used to determine whether the intervention significantly reduced the measured levels of phage. Statistical significance was defined as $p<0.05$.

Results

The results of the pre-intervention and post-intervention analysis indicate that the HWP significantly reduced the presence of phage on communal fomites and on employees' hands (Tables 2 and 3). The percent of personal and communal fomites testing positive for the seeded phage in the combined trials was reduced from 47% to 19% and 51% to 5%, respectively. The percent of hands positive for phage in the combined trials was reduced from 38% to 11%. Although the presence of phage on personal fomites was significantly reduced for the combined trials, a statistically significant reduction was not achieved in one of the individual trials.

The HWP also significantly reduced the concentration of phage measured on communal fomites and hands (Tables 4 and 5). The reduction in phage levels resulting from the intervention was attenuated for personal fomites. All of the personal fomite samples came from only 4 workspaces, and individual variability may have a substantial influence on the effectiveness of the HWP in personal spaces. However, the significant reduction of virus on

communal fomites did result in a significant overall decrease in virus detected on hands, including the hands of those individuals whose personal fomites were sampled.

Discussion

Implementation of the HWP resulted in a significant reduction in the spread of phage on surfaces and hands in an office workplace, suggesting a corresponding reduction in the risk of human virus transmission. No other studies have been published evaluating the effectiveness of an intervention in reducing microbial transmission in an office environment. Thus, the current study appears to be the first to explore this important economic and public health issue. During Trial 1 for both the baseline and intervention, only one seeded participant's hands prompted contamination of more than half of all communal and personal fomites tested, as well as one quarter of the hands, within four hours. Seeded hands were more effective at spreading the phage than the initial seeding of a commonly touched surface (i.e., the entrance door push plate). This observation demonstrates the potential for rapid spread of infectious agents from only one infected person when proper preventive hygiene measures are not employed.

A significant reduction in the percent of surfaces or hands testing positive, and the concentration of phage detected, was observed for all fomites except those in the personal fomites category. All of the personal fomite samples came from personal areas of only 4 workers suggesting that individual compliance with the HWP may have varied, resulting in a greater effect on the phage presence. However, given the significant reduction of phage detected on communal fomites and employee hands, a failure by some workers to fully comply did not appear to reduce the overall effectiveness of the intervention.

Phage are a safe tracer model to assess routes of human viral transmission and are preferred to a chemical due to the ability to measure viability and die-off. In order to serve as an appropriate surrogate for pathogen transmission, it is also important that the phage behave similarly in the environment. MS-2 phage was selected for this study because of its similar shape and size to many human enteric and respiratory viruses and its stability in the environment (Table 6).[22–24] Based on previous studies where the observed inactivation rate for MS-2 and influenza was nearly 0 and approximately 0.1 log per hour, respectively, it was assumend in this study that human viruses and bacteriophage survive and are transmitted similarly in an office setting.[25] Thus, it was expected that significant reduction of MS-2 would not occur over a period of only a few hours. The assumption that MS-2 is representative of common human viral pathogens in terms of transmission is supported by the work of Sattar et al., who examined rotavirus survival on fomites and showed no measurable reduction in viable rotavirus after a 3-hour period.[26] The small size of MS-2 and lack of an envelope are similar to the structures of both rhinovirus and norovirus. When comparing MS-2 to the larger, more complex structures of the influenza virus, MS-2 is expected to be more resistant to inactivation, therefore overestimating the occurrence of more fragile viruses.

Selected methods of sampling environmental fomites may also have contributed variability to the results. A previous study conducted by Julian et al. demonstrated that of the

commonly available swabs, those with a polyurethane tip moistened with either water or Letheen broth produced the greatest mean MS-2 recovery when sampling smooth fomites.[27] The mean fraction of MS-2 recovered using growth media, which included Letheen swabs, was 0.29 for stainless steel and 0.39 for plastic. The standard deviation of fraction recovered from both stainless steel and plastic surfaces was equal to 0.13. Therefore, poor recovery efficiencies may contribute to an underestimation of viruses present.

The total amount of phage seeded onto the hands and push plate after drying (10^6 PFU) is consistent with the amount commonly isolated from 0.01 to 0.001 g of feces from an infected person with gastroenteritis.[28] Respiratory viruses, which are more likely to be found on contaminated surfaces in office buildings, are excreted in slightly lower numbers (10^5 to 10^6 PFU /ml) in mucus[28–30] Thus, the seeded level of virus used in this study is consistent with amounts that might reasonably be transmitted by an infected individual. Because the detection limit was sometimes not reached due to sampling of surfaces less than the targeted 225 cm^2 area, the seeded concentration of phage should be increased by at least a factor of 10^2 PFU in future studies. A larger seed concentration would increase the number of circulating viruses and reduce the number of pre-intervention samples with nondetect values. This would ensure that viruses would remain detectable even for fomites with swab areas 25 cm^2 and would improve evaluation of the HWP effectiveness in reducing virus transmission. The phage used in this study is not pathogenic to humans and therefore does not directly quantify the reduction of risk from human pathogens in the office setting. Nicas et al. developed, but did not validate, a model for assessing infection risk resulting from pathogens transferred to target facial membranes via contact with contaminated surfaces.[31] The phage surrogate data reported here, was recently used to validate this model and assess the efficacy of the HWP at variable phage levels and below the current limit of detection.[20]

Implementation of the HWP (i.e., providing hand sanitizer, disinfecting wipes, facial tissues, and simple instructions to office employees to alter behavior) was shown to significantly reduce the detection of phage on communal fomites and hands. This demonstrates that the HWP could reduce the potential risk of infection from common enteric and respiratory pathogens that are frequently responsible for absenteeism and loss of productivity in the workplace. Unlike vaccination programs that are designed to reduce illness from a single pathogen, the HWP could simultaneously reduce the risk of infection for multiple pathogens. In this study, only 41 of the 80 total employees participated in the intervention. Greater health benefits could also be realized if the intervention were implemented across the entire employee population and over a greater duration of time. Therefore, future studies should focus on increasing compliance with the HWP in office workers.

Acknowledgments

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Table 1

The Healthy Workplace Project* Program

Type	Description
Individual	<u>Hand Sanitizer</u> – use daily upon entering and leaving the office; before and after shaking hands, after touching frequently-touched surfaces and after touching nose or face,
	<u>Hand washing</u> – wash hands for 15 seconds with soap and water and dry with a clean paper towel after using the restroom and before eating food
	<u>Tissues</u> – use to wipe or blow your nose
	<u>Surface wipes</u> – use to wipe down personal keyboard, mouse, phone and desk at the beginning of each day
Communal	<u>Surface wipes</u> (conference room) – wipe down the conference room table before starting a meeting; (kitchen) – use to wipe down frequently touched items in the break room like refrigerator handles, microwave handles and buttons, coffee pot handles, vending machine buttons and tables
	<u>Hand sanitizer</u> (conference room) – freely available for use; (at all exterior entrances) – freely available for use from self-dispensing floor stands
Informational	<u>Promotional signs</u> were placed on hand sanitizer dispensers and in bathrooms, conference rooms, kitchens, and other common areas with statistics on effective workplace hygiene interventions
	Intervention instructions were posted in all conference rooms and kitchen

Table 2

Frequency and Odds Ratio of Phage Detection on Fomites

	Personal Fomites				Communal Fomites			
	N	%[a]	OR[b]	95%CI[c]	P	N	%[a]	OR[b]	95%CI[c]	P
Baseline 1[d]	18	56	ref			36	56	ref		
Intervention 1[d]	18	17	0.16	0.02, 0.91	0.02	36	6	0.05	0.01, 0.24	<0.0001
Baseline 2[e]	18	39	ref			35	46	ref		
Intervention 2[e]	18	22	0.45	0.08, 2.38	0.28	35	9	0.11	0.02, 0.48	0.0005
Baseline 1+2	36	47	ref			71	51	ref		
Intervention 1+2	36	19	0.27	0.08, 0.86	0.01	71	5	0.07	0.02, 0.22	<0.0001

[a]Percent of total samples where phage was detected

[b]OR is odds ratio

[c]95% confidence interval

[d]During baseline 1 and intervention 1 a hand was seeded with phage

[e]During baseline 2 and intervention 2 a door was seeded with phage

Table 3

Frequency and Odds Ratio of Phage Detection on Hands

	N	%[a]	OR[b]	95%CI[c]	P
			Hands		
Baseline 1[d]	50	38	ref		
Intervention 1[d]	42	7	0.13	0.02, 0.49	0.0005
Baseline 2[e]	50	38	ref		
Intervention 2[e]	44	14	0.26	0.08, 0.79	0.008
Baseline 1+2	100	38	ref		
Intervention 1+2	86	11	0.19	0.08, 0.44	<0.0001

[a] Percent of total samples where phage was detected

[b] OR is odds ratio

[c] 95% confidence interval

[d] During baseline 1 and intervention 1 a hand was seeded with phage

[e] During baseline 2 and intervention 2 a door was seeded with phage

Table 4

Distribution of Phage (PFU) on Fomites

	Personal Fomites					Communal Fomites					
	Min	25th	50th	75th	Max	P	Min	25th	50th	75th	Max	P
Baseline 1[a]	ND[c]	ND	20	100	28000	0.10	ND	ND	10	120	5800	<0.0001
Intervention 1[a]	ND	ND	ND	ND	TNTC[d]		ND	ND	ND	ND	60	
Baseline 2[b]	ND	ND	ND	160	15400	0.03	ND	ND	ND	50	1680	0.001
Intervention 2[e]	ND	ND	ND	ND	580		ND	ND	ND	ND	210	
Baseline 1+2	ND	ND	ND	125	28000	0.005	ND	ND	10	110	5800	<0.0001
Intervention 1+2	ND	ND	ND	ND	TNTC		ND	ND	ND	ND	210	

[a]During baseline 1 and intervention 1 a hand was seeded with phage

[b]During baseline 2 and intervention 2 a door was seeded with phage

[c]None detected

[d]Too numerous to count

Table 5

Distribution of Phage (PFU) on Hands

	Hands					
	Min	25th	50th	75th	Max	P
Baseline 1[a]	ND [c]	ND	ND	40	3200	0.005
Intervention 1[a]	ND	ND	ND	ND	57000	
Baseline 2[b]	ND	ND	ND	20	23600	0.02
Intervention 2[b]	ND	ND	ND	ND	680	
Baseline 1+2	ND	ND	ND	35	23600	0.003
Intervention 1+2	ND	ND	ND	ND	57000	

[a] During baseline 1 and intervention 1 a hand was seeded with phage

[b] During baseline 2 and intervention 2 a door was seeded with phage

[c] None detected

Table 6

Physical Characteristics of MS-2 and Human Viruses (29–33)

	Enteric Viruses		Respiratory Viruses		Tracer Phage
	Norovirus	**Rotavirus**	**Influenza**	**Rhinovirus**	**MS2**
DNA/RNA	RNA	RNA	RNA	RNA	RNA
Size	7.5 kb	38 kb	13 kb	7 kb	4 kb
Structure	Nonenveloped	Internal Lipid in Capsid	Enveloped	Nonenveloped	Nonenveloped