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RESEARCH ARTICLE

The Effects of Hygiene Standards Pre- and Post-COVID-19 Shutdown on Fever and Diarrhea Incidence in a Daycare

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ABSTRACT

Background: One of the most broadly available forms of child care in the United States is a childcare program (CCP). Because of the nature of CCPs, children and their caregivers interact closely within confined spaces, creating opportunities for infectious agent transmission. We hypothesized that a reduction in the room's population density due to requirements related to the COVID-19 outbreak would lead to a reduction in incidence of disease symptom presentation.

Methods: For this observational study, data were collected beginning in January 2018 and lasting until May 2021 from a university-run CCP. Searches of email communications between caregivers and parents were conducted to look for disease exposure notices and phrases related to enteric illness. Zero-inflated Poisson models were used to look for significant influences affecting incidence rates.

Results: Our modeling found limited evidence for seasonality in fever and diarrhea incidence rates. However, there was significant evidence that an increase in attendance was associated with a decrease in fever and an increase in diarrhea incidence. The data also indicated lower fever incidence before the COVID-19 shutdown with an increase in fever incidence as time after shutdown increased.

Conclusion: This study shows evidence of a relationship between rising attendance and increasing transmission events and begins to quantify the impact of CCPs on disease transmission in infants.

Keywords: Infant; Fever; Diarrhea; COVID-19; Observational study

INTRODUCTION

In many family households in the United States today, it is typical for both parents to maintain full-time jobs, whether at home or another workplace, leaving a need for some form of childcare. Enrolling an infant in a childcare program (CCP) is often a necessary step for working families, however, it comes with an increased risk of exposure to diseases for both the infants and their parents. As a result, CCPs and the agencies that license them often have policies in place to reduce the spread of disease. For example, infants affected by diarrhea are prevented from attending CCPs, leaving their parents to either find alternative care or remain at home to care for their ill children. Children attending CCPs are at an increased risk of hospitalization from gastroenteritis within their first 12 months of attendance.[1] Parents are also at risk of being affected by infectious diarrheal and febrile diseases; one study showed that of a combined 28 cases per 100 child-months of diarrheal and respiratory illnesses, the illness was transmitted to parents an average of 6 times.[2] The COVID-19 pandemic brought

evidence-based hygiene to the forefront of the public's consciousness, with a particular focus on increasing diligence to prevent disease transmission.

A COVID-19-related CCP shutdown and subsequent reopening with added sanitary measures in place allowed us a unique opportunity to study the downstream effects directly contrasted against pre-pandemic events. We investigated records, email communications between families and staff, and exposure notices at a university-based CCP between January 2018 and May 2021. Illness events were separated into a "pre-shutdown" and "post-shutdown" period, delineated by its COVID-19 related shutdown which occurred from April through May 2020. The investigation into the email communications consisted of a series of searches for keywords indicating diarrhea or febrile illness. The CCP, according to state licensing requirements,[3] posted exposure notices outside of any rooms with diagnosed infectious diseases to inform parents and staff of infectious disease events.

The objective of this study was to examine diarrheal and febrile disease transmission before and after the COVID-19 CCP closure, when changes in health policies on group sizes, disinfection, and personal protective equipment created a natural experiment. This was to directly test our hypothesis that the reduced class sizes would lead to a reduction in incidence of enteric disease symptoms. A secondary objective was to explore potential causative agents for diarrheal and febrile illnesses causing the observed pattern.

METHODS

Information was gathered by searching the official classroom email accounts of caregivers at the CCP. A keyword search was used to find correspondence between staff and parents pertaining to potential cases of diarrheal disease in infants enrolled at the CCP. Distinction was made between diagnosed diseases (exposure notices) and symptoms noted by caregivers and parents. Additionally, the metadata were examined for number of children present each day, season of the year, pre- versus post-shutdown, and time since shutdown to test our hypothesis in the presence of potential confounding variables. This study used the CCP policy's definition of diarrhea as 3 or more consecutive cases of diarrhea, which closely mirrors the World Health Organization (WHO) definition of 3 or more loose stools in a 24-hour period.

Study Site

The study took place at a CCP run by the Office of Human Resources at The Ohio State University between January 1, 2018, and May 31, 2021. The program cares for children from newborn through 5 years of age. This facility has 3 preschool rooms (age 3 to 5 years), 2 toddler rooms (18 months to 3 years), and 3 infant rooms (newborn to 18 months). The CCP Family Handbook states that infant and toddler rooms have groups up to 10 with a staff-to-child ratio of 1:4 for infants and 1:5 for toddlers, and the preschool rooms have up to 18 children with a 1:9 staff ratio.[3] This study focused on infants up to 18 months of age in the 3 infant rooms.

Study Design and Participants

This CCP was selected because it was a partner center with the university, allowing for ease of access with an existing relationship from a trusted partner. Consent of parents was not required for this study as there were no human subjects involved.

Data Collection

Data (date, room, and symptom) were collected at the individual level, without identifiers to protect the privacy of persons involved, and aggregated by room. The selected daycare has children grouped in cohorts which move together with their caregiver to the next room when they age out of their current room. Therefore, each room is designed and tailored to meet the needs of the age group currently occupying it, while having the same caregiver gives the children some stability. For ease of use, meteorological dates were used to mark the start of a season. This system marks the beginning of a season as being the first day of the month in which the equinoxes and solstices occur.

Email Correspondence

To calculate the incidence of diarrheal disease symptoms in infants at CCP, we examined email data from the center between January 2018 and May 2021. Caregivers in infant rooms at CCP used Microsoft Outlook (Microsoft Outlook for Microsoft 365 MSO, Version 2205 16.0.15225.20172) to communicate with parents about absences and closures. To reduce disease transmission, CCP follows state guidelines on refusing entrance to caregivers and children who exhibit signs of illness, as well as sending home early any children who have at least 101 °F temperature, 3 consecutive diaper changes showing diarrhea, vomiting more than once, or showing other signs of communicable diseases during their time under care.[4] Notifications of early dismissal due to illness are sent from each individual room's designated company email address. In addition, parents often communicate to caregivers through these email addresses if they are keeping their child home due to illness. It is the center's policy to not delete or clear any of their sent or received messages.

There were 2 data collection searches completed using the Outlook desktop application, with the first looking at data from January 1, 2018, to August 31, 2020. For the months of April and May in 2020, the daycare was closed to comply with the nationwide shutdown, so no results were found for this period. The search terms used for the first collection were limited to the keywords "diarrhea" and "fever." Emails retrieved from the search were viewed and data were extracted into a spreadsheet with room number as the only identifier to ensure privacy of the involved individuals. The first search returned 135 emails relating to diarrhea or fever events at CCP. Terms related to vomiting were not used because of the difficulty in differentiating regurgitation and vomiting in infants.

The second search used a date range beginning on May 31, 2021, and going back in 90-day increments to where the previous search had completed. The searches were limited to 90-day increments due to Outlook limiting the number of emails it returns in each pull and the increased volume of email sent during the pandemic because parents were not allowed into the building and could not communicate directly with caregivers. The search terms were established ahead of time using Boolean logic and selected to catch as many potential emails pertaining to sick children and those who were believed to be sick by their parents. Though terms related to vomiting were used in this second search, they were not analyzed here for consistency with the former data set.

Exposure Notices

The information recorded when going through the emails included the initials of the caregivers, the room number, the disease or symptoms, the date, and if the child remained at school or was sent home. Based on state licensing requirements, the facility publishes exposure notices of infectious disease events. Exposure notices are formal notifications from the daycare center sent to parents and posted outside of any affected rooms to inform the parents and staff of clinically confirmed communicable diseases. The information within the notices include disease, date symptoms were first seen, date the disease was diagnosed, incubation duration, typical symptoms, and standard treatment. All the exposure notices released during the study period are detailed in Table 1. The number of days after a holiday that an exposure notice was posted was calculated using the university's academic calendar and the CCP's holiday schedule.

Infant Attendance

Classroom attendance (infant-days) for each day, week, and month were calculated as the number of enrolled infants present at any point during that day per room. Infant-hours breaks the days down into a per room sum of the duration in which the infants were under the caregivers' supervision for that day. The totals for each day were tracked by software at the facility and were provided by the data manager at the request of the project. These data were aggregated for the specific rooms and converted to an overall average for each month within the date range selected for the study. That information was then used to determine the respective monthly incidence rate for diarrhea and fever occurrences, as seen in Figure 1 and their relationship with proposed risk factors.

Data Analysis

A multivariable zero-inflated Poisson regression model was constructed to separately model the incidence of fever and diarrhea reported by email and adjust for the expected extra zeroes within the model from days when there were no reported symptoms. The zero-inflated model in the Political Science Computational Laboratory (PSCL) version 1.5.5 package in RStudio allows for the probability of an outbreak to be calculated in a logistic, zero-inflated, model simultaneously with the Poisson portion modeling the magnitude of an outbreak. The first model (Table 2) examined the probability of the outcome of fever incidence when considering infant-days, the pre- or post-shutdown period, the number of days following the shutdown, and room number as a grouping variable, with seasonality being included as an independent variable for the probability of the outbreak in the zero-inflated Poisson portion of the model. The second zero-inflated Poisson (Table 3) used the same independent variables but substituted the fever incidence rate with the diarrhea incidence rate as the dependent variable.

RESULTS

Of all 3 rooms, 2849 emails were found from the search string used. Of the initial list of emails, 78 in total were retained as being potentially useful for the study, with a breakdown by room in Table 4. A total of 2771 emails were excluded for various reasons, including parents checking up on children, duplicates of or replies to previous emails relevant to the study, or emails regarding pickup at the end of the day instead of early pickup due to illness. Another common issue was that the children were out sick, but with an illness not pertaining to this study. Within the emails that

Table 1. Exposure Notice Diseases and Dates

Disease	Room Identifier	Date Diagnosed
Ringworm	1	07/24/2020
Influenza	2	02/20/2020
Influenza	3	01/18/2020
Conjunctivitis	3	01/18/2020
Diarrheal disease	3	01/15/2020
Roseola	3	09/03/2019
Roseola	2	05/13/2019
Influenza	2	04/01/2019
Strep throat	1	03/14/2019
Roseola	2	02/25/2019
Influenza	1	01/27/2019
Diarrheal disease	2	01/25/2019
Croup	1	10/29/2018
Roseola	1	09/14/2018
Croup	1	03/22/2018
Influenza	3	01/09/2018

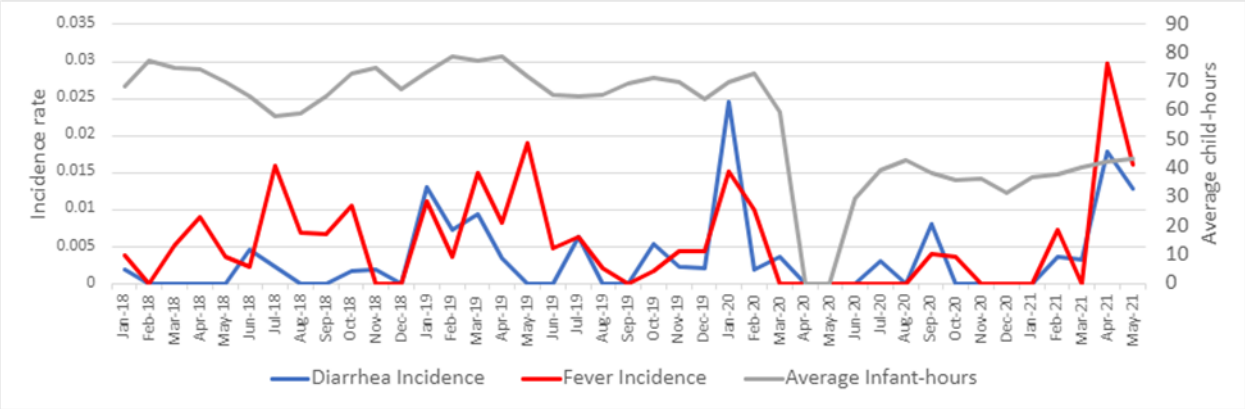

Figure 1. Incidence Rate in Fever and Diarrhea Cases per Infant-Hours by Month Across the Study Period

Table 2. Fever Incidence Using Spring as the Zero-inflated Intercept

Poisson	Log Incidence Rate Ratio	Standard Error	*p*
Intercept	1.434	0.916	0.118
Infant-Days	-0.364	0.104	<0.001*
Post-Shutdown	-7.068	1.924	<0.001*
Days Post-Shutdown	0.019	0.006	0.002*
Room 2	0.473	0.328	0.150
Room 3	0.305	0.328	0.352
Zero-Inflated Poisson	Log Odds	Standard Error	*p*
Intercept	1.128	0.356	0.002*
Fall	0.705	0.462	0.127
Summer	0.915	0.433	0.034*
Winter	0.181	0.407	0.657

Table 3. Diarrhea Incidence Using Spring as the Zero-inflated Intercept

Poisson	Log Incidence Rate Ratio	Standard Error	*p*
Intercept	-1.503	0.885	0.090
Infant-Days	-0.044	0.089	0.623
Post-Shutdown	-2.192	1.053	0.037*
Days Post-Shutdown	0.007	0.004	0.076
Room 2	0.506	0.350	0.148
Room 3	0.308	0.361	0.395
Zero-Inflated Poisson	Log Odds	Standard Error	*p*
Intercept	1.287	0.556	0.021*
Fall	0.745	0.527	0.158
Summer	0.991	0.564	0.079
Winter	-0.210	0.448	0.640

Table 4. Email Inclusion and Exclusion Breakdown by Room

Room	Relevant (*n*)	Excluded (*n*)	Total (*n*)
1	27	714	741
2	35	1554	1589
3	16	503	519
Total	78	2771	2849

were rejected from inclusion, half were for congestion, 11 pertained to vomiting, 1 was for congestion and vomiting, 1 was for an ear infection, 2 related to colds, 1 for a possible urinary tract infection, 1 for lack of sleep, 2 not feeling well, and 1 with no reason given. The ultimate result was a total of 38 relevant events over the 11-month period. These were combined with the 135 emails identified from January 1, 2018, to August 31, 2020, for a total of 173 instances of parent or caregiver reported disease (109 fever and 64 diarrhea). The post-shutdown period's average daily attendance rate across all rooms combined was reduced by 55.6%

while the average daily infant-hours were reduced by 54.7% compared to the period before the closure. Over the full course of the study the 64 cases of diarrhea led to a case-rate of 3.82 per 1000 infant-days with the 109 cases of fever leading to an overall case-rate of 6.52 per 1000 infant-days.

The exposure reports that were discovered were a mean of 18.19 days after a holiday with a median of 15.50 days. The most extreme lag times following a day off were 1 day for roseola in September 2019, and 59 days for roseola in May 2019. There were 9 site closures for holidays in 2018, 10 in 2019, and 2 in 2020 during the study period in which there were no exposure reports sent to parents. Over the course of the study 8 of the 16 exposure notices happened 14 days or fewer after a holiday or closure, with 13 of the 16 (81.25%) happening within 21 days. Email communication about diarrhea and fevers was much more frequent than exposure notices. Exposure notice diseases observed during the study period were influenza, conjunctivitis, roseola, strep throat, croup, thrush, hand foot and mouth disease (HFMD), chicken pox, and respiratory syncytial virus (RSV).

The incidence rates for diarrhea showed a seasonal pattern of late winter and early spring, roughly January to March (Figure 1), before the nationwide shutdown. However, there was an atypically large spike in diarrhea in January 2020, with another atypical spike of both diarrhea and fever in April and May of 2021. Fever incidence rates were lowest in the fall of 2018 and 2019, followed by a large spike in the winter months preceding the closure.

The Poisson analysis for fever incidence in Table 2 showed a significant, negative correlation with increasing infant-days and the number of days after resuming class from the shutdown. A significant, negative correlation when comparing fever incidence rates before the shutdown to after care had resumed was found, meaning that fevers were less likely in the period just after the shutdown. The Poisson analysis for diarrhea incidence in Table 3 showed similar results to Table 2 regarding post-shutdown significance, with the model showing that increasing time after resuming care approached significance. No significant correlation was found between room number and either of the fever or diarrhea incidence rates. The zero-inflated portion of the model for the fever incidence rate showed that only summer was significantly different from the comparator season of spring. There were no significant differences seen in the diarrhea incidence rate analysis for the seasons, but the intercept was significant in both models.

DISCUSSION

Our focus on symptoms for this study suggest that the post shutdown period, which included measures like increased hygiene requirements, fever screenings, and reduced classroom sizes led to a decrease in diarrhea and fever incidence rate. We also found that reducing attendance rates, when controlling for other aspects of the post-shutdown period, was only significant in decreasing fevers with limited evidence for seasonality in either incidence. Our analysis of fever incidence from the zero-inflated Poisson model opposes what traditional literature has shown of seasonality spikes in colder weather leading to more incidences of illness.[5] Additionally, fevers decreased post-shutdown beyond what would be expected just on the basis of decreased attendance, which exceeds what we expected with our hypothesis. For both diarrhea and fever, incidence increased with time post-shutdown. We looked at fever and diarrhea specifically because of the tremendous number of hurdles present for a disease to be clinically diagnosed and reported back to the daycare.

After returning from the planned closure, the university required weekly staff testing for COVID-19 and the daycare increased hygiene requirements and mandated that caregivers wear masks. The spike of diarrhea and fever in 2020 seen in Figure 1 may be linked to the fact that infants tend to experience more COVID-19 related gastrointestinal issues.[6] The larger and apparent propagating pattern of fever and diarrhea spikes seen for 2021 may be due to complacency with the caregivers being less diligent with hygiene, with families starting to interact more with other individuals, or simply the natural propagation of infectious diseases upon remixing of infants and staff post-closure. Some of the incidence increases and exposure notices occur within 2 weeks of a national holiday or university closure, allowing for the potential of transmission from outside of people affiliated with the CCP. However, not all notices and symptoms happened following a day off, meaning that holidays are not a good indicator of exposure for the CCP. We believe it is likely that other transmission events through siblings, parents, caregivers, or other infants were present, keeping in mind that not all outside exposures happen during holidays.

Our results indicate that fevers are more common in the spring and summer compared with the fall and winter, counter to the cold weather seasonality found for 2017 and 2018 by the Centers for Disease Control and Prevention (CDC).[5] Spring was the only significant seasonal association seen in the zero-inflated section of the model for diarrhea, possibly due to the unusually large spike seen in 2021. Future studies may want to consider controlling for COVID-19 prevalence in the surrounding communities. Due to the lower incidence rate observed for diarrhea compared with fevers and a similar directionality in the coefficient estimates, we suspect a larger sample may highlight important underlying relationships not detected in our current analysis.

A significant association between an increase in infant-days and a decrease in fever incidence was found which may have resulted from the facility screening incoming infants for fever upon entry to the facility. Infants who had fevers upon arrival were sent home immediately, so these incident cases would not be observed in the facility email unless parents later communicated about progress at home. There was a significant decrease of fever and diarrhea in the post-shutdown period. The decreased incidences may have been due to increased hygiene requirements after returning and immunity from past acute gastroenteritis infections among infant

groups. There is a significant and positive correlation between days after reopening and fever incidence rate, as reflected in the spike seen in Figure 1. A similar correlation approaches significance in the model for diarrhea. There is no significant difference in either incidence rate among the different rooms, showing that there is no specific room in which fever or diarrhea were more likely.

The exposure notices (Table 1) did not always line up with increases in incidence rates (Figure 1), and when exposure notices were released, it was difficult to associate the illness with the corresponding spike. In January 2018 there was a low fever incidence, but it corresponded with a notice of influenza type A. The same was also seen in September 2019 with roseola and no fevers reported and, in February 2020, with another influenza notice and low fever incidence. This shows that either transmission does not always occur due to effective removal of diagnosed infants from the facility, or it may go unnoticed in the new cases. Conversely, there was a large spike of both fever and diarrhea in January 2020 which corresponds with notices for influenza and a nonspecific diarrheal disease. There was also an increase of fever and diarrheal incidence from December 2018 to January 2019 coinciding with the release of diarrheal disease and influenza exposure notices. February to March 2019 also saw a slight increase in fever incidence along with a confirmed case of strep throat, likewise with April to May 2019 and a clinically confirmed case of roseola. The remaining exposure notices were associated with declines or no change in incidence from month to month. We believe that our work here can contribute to the broader body of work centering around diseases and the importance of hygiene standards within the daycare's role of transmission reduction.

One of the largest limitations of this study is the self-reported nature of parents sending notification emails regarding their child being sick. The study required accurate and timely reporting to track incidence and associate that information with clinically confirmed cases through exposure notices. This was further hindered by a need for caregivers to properly report diarrhea and notice low-grade fevers. The study was also limited by the single CCP as a source of data even though there were 3 rooms surveyed at the CCP. There is also the potential for bias present in the search methods, since the first search period used fewer terms than the second. The less specific search string would lead to underreporting of data during that period with results being closer to the actual number of cases for the second search period. Another potential source of bias is present in the self-reported nature of the email searches leading to underreporting for the entire period of the study.

PUBLIC HEALTH IMPLICATIONS

The conditions presented by the COVID-19 pandemic and nationwide shutdown allowed for a unique opportunity for a natural experiment. In this study, fever and diarrhea transmission in a daycare setting were examined for any potential relationship with seasonality and attendance rates. A significant relationship between incidence rates and child attendance was found to be present, while there were mixed results relating to seasonality. This study also suggests that there is a lag between mixing of children in daycare and increasing incidence of disease which may relate to pathogen incubation, generation intervals, or fading compliance with hygiene protocols. This study suggests that diarrheal and febrile illness incidence immediately following the nationwide closure was reduced beyond what could be expected from decreased attendance alone. Future studies should look at a broader range of daycares with more children included, as well as testing attendees and staff for specific diseases to discriminate potential outbreaks of multiple diseases.

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AUTHOR CONTRIBUTION

Jeremiah Cox: primary author and researcher. Matthew Salerno: secondary researcher. Jenessa Winston and Kelly Baker: expertise contributors. Jiyoung Lee and Rebecca Garabed: co-principal investigators.

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