Clinical Infectious Diseases
MAJOR ARTICLE

Five-Year Community Surveillance Study for Acute Respiratory Infections Using Text Messaging: Findings From the MoSAIC Study

Melissa S. Stockwell,[1,2,3] Carrie Reed,[4] Celibell Y. Vargas,[1] Liqun Wang,[1] Luis R. Alba,[1] Haomiao Jia,[2,5] Philip LaRussa,[1] Elaine L. Larson,[2,5] and Lisa Saiman[1,3]

[1]Department of Pediatrics, Columbia University Vagelos College of Physicians and Surgeons, New York, New York, USA; [2]Mailman School of Public Health, Columbia University Irving Medical Center, New York, New York, USA; [3]NewYork-Presbyterian Hospital, New York, New York, USA; [4]Centers for Disease Control and Prevention, Atlanta, Georgia, USA; and [5]School of Nursing, Columbia University Irving Medical Center, New York, New York, USA

Background. Acute respiratory infections (ARI) are the most common infectious diseases globally. Community surveillance may provide a more comprehensive picture of disease burden than medically attended illness alone.

Methods. In this longitudinal study conducted from 2012 to 2017 in the Washington Heights/Inwood area of New York City, we enrolled 405 households with 1915 individuals. Households were sent research text messages twice weekly inquiring about ARI symptoms. Research staff confirmed symptoms by follow-up call. If ≥2 criteria for ARI were met (fever/feverish, cough, congestion, pharyngitis, myalgias), staff obtained a mid-turbinate nasal swab in participants' homes. Swabs were tested using the FilmArray reverse transcription polymerase chain reaction (RT-PCR) respiratory panel.

Results. Among participants, 43.9% were children, and 12.8% had a chronic respiratory condition. During the 5 years, 114 724 text messages were sent; the average response rate was 78.8% ± 6.8%. Swabs were collected for 91.4% (2756/3016) of confirmed ARI; 58.7% had a pathogen detected. Rhino/enteroviruses (51.9%), human coronaviruses (13.9%), and influenza (13.2%) were most commonly detected. The overall incidence was 0.62 ARI/person-year, highest (1.73) in <2 year-olds and lowest (0.46) in 18–49 year-olds. Approximately one-fourth of those with ARI sought healthcare; percents differed by pathogen, demographic factors, and presence of a chronic respiratory condition.

Conclusions. Text messaging is a novel method for community-based surveillance that could be used both seasonally as well as during outbreaks, epidemics and pandemics. The importance of community surveillance to accurately estimate disease burden is underscored by the findings of low rates of care-seeking that varied by demographic factors and pathogens.

Keywords. influenza; SMS; text message; surveillance; acute respiratory infections.

Acute respiratory infections (ARI) are the most common infectious diseases globally [1]. ARI leads to over 25 million primary care and 9 million emergency department (ED) visits annually in the United States [2, 3] and is 1 of the 5 most common medical conditions associated with the highest amount of direct medical spending for children [4]. ARI also result in indirect costs and societal burden due to healthcare resource use [5, 6], reduced productivity, and an estimated 42 million missed work/school days annually [7].

ARI surveillance, including influenza, is primarily performed by assessing medically-attended episodes, including outpatient visits and/or hospitalizations. Community-based surveillance may provide a more comprehensive picture of disease burden; for the influenza A H1N1 pandemic, the Centers for Disease Control and Prevention (CDC) calculated the median multiplier needed to more accurately report estimated cases was 79 [8].

One challenge in conducting community-based ARI surveillance is the timely identification of illness and laboratory sample collection. Previous studies have used phone calls, either in person or automated, to conduct ARI assessments [9, 10]. Text messaging is a potentially novel way to rapidly, consistently, and frequently conduct surveillance longitudinally for ARI in a community sample. More recently, other surveillance studies have used emails and text messages as a prompt to complete symptom questionnaires online and collect swabs [11]. However, the use of stand-alone text messages, which may be more accessible to low-income populations with limited data plans, has been less well described. Limited information is also available on longitudinal use.

The objectives of this 5-year community surveillance study were to describe ARI incidence, etiology, and factors associated with infection and care-seeking, as well as to evaluate use of text messaging for longitudinal surveillance in a low-income population.

Received 3 October 2021; editorial decision 11 January 2022; published online 17 January 2022.

Correspondence: M. S. Stockwell, Division of Child and Adolescent Health, Columbia University, 622 W 168th St, VC 417, New York, NY 10032 (mss2112@cumc.columbia.edu).

Clinical Infectious Diseases® 2022;XX(XX):1–9
© The Author(s) 2022. Published by Oxford University Press for the Infectious Diseases Society of America. All rights reserved. For permissions, e-mail: journals.permissions@oup.com.
https://doi.org/10.1093/cid/ciac027

METHODS

Study Design and Population

In the Centers for Disease Control and Prevention (CDC)-funded Mobile Surveillance for Acute Respiratory Infections and Influenza-Like Illness in the Community (MoSAIC) study, we recruited and followed households in a low-income community in New York City from December 2012 to September 2017 in which 20% of residents live in poverty [12]. Recruitment methods have been previously reported [13] and were supplemented in subsequent years by participant referral. Eligibility criteria included: living within the surveillance community located in Washington Heights/Inwood in Northern Manhattan; household with ≥3 persons, including ≥1 member <18 years-old; Spanish or English-speaking; and having a household member with a cellphone with text messaging capabilities who agreed to complete twice-weekly symptom assessments for all household members and participate in monthly home visits. Households were required to participate for 1 year, October through September, and could remain in the next year if they continued to meet eligibility. For the 2012–13 season, 161 household were under surveillance, for subsequent seasons, new households were recruited through February 2017 to maintain 250 households.

Text Messaging and Swab Collection

Study procedures have been previously reported [13]. Briefly, one person (the household reporter) received a text message twice-weekly: "Reply with 1 or 2. Does anyone in the household have runny nose, congestion, sore throat, cough, body aches, or fever, or feels [sic] hot? 1: yes; 2: no." In May 2015, the term "allergies" was added because households were not reporting qualifying symptoms that they believed were due to allergies as illness. Messages were sent in English or Spanish based on reporter's preference. Research staff followed up by phone for positive responses to confirm symptoms and elicit secondary symptoms. For those ≥1 years-old, if ≥2 criteria for ARI were met (fever [feverish], runny nose/congestion, sore throat, cough, and/or myalgias) research staff obtained a mid-turbinate nasal swab from the ill participant in their home, generally within 2 days. For those <1 years old, congestion alone qualified. All households were visited monthly to promote retention, update household composition if someone left the household for >2 weeks, and capture illnesses not reported. If a household member met ARI criteria at an enrollment or monthly visit, a swab was obtained.

Research staff made follow-up phone calls starting 10 days post-illness to capture illness length, medical care sought, and missed school and work. The household reporter received $20/month for responding to ≥75% of text messages. Families who stopped responding were called, and alternative cell phones used to continue messaging if needed. The Columbia University Irving Medical Center and CDC institutional review boards approved this study. Informed consent from adults and verbal assent from appropriately aged children were obtained to collect swabs.

Respiratory Pathogen Detection

Swabs were analyzed using a multiplex reverse transcription polymerase chain reaction (RT-PCR) (FilmArray Respiratory panel BioFire Diagnostics, Inc) for 20 respiratory pathogens including adenovirus, human coronavirus (HKU1, NL63, 229E, OC43); human metapneumovirus (HMPV), rhino/enterovirus; influenza (A, A/H1, A/H3, A/H1-2009, B); parainfluenza (type 1, 2, 3, 4); respiratory syncytial virus (RSV), *Bordatella pertussis*; *Chlamydophila pneumoniae*, and *Mycoplasma pneumoniae* [14]. Results were not reported to households.

Statistical Analysis

Text message response rates and proportions of each pathogen detected were calculated. Annual incidence (ARI/person-year) was assessed overall and by age group. Number of ill days (symptom onset to reported normal activity resumption) were assessed overall and by pathogen.

The association with ARI of factors (age, sex, self-reported health [excellent, good, fair, poor], chronic respiratory or nonrespiratory condition, smoking status [≥18 years], smokers in household, birthplace [in/outside US], health insurance, occupation [≥18 years], having a child in household <5 years [≥18 years], education, and surveillance season October–September annually) was assessed using a generalized linear mixed model (GLMM) with logit-link function (logistic) [15]. The GLMM included a random intercept for each household and for each individual nested within each household. Backward elimination was utilized for final model selection at $P < .05$. Season was controlled for by including trigonometric functions for the month of year as fixed effectors. Analyses were using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina, USA) and SPSS, version 26 (IBM Corp. Armonk, New York, USA).

RESULTS

Study Population

Overall, 405 households were enrolled; 54.6% enrolled in year 1 or 2 remained under surveillance until year 5. All households eligible to continue chose to do so; household loss was due to moving outside of surveillance community or household change including a child aging out and/or <3 household members. Education level of the household reporter, but not sex, language, or insurance status, was associated with not remaining (<high school 64.2% vs high school/college 47.9%, $P = .006$). Of the 1915 unique participants, 43.9% were children, and 12.8% had a chronic respiratory condition including asthma or chronic obstructive pulmonary disease (COPD) (Table 1). The mean number of persons per household was 4.8 ± 1.8 (range

Table 1. Characteristics of Study Population

	N = 1915
Median length of enrollment (interquartile range)	908 [395, 1453]
Number of people enrolled per season	
10/2012 to 9/2013	973
10/2013 to 9/2014	1506
10/2014 to 9/2015	1387
10/2015 to 9/2016	1293
10/2016 to 9/2017	1146
Age	
<2 y	110 (5.7)
2-4 y	121 (6.3)
5-17 y	610 (31.9)
18-49 y	760 (39.7)
50-64 y	230 (12.0)
≥65 y	84 (4.4)
Sex	
Female	1149 (60.0)
Male	766 (40.0)
Race	
Black	4 (0.2)
White	458 (23.8)
Asian	1 (0.1)
American Indian	16 (0.8)
Other	1444 (75.1)
Ethnicity	
Latino	1905 (99.5)
Nativity (adults and children)	
Born in US	878 (46.0)
In US ≥10 y	622 (32.6)
In US <10 y	407 (21.3)
Preferred language (adults)	
Spanish	775 (72.2)
Education level (adults)	
Less than high school	436 (41.1)
Completed high school	262 (24.7)
Beyond high school	364 (34.3)
Education/Child care (children)	
Elementary/high school	606 (75.8)
Day care/prenursery	29 (3.6)
Head Start	21 (2.6)
Care in outside private home	55 (6.9)
No routine care outside of home	89 (11.1)
Insurance	
Public	1466 (77.0)
Commercial	203 (10.7)
Uninsured	235 (12.3)
Self-reported health status	
Excellent	413 (21.6)
Good	954 (49.9)
Fair	478 (25.0)
Poor	67 (3.5)
Chronic respiratory condition (including asthma or chronic obstructive pulmonary disease)	244 (12.8)
Chronic non-respiratory condition	512 (26.7)
Occupation	
Unemployed/ retired/ on disability	203 (19.3)
Homemaker	183 (17.4)
Healthcare- related field	109 (10.3)
Other employment	398 (37.8)
Babysitter/ daycare/school employee	66 (6.3)
College/ other type of student	95 (9.0)

3–16). Household density (ratio of people to bedrooms) was 2.4 ± 1.2 (range 0.6–11). Overall, 40.2% of households were multigenerational.

ARI Incidence

In total, 114 724 text messages were sent. Across the 5 years, the mean response rate per twice-weekly prompts was 78.8% ± 6.8% (range: 52% to 100%). Mean response rate differed significantly by year, but remained above 75%: year 1: 75.2% ± 8.8%; year 2: 75.4% ± 6.2%; year 3: 80.5% ± 4.6%; year 4: 78.5% ± 5.2%; year 5: 83.9% ± 4.9%; $P < .05$ (Supplementary Figure 1).

Swabs were collected for 91.4% of confirmed ARI (2756/3016); median 2 days from ARI onset (interquartile range [IQR] 1–4). Overall, 1.4% refused swabbing, and 7.3% of ARI were missed not reported at the time of illness but reported retrospectively in a monthly visit. Half (54.1%) of ARI were in children. In 58.7% of ARI (1617/2756), a pathogen was detected (71.4% in children <5 years). Rhino/enteroviruses, human coronaviruses, and influenza were most commonly detected (Figure 1); 5.6% of swabs had more than 1 pathogen detected. Seasonal variations occurred by pathogen (Supplementary Figure 2). Influenza was detected as early as October and as late as June. Symptoms also varied by pathogen (Supplementary Figure 3). Nearly half (45.8%) of ARI episodes included multiple people within a household; 48.4% for episodes that included a child <5 years.

The overall ARI incidence was 0.62 per person-year, with the highest incidence in <5 year-olds (Table 2; Supplementary Table 1). Pathogen-specific incidence varied by age. While most pathogens had the highest incidence in <5 year-olds, influenza A had the greatest incidence in 2–17 and 50–64 year-olds and influenza B in 2–17 year-olds. Children <5 years had the greatest disease burden with almost 13 days of illness/year. Adults had, on average, 4–5 days of illness/year. The mean number of ill days for an ARI also varied by pathogen (Supplementary Table 2). ARI with *C. pneumoniae* had the longest illnesses (average 13 days). Those with influenza had, on average, 9 days of illness.

Among children, age <5 years-old, a chronic respiratory condition, being born in the United States, and surveillance year were associated with ARI. Among adults, being female, being a homemaker, a college education, a chronic nonrespiratory condition, and surveillance year were associated with ARI (Table 3).

Care-Seeking for ARI

Only 26.0% of participants with an ARI reported seeking medical care. Visits were to primary care providers (84.8%), emergency departments (12.6%), urgent care (2.2%), and retail clinics (0.7%). Ten participants (1.4%), including 3 children and 7 adults, reported hospitalization; 4 had a pathogen detected (3 rhino/enterovirus and 1 influenza). Among those hospitalized, the following were reported: 1 influenza, 3 pneumonia, 3 asthma,

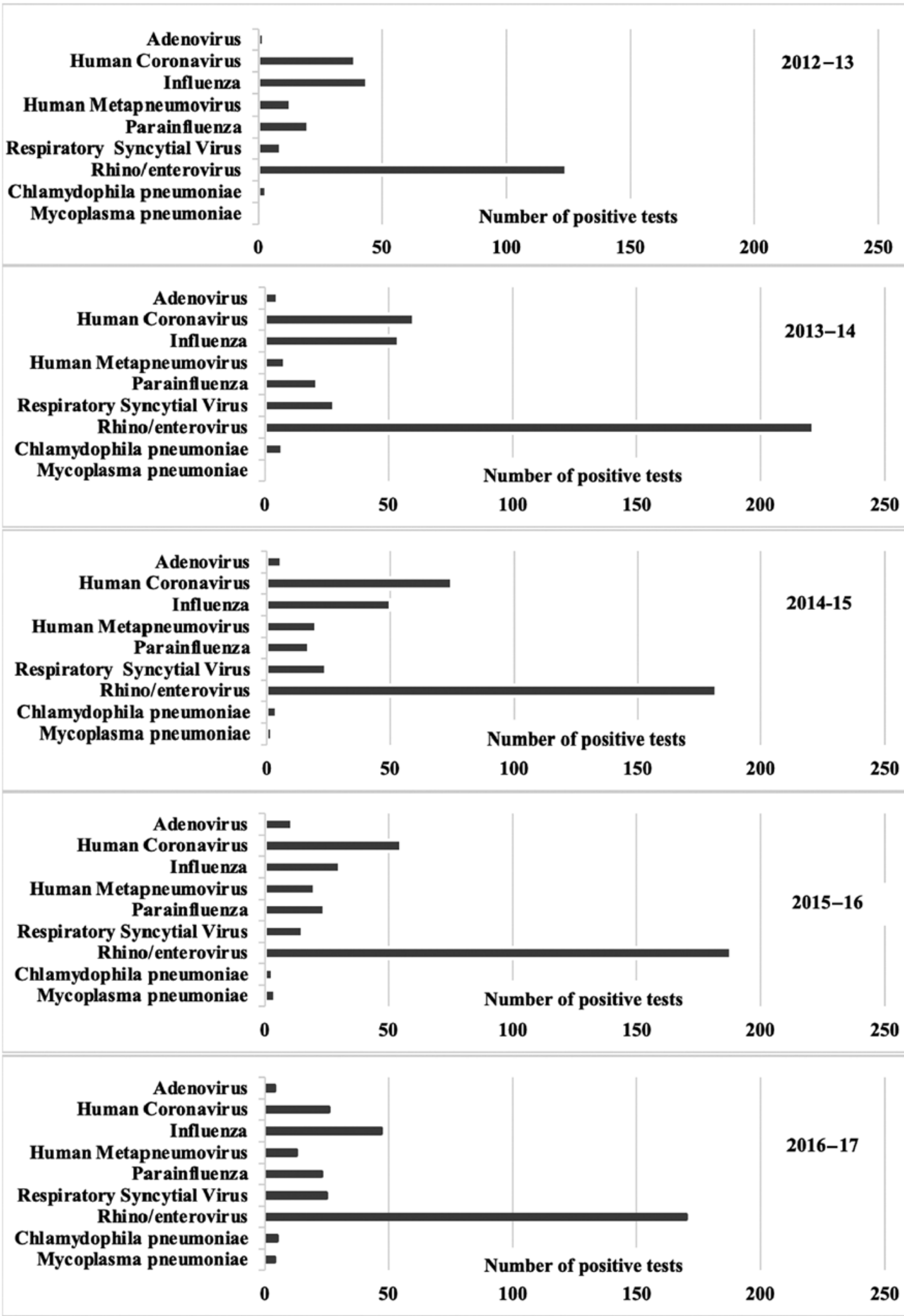

Figure 1. Frequency of detected respiratory pathogens in community-based surveillance.

1 cold/viral infection, 1 thyroid issue, and 1 did not report diagnosis. Care-seeking varied by pathogen and was highest for *M. pneumoniae* (63.6%), adenovirus (60.7%), HMPV (45.9%), *Chlamydia pneumoniae* (40.9%), RSV (42.6%), or any influenza (40.0%) and lowest for human coronaviruses (17.3%). Age, sex, insurance, chronic respiratory condition, birthplace, and type of regular provider were associated with care-seeking (Table 4). Care-seeking was higher in those reporting fever (40.9% vs 19.1%, $P < .001$).

Overall, 25.9% of ARI were associated with someone in the household missing work or school. The highest proportion of missed work and/or school was associated with adenovirus (46.4%), influenza (45.3%), RSV (42.6%), or *Mycoplasma pneumoniae* (40.0%). Care-seeking was associated with missed

Table 2. Incidence and Disease Burden of Acute Respiratory Infections

	Age	ARI episodes	Person-days	ARI Incidence per Person-year (95% CI)	Reported Sick-days	Sick-days per Person-year (95% CI)
Total sample		3016	1 788 146	0.62 (.59, .64)	24 629	5.03 (4.97, 5.09)
By age						
	<2 y	196	41 419	1.73 (1.49, 1.97)	1470	12.96 (12.31, 13.61)
	2–4 y	440	101 534	1.58 (1.44, 1.73)	3590	12.91 (12.50, 13.33)
	5–17 y	995	609 573	0.60 (.56, .63)	7729	4.63 (4.53, 4.73)
	18–49 y	931	744 097	0.46 (0.43, 0.49)	7695	3.78 (3.69, 3.86)
	50–64 y	346	216 206	0.59 (.52, .65)	3099	5.24 (5.05, 5.42)
	≥65 y	108	75 317	0.52 (.43, .62)	1046	5.07 (4.77, 5.38)

Abbreviations: ARI, acute respiratory infection; CI, confidence interval.

school/work (48.8% who sought care missed work vs17.7% who did not seek care, $P < .0001$).

DISCUSSION

This 5-year study identified a number of important findings that contribute to our understanding of ARI epidemiology. First, it underscores the additional importance of community-based surveillance to more completely understand disease burden by capturing non-medically attended ARI during year round surveillance. Second, it adds to the literature that demonstrates the feasibility of text messaging as a surveillance method, including use of this method over a sustained period of time. Our findings have potential implications not only for seasonal surveillance, but also for outbreaks, epidemics and pandemics. Third, it provides measures of ARI incidence, factors associated with infection in both adults and children, and causative pathogens.

Only a quarter of ARI episodes were associated with healthcare-seeking; this proportion increased to 40% of ARI associated with influenza. Not all demographic groups sought care equally. Therefore, potential biases likely exist when disease burden calculations are made based solely on medically attended illness, which may differ for different demographic groups. However, medically attended illness surveillance has been the primary data source for a variety of important public health activities, including disease burden estimates, the impact of public health interventions like vaccination, understanding spread of novel pathogens (eg, severe acute respiratory syndrome coronavirus 2 [SARS-CoV-2] or pandemic influenza), and forecasting influenza activity [16]. Furthermore, only half of ARI associated with missed school or work were associated with care-seeking. These findings underscore that even non-medically attended illness can lead to substantial disease burden and societal impact that may not be fully captured in current modeling of respiratory diseases. Thus, community-based surveillance provides an important complement to current medically attended disease surveillance strategies.

One potential challenge in conducting community surveillance is how to rapidly identify when illnesses occur and collect data from disparate households in a scalable-efficient manner. With advances in technology and creative approaches to follow-up and community engagement, there may be ways for community-level surveillance to be more routinely conducted. This study demonstrated that large-scale text message-based surveillance was feasible with continued high response rates throughout 5 years. The rapid replies also allowed collection of samples within 1–2 days of symptom onset. Although text messaging was successfully used for performing vaccine adverse event surveillance by us and others [17], there had been limited experience with using text messaging for ARI surveillance. In Madagascar, text messaging was used to collect aggregate practice-level incidence [18], and in Mexico, it was utilized as a 1-time cross-sectional survey of symptoms during the 2009 H1N1 influenza pandemic [19]. Since the onset of this study, others have studied using text messages as a prompt to complete a web-based symptom questionnaires and to prompt self-collected samples; however, this strategy relies on families having a data plan on their phone or access to WIFI to use the linked system [11, 20]. Other surveillance systems have also been explored to complement outpatient and hospital-based surveillance, including Twitter, Wikipedia, the now defunct Google Flu Trends, and crowd-source reporting like Flu Near You [21]. However, these type of surveillance do not include collection of samples which precludes determining how much of the observed illness burden is attributable to a specific pathogen, like influenza.

The overall ARI incidence calculated in this study is less than that calculated in previous studies performed decades ago, although as with previous studies, incidence varied by year [22]. However, previous studies also included enteric infections and used broader definitions of respiratory illness including single symptoms and symptoms, such as earache, not included in the current CDC definition [9, 23, 24]. Other possibilities for differences in incidence calculations include increased influenza vaccination, household composition changes such as size of households, and study design differences [25, 26]. Of note, a recent community surveillance study that assessed

Table 3. Factors Associated With Incidence of Acute Respiratory Infections (ARI) in Children and Adults

	Adjusted Odds Ratio	95% Confidence Intervals
Children		
Age		
<2 y	2.57	2.14–3.09
2–4 y	1.99	1.71–2.31
5–17 y	…	…
Chronic respiratory condition (present)	1.27	1.05–1.54
Birth place		
Non-US	…	…
US	1.29	1.03–1.62
Study year 2012–13	1.92	1.57–2.35
2013–14	1.34	1.13–1.58
2014–15	1.38	1.18–1.62
2015–16	1.08	0.92–1.27
2016–17	…	…
Adult		
Sex		
Male	…	…
Female	2.39	1.95–2.94
Chronic non-respiratory condition (present)[a]	1.37	1.17–1.62
Occupation		
Unemployed/ retired/ on disability	1.31	0.92–1.87
Homemaker	1.64	1.16–2.31
Healthcare-related field	1.14	0.79–1.65
Other employment	1.15	0.83–1.59
Babysitter/ daycare/school employee	0.99	0.65–1.52
Student	…	
Education		
Less than high school	…	…
Completed high school	0.97	0.78–1.20
Beyond high school	1.36	1.12–1.66
Study year		
2012–13	1.81	1.46–2.25
2013–14	1.13	0.95–1.35
2014–15	1.11	0.94–1.33
2015–16	1.10	0.93–1.31
2016–17	…	…

Model includes trigonometric functions for the month of the year as fixed effectors. Adult model adjusted for presence of child under 5 in the household.

Abbreviation: ARI, acute respiratory infection.

[a]The most common comorbidities in those with an ARI were asthma and type 2 diabetes mellitus.

partial respiratory seasons also had lower ARI incidence than previously reported, even when accounting for its shortened surveillance period [27]. Some studies, like a recent one that demonstrated ARI incidence of ~5% per week, only took place during the winter [28]. Another study from Utah also found higher incidence but collected weekly samples regardless of symptoms and included a broader symptom constellation than the CDC ARI definition used in this study [29].

This current study confirmed some ARI-associated factors identified in previous studies and highlighted new ones. In this and previous studies, young age in children was associated with higher ARI incidence [9, 23, 27, 30], as were being an adult female and/or a homemaker likely due to caretaking roles [9, 27]. We also observed that ARI incidence was associated with higher education [30]. Although a study published in 1971 speculated higher education may have been associated with reporting of minor symptoms, in our study, surveillance was conducted by prompting symptom reporting regardless of whether participants felt ill. We also identified some different risk factors for ARI. Although in previous studies, sex played a role in childhood infection [30], it did not in this study. Nor did household density [31]; however, it may be patterns of contact within households rather than density that matter most [32]. We also found that increased ARI incidence was associated with respiratory (children) or non-respiratory (adults) chronic medical condition. Although those factors are known to increase respiratory illnesses severity, they had not themselves been identified as risk factors for ARI [27]. These comorbid conditions may be associated with an increased risk of infection or of symptomatic infection. It is also possible that those with a chronic condition were more attuned to symptoms. In addition, being US born was associated with higher ARI incidence in children. One previous cross-sectional study suggested that being US born was linked to poorer respiratory health [33].

This study also adds to the knowledge about which respiratory pathogens are causing ARI year-round over multiple seasons. Previous studies focused on specific viruses [34–36], medically attended groups such as hospitalized or ambulatory patients [34, 35], certain ages [37, 38], certain characteristics like attending daycare [39], or only conducted partial-year surveillance [11, 27, 28]. More modern diagnostic techniques are also available, and can detect more respiratory pathogens. In our study, similar to the 1970s, rhino/enteroviruses and influenza were commonly detected [11]. However, in the 1970's, parainfluenza was one of the most common respiratory pathogens detected [30], although in our study human coronaviruses were common. Although human coronaviruses can cause mild ARI, even nonpandemic coronaviruses can cause severe disease [40, 41]. A recent study demonstrated that influenza, human coronavirus, and RSV were most commonly associated with medically attended ARI [42], and a community surveillance study in Seattle that focused on the respiratory season similarly found rhinovirus, human coronaviruses, and RSV to be most common [11]. We also found differential pathogen representation by month, highlighting the importance of year-round surveillance. Finally, pathogen detection differed by age. Although younger children had higher pathogen-specific ARI incidences for most pathogens than older children and adults, age did not impact patterns for influenza.

This study has limitations. First, households were from a single low-income, primarily Latino community in New York City and thus are not nationally representative. However, understanding ARI epidemiology may be particularly important

Table 4. **Proportion of Participants by Demographic and Clinical Factors Seeking Healthcare**

	No. of ARI N = 2795	No. (%) Sought care	*P*
Age			<.0001
<5 y	597	234 (39.2)	
5–17 y	937	294 (31.4)	
≥18 y	1261	200 (15.9)	
Sex			<.0001
Female	1793	412 (23.0)	
Male	1002	316 (31.5)	
Nativity			<.0001
Born in US	1601	528 (33.0)	
In US ≥10 y	707	134 (19.0)	
In US < 10 y	480	65 (13.5)	
Preferred language (adults)			.82
Spanish	912	148 (16.2)	
English/Other	300	47 (15.7)	
Education level (adults)			.43
Less than high school	449	80 (17.8)	
Completed high school	265	38 (14.3)	
Beyond high school	490	76 (15.5)	
Insurance			<.0001
Public	2220	617 (27.8)	
Commercial	333	83 (24.9)	
Uninsured	227	25 (11.0)	
General self-reported health status			.88
Excellent	577	153 (26.5)	
Good	1244	331 (26.6)	
Fair	853	214 (25.1)	
Poor	117	30 (25.6)	
Chronic respiratory condition			.002
Present	534	168 (31.5)	
Absent	2260	560 (24.8)	
Chronic nonrespiratory condition			<.0001
Present	820	173 (21.1)	
Absent	1975	555 (28.1)	
Regular care			.004
Has a regular provider[a]	2574	689 (26.8)	
Has regular place of care but not provider	49	8 (16.3)	
No regular provider or place of care	117	17 (14.5)	

Denominator are the 2795 illness episodes for which seeking care was reported.

Abbreviation: ARI, acute respiratory infection.

[a] Having a regular provider was defined as answering "yes" to "Does this household member have someone they/their parents consider to be the irregular doctor?"

in low-income communities, as individuals may be at different risk of infection and transmission due to crowded living conditions as highlighted in some but not other studies [31], and having multigenerational households [43]. Low-income communities have also been disproportionately affected during the SARS-CoV-2 pandemic and therefore important to study. They may also have decreased healthcare access leading to under-representation in previous surveillance studies relying on medically-attended illness [44]. Requiring there to be a child in the household could overestimate disease burden in the population as children are thought to play a major role in introduction of infection in households [45]; this requirement also affected the number ≥65 year-old participants as few participants were in this age strata. In addition, this high-intensity study required substantial staff resources and families needed to have text messaging; for such surveillance to be sustainable low-touch methods may need to be explored such as phone follow-up only and collection of self-swabs [11, 46]. Other limitations include under-reporting although prompts were sent twice-weekly, false negative results although the percentage of swabs with a pathogen detected was consistent with other studies [27], being part of the study could increase or decrease care-seeking, and enrollment of only Spanish and English speakers [47].

CONCLUSION

Text messaging is a novel method for community-based surveillance that could be used both seasonally as well as during outbreaks, epidemics and pandemics as a complementary mode of potential case identification. The importance of adding community surveillance to medical visit based surveillance to accurately estimate disease burden is underscored by the findings of low rates of care-seeking that varied by demographic factors and pathogens and the burden of missed work/school.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Acknowledgments. The authors thank the other members of the MoSAIC study team for their assistance: Hilbania Diaz, Yaritza Castellanos de Belliard, Maria Morban, Julia Nunez, Asha Liverpool, Othanya Garcia, Raul Silverio, and Manuel Cifuentes.

Financial support. This work was supported by the Centers for Disease Control and Prevention (CDC) (grant number U01IP000618 to M. S. S.). The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC. BioFire Diagnostics, Inc, loaned machines for this study and provided kits at a reduced rate for research.

Potential conflicts of interest. M. S. reports several grants and subcontracts from the National Institutes of Health (NIH), CDC, to trustees of Columbia University outside of the submitted work; received honoraria for speaking at the Kentucky Infectious Diseases Coronavirus Disease 2019 (COVID-19) Task Force Forum and the 23rd Annual Frontiers in Pediatrics Conference Charleston, South Carolina; Associate Director of American Academy of Pediatrics Pediatric Research in Office Settings (PROS) to Trustees of Columbia University; and BioFire Diagnostics, Inc, loaned machines for this study, and provided kits at a reduced rate for research. L. S. reports grants or contracts from Merck Co, Inc, National Institute of Allergy and Infectious Diseases (NIAID), Bill and Melinda Gates Foundation, and Cystic Fibrosis Foundation outside of the submitted work; consulting fees from Cystic Fibrosis Foundation and Matrix Inc; and participation on a Data Safety Monitoring Board or Advisory Board for Merck Co, Inc, and Armata. P. L. reports grants or contracts from Merck Co, Inc, outside of the submitted work and unrestricted gift from Pfizer for vaccine education to Trustees of Columbia University, used for salary, and conference. L. S., E. L., and P. L. received funding from Merck for a project related to RSV. The work detailed in this manuscript pre-dates that funding. All other authors report no potential conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

References

1. GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet **2016**; 388:1545–602.
2. Cairns C, Kang K, Santo L. National Hospital Ambulatory Medical Care Survey: 2018 Emergency Department Summary Tables. National Center for Health Statistics. Available at: https://www.cdc.gov/nchs/data/nhamcs/web_tables/2018-ed-web-tables-508.pdf. Accessed on 12 September 2021.
3. Santo L, Okeyode T. National Ambulatory Medical Care Survey: 2018 National Summary Tables. Available at: https://www.cdc.gov/nchs/data/ahcd/namcs_summary/2018-namcs-web-tables-508.pdf Accessed on 12 September 2021.
4. Soni A. Top five most costly conditions among children, ages 0–17, 2012: Estimates for the U.S. Civilian Noninstitutionalized Population. Statistical brief 472. April 2015. Agency for Healthcare Research and Quality, Rockville, MD. Available at: http://www.meps.ahrq.gov/mepsweb/data_files/publications/st472/stat472.shtml. Accessed on 12 September 2021.
5. Principi N, Esposito S, Marchisio P, Gasparini R, Crovari P. Socioeconomic impact of influenza on healthy children and their families. Pediatr Infect Dis J **2003**; 22(10 Suppl):S207–10.
6. Ebell MH, Radke T. Antibiotic use for viral acute respiratory tract infections remains common. Am J Manag Care **2015**; 21:e567–75.
7. Adams PF, Hendershot GE, Marano MA; Centers for Disease Control and Prevention/National Center for Health Statistics. Current estimates from the National Health Interview Survey, 1996. Vital Health Stat 10 **1999**:1–203.
8. Reed C, Angulo FJ, Swerdlow DL, et al. Estimates of the prevalence of pandemic (H1N1) 2009, United States, April–July 2009. Emerg Infect Dis **2009**; 15:2004–7.
9. Monto AS, Sullivan KM. Acute respiratory illness in the community: frequency of illness and the agents involved. Epidemiol Infect **1993**; 110:145–60.
10. Larson EL, Ferng YH, Wong-McLoughlin J, et al. Impact of non-pharmaceutical interventions on URIs and influenza in crowded, urban households. Public Health Rep **2010**; 125:178–91.
11. Emanuels A, Heimonen J, O'Hanlon J, et al. Remote household observation for noninfluenza respiratory viral illness. Clin Infect Dis **2021**; 73:e4411–e8.
12. Hinterland K, Naidoo M, King L, et al. Community health profiles 2018, Manhattan Community District 12: Washington Heights and Inwood. **2018**; 12:1–20. Available at: https://www1.nyc.gov/assets/doh/downloads/pdf/data/2018chp-mn12.pdf.
13. Stockwell MS, Reed C, Vargas CY, et al. MoSAIC: Mobile Surveillance for Acute Respiratory Infections and Influenza-Like Illness in the Community. Am J Epidemiol **2014**; 180:1196–201.
14. BioFire Diagnostics. FilmArray®Respiratory Panels. Available at: https://www.biofiredx.com/products/the-filmarray-panels/filmarrayrp/. Accessed on 21 January 2020.
15. McCulloch CE, Searle SR. Generalized, linear, and mixed models. Hoboken, NJ: John Wiley & Sons; **2001**.
16. Simonsen L, Gog JR, Olson D, Viboud C. Infectious disease surveillance in the big data era: towards faster and locally relevant systems. J Infect Dis **2016**; 214:S380–S5.
17. Stockwell MS, Marchant CD, Wodi AP, et al. A multi-site feasibility study to assess fever and wheezing in children after influenza vaccines using text messaging. Vaccine **2017**; 35:6941–8.
18. Rajatonirina S, Heraud JM, Randrianasolo L, et al. Short message service sentinel surveillance of influenza-like illness in Madagascar, 2008–2012. Bull World Health Organ **2012**; 90:385–9.
19. Lajous M, Danon L, Lopez-Ridaura R, et al. Mobile messaging as surveillance tool during pandemic (H1N1) 2009, Mexico. Emerg Infect Dis **2010**; 16:1488–9.
20. Dawood FS, Porucznik CA, Veguilla V, et al. Incidence rates, household infection risk, and clinical characteristics of SARS-CoV-2 infection among children and adults in Utah and New York City, New York. JAMA Pediatr **2022**;176:59–67. doi:10.1001/jamapediatrics.2021.4217.
21. Sharpe JD, Hopkins RS, Cook RL, Striley CW. Evaluating Google, Twitter, and Wikipedia as tools for influenza surveillance using Bayesian change point analysis: a comparative analysis. JMIR Public Health Surveill **2016**; 2:e161.
22. Heikkinen T, Jarvinen A. The common cold. Lancet **2003**; 361:51–9.
23. Fox JP, Hall CE, Cooney MK, Luce RE, Kronmal RA. The Seattle virus watch. II. objectives, study population and its observation, data processing and summary of illnesses. Am J Epidemiol **1972**; 96:270–85.
24. Monto AS, Napier JA, Metzner HL. The Tecumseh study of respiratory illness. I. Plan of study and observations on syndromes of acute respiratory disease. Am J Epidemiol **1971**; 94:269–79.
25. Doshi P. Trends in recorded influenza mortality: United States, 1900–2004. Am J Public Health **2008**; 98:939–45.
26. U.S. Census Bureau. Historical Households Tables. Available at: https://www.census.gov/data/tables/time-series/demo/families/households.html. Accessed on 12 September 2021.
27. Monto AS, Malosh RE, Petrie JG, Thompson MG, Ohmit SE. Frequency of acute respiratory illnesses and circulation of respiratory viruses in households with children over 3 surveillance seasons. J Infect Dis **2014**; 210:1792–9.
28. Szilagyi PG, Blumkin A, Treanor JJ, et al. Incidence and viral aetiologies of acute respiratory illnesses (ARIs) in the United States: a population-based study. Epidemiol Infect **2016**; 144:2077–86.
29. Byington CL, Ampofo K, Stockmann C, et al. Community surveillance of respiratory viruses among families in the Utah Better Identification of Germs-Longitudinal Viral Epidemiology (BIG-LoVE) study. Clin Infect Dis **2015**; 61:1217–24.
30. Monto AS, Ullman BM. Acute respiratory illness in an American community: the Tecumseh study. JAMA **1974**; 227:164–9.
31. Hirota Y, Takeshita S, Ide S, et al. Various factors associated with the manifestation of influenza-like illness. Int J Epidemiol **1992**; 21:574–82.

32. Goeyvaerts N, Santermans E, Potter G, et al. Household members do not contact each other at random: implications for infectious disease modelling. Proc Biol Sci **2018**; 285:20182201.
33. Iqbal S, Oraka E, Chew GL, Flanders WD. Association between birthplace and current asthma: the role of environment and acculturation. Am J Public Health **2014**; 104:S175–82.
34. Prill MM, Iwane MK, Edwards KM, et al. Human coronavirus in young children hospitalized for acute respiratory illness and asymptomatic controls. Pediatr Infect Dis J **2012**; 31:235–40.
35. Iwane MK, Prill MM, Lu X, et al. Human rhinovirus species associated with hospitalizations for acute respiratory illness in young US children. J Infect Dis **2011**; 204:1702–10.
36. Edwards KM, Zhu Y, Griffin MR, et al. Burden of human metapneumovirus infection in young children. N Engl J Med **2013**; 368:633–43.
37. Lambert SB, Allen KM, Druce JD, et al. Community epidemiology of human metapneumovirus, human coronavirus NL63, and other respiratory viruses in healthy preschool-aged children using parent-collected specimens. Pediatrics **2007**; 120:e929–37.
38. Nicholson KG, Kent J, Hammersley V, Cancio E. Acute viral infections of upper respiratory tract in elderly people living in the community: comparative, prospective, population based study of disease burden. BMJ **1997**; 315: 1060–4.
39. Montejano-Elias L, Alpuche-Solis AG, Zarate-Chavez V, et al. Human metapneumovirus and other respiratory viral infections in children attending a day care center. Pediatr Infect Dis J **2009**; 28:1024–6.
40. Varghese L, Zachariah P, Vargas C, et al. Epidemiology and clinical features of human coronaviruses in the pediatric population. J Pediatric Infect Dis Soc **2018**; 7:151–8.
41. Talbot HK, Crowe JE Jr., Edwards KM, et al. Coronavirus infection and hospitalizations for acute respiratory illness in young children. J Med Virol **2009**; 81:853–6.
42. Jackson ML, Starita L, Kiniry E, et al. Incidence of medically attended acute respiratory illnesses due to respiratory viruses across the life course during the 2018/19 influenza season. Clin Infect Dis **2021**; 73:802–7.
43. Findley SE, Irigoyen M, Schulman A. Children on the move and vaccination coverage in a low-income, urban Latino population. Am J Public Health **1999**; 89:1728–31.
44. Jerant A, Fenton JJ, Franks P. Primary care attributes and mortality: a national person-level study. Ann Fam Med **2012**; 10:34–41.
45. Viboud C, Boelle PY, Cauchemez S, et al. Risk factors of influenza transmission in households. Br J Gen Pract **2004**; 54:684–9.
46. Vargas CY, Wang L, Castellanos de Belliard Y, et al. Pilot study of participant-collected nasal swabs for acute respiratory infections in a low-income, urban population. Clin Epidemiol **2016**; 8:1–5.
47. Chen LF, Vander Weg MW, Hofmann DA, Reisinger HS. The Hawthorne Effect in infection prevention and epidemiology. Infect Control Hosp Epidemiol **2015**; 36:1444–50.