Exploring Calendar Effects for Influenza

Evaluating Incidence Rates for Social, Religious, and School Holidays

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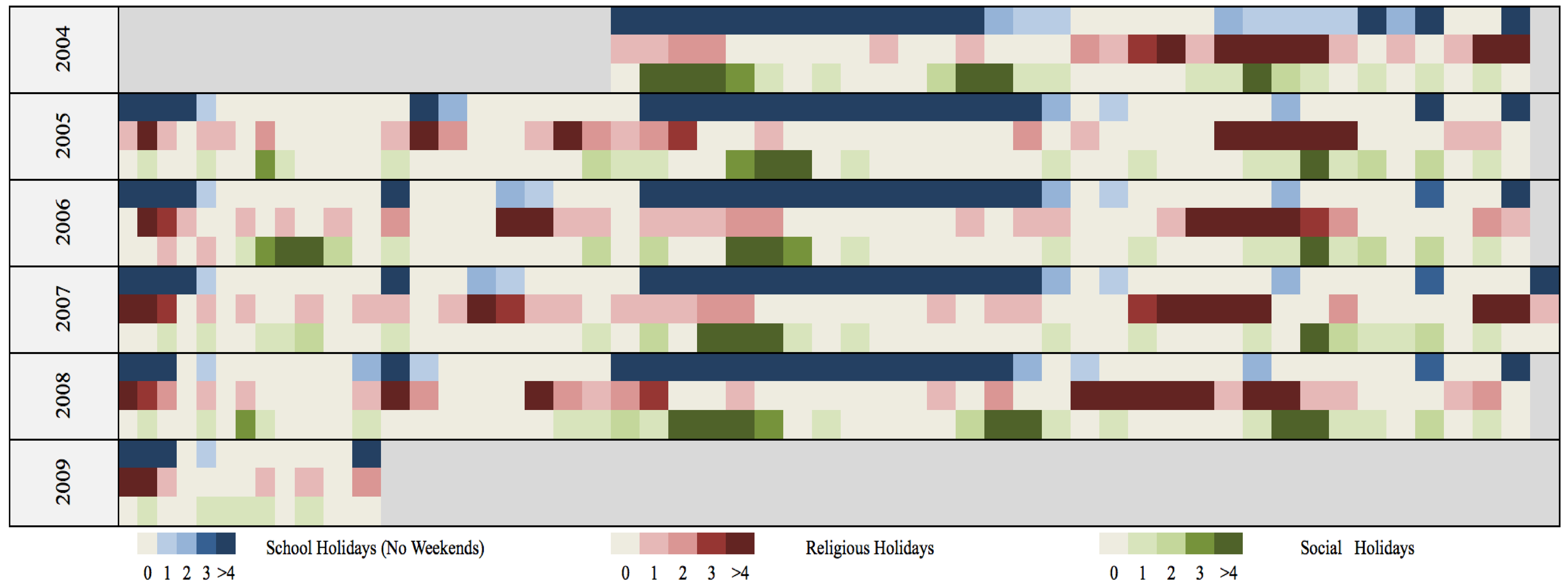
INRODUCTION

Heightened social mixing and holiday-related congregation is often considered a prominent cause of increasing influenza case counts [1]. Mixing patterns vary according to differing age groups with the most well-established holiday effect seen for school closures [2]. Differential effects on differing subpopulations for non-school holidays, namely social and religious gatherings, are poorly investigated. By analyzing these components, we evaluated incidence rate according to different classifications of holidays (e.g. social, religious, and school) and the frequency of holiday days per week (e.g. 1, 2, 3, or >4). This study also evaluates the relative risk ratio (RR) between the incidence rate during the week a holiday occurs and the leading or lagging weeks surrounding the holidays.

METHODS

All laboratory-confirmed cases of influenza were retrieved from the Milwaukee Health Department Laboratory (MHDL) from May 16, 2004—December 19, 2009 for a total of 251 weeks. Influenza records were sub-aggregated by strain (H1N1, H3N2, unknown, swine), serotype (Influenza A & B), and age groups: <1 years, 1-4 years, 5-24 years, 25-44 years, 45-64 years, and >65 years. Daily minimum, average, and maximum humidity, temperature, and dewpoint were obtained from Weather Underground. A calendar of religious (Christian, Jewish, and Muslim observances) was compiled. Social holidays included a collection of the top-ranking sporting events and other national observances. School calendars obtained from Marquette University. Social and religious holidays included 9 floating and 25 fixed days, and 9 floating and 37 fixed days, respectively. In addition to univariate analyses for individual holidays, exploratory models also reviewed group effects of overlapping holiday types, holiday categories as a whole, and various thresholds of holiday days per week. No significant results were found.

Table 1. Annual Holiday Alignment, Frequency, and Intensity



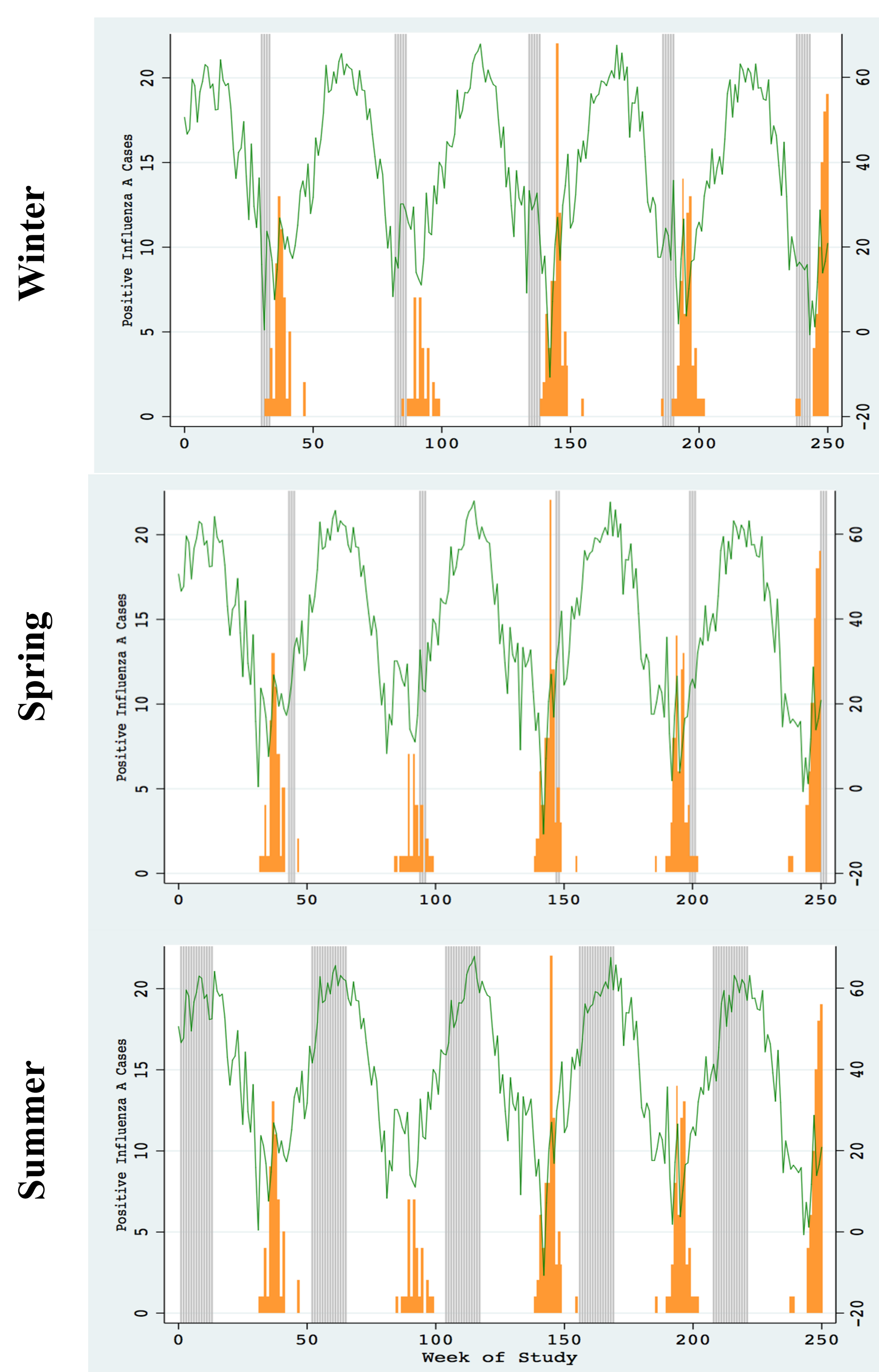


Figure 1 (Above). Time Series of Weekly Influenza Count (■), Dewpoint (■), and School Holiday (■) for Persons Aged 5-24 Years

Table 3. An Overview of Religious Practices in Milwaukee, WI

Religious Bodies	*Tradition*	*Congregations*	*Adherents*	*Adherence Rate*	*2004-10 Change*
Catholic Church	Catholic	80	199,153	210.1	-23.80%
Evangelical Protestant	Lutheran	265	104,073	27.425	-17.67%
Other Protestant	Baptist / Pentecostal	107	53,399	14.1	19.65%
Muslim Estimate	Other	8	9,156	9.7	220.50%
Reform Judaism	Other	3	5,322	5.6	-----

RESULTS & DISCUSSION

Results show that the so-called "holiday effect" remains far more complicated than expected. By incorporating holidays as dichotomous indicators, models using time series of influenza records fail to adequately capture differences in holiday effects. Social and religious holidays associate with overall influenza incidence contingent upon age groups. For example, the week of the Superbowl has a protective effect on weekly influenza counts, with increases both before and after for those aged 5-24 years (see Table 2). Those aged 25-44 years experience increased incidence in the weeks after Winter Break. Increased incidence is also observed for this same age group both in preceding and succeeding weeks around Easter. As holidays promote a greater level of social mixing and interpersonal interaction, transmission is expected to increase among those engaging in holiday festivities during or around the event.

This approach encounters difficulties in separating the effects of overlapping holiday types (see Table 1). As traditions vary across families, cultures, and geographic location, weeks with religious and social holidays are difficult to define. Additionally, population measures such as density of living areas and number of religious followers may also influence these counts (see Table 3).

Table 2. Annual Holiday Alignment, Frequency, and Intensity

Age	Time	SCHOOL HOLIDAYS: Winter Break IRR	RR	Hyp.	Spring Break IRR	RR	Hyp.	RELIGIOUS HOLIDAYS: Easter Week IRR	RR	Hyp.	Eid-al Adha IRR	RR	Hyp.
Age Group 3 (5-24 Years)	Lead (t+2)	0.821	0.935	$>R_0$	1.038	0.951	$<R_0$	**0.539**	**0.534**	**$>R_0$**	**0.948**	**0.784**	**$<R_0$**
	Lead (t+1)	**0.697**	**0.794**	**$>R_0$**	1.187	1.088	$<R_0$	**0.565**	**0.560**	**$>R_0$**	**0.872**	**0.721**	**$<R_0$**
	Holiday (t)	0.878	1.000	R_0	1.091	1.000	R_0	1.009	1.000	R_0	1.209	1.000	R_0
	Lag (t-1)	1.142	1.301	$<R_0$	1.055	0.967	$<R_0$	0.736	0.729	$>R_0$	0.942	0.779	$>R_0$
	Lag (t-2)	**2.227**	**2.536**	**$<R_0$**	1.047	0.960	$<R_0$	**1.372**	**1.360**	**$>R_0$**	0.910	0.753	$>R_0$
Age Group 4 (25-44 Years)	Lead (t+2)	**0.738**	**1.724**	**$<R_0$**	**1.404**	**1.115**	**$>R_0$**	**1.461**	**1.174**	**$>R_0$**	-	-	$<R_0$
	Lead (t+1)	**0.657**	**1.535**	**$<R_0$**	1.208	0.959	$>R_0$	2.498	2.008	$>R_0$	**0.841**	**0.442**	**$<R_0$**
	Holiday (t)	**0.428**	**1.000**	**R_0**	**1.259**	**1.000**	**R_0**	1.244	1.000	R_0	1.904	1.000	R_0
	Lag (t-1)	0.616	1.439	$>R_0$	**1.295**	**1.029**	**$<R_0$**	**1.340**	**1.077**	**$>R_0$**	1.027	0.539	$>R_0$
	Lag (t-2)	0.666	1.556	$>R_0$	1.159	0.921	$<R_0$	**1.387**	**1.115**	**$>R_0$**	1.030	0.541	$>R_0$
Age Group 5 (45-64 Years)	Lead (t+2)	1.024	0.932	$<R_0$	1.220	0.989	$>R_0$	-	-	$>R_0$	**2.634**	**1.383**	**$>R_0$**
	Lead (t+1)	1.292	1.176	$<R_0$	1.160	0.941	$>R_0$	**0.154**	**0.132**	**$>R_0$**	**0.648**	**0.340**	**$>R_0$**
	Holiday (t)	1.099	1.000	R_0	**1.233**	**1.000**	**R_0**	1.167	1.000	R_0	1.904	1.000	R_0
	Lag (t-1)	0.950	0.864	$>R_0$	**1.259**	**1.021**	**$<R_0$**	**1.176**	**1.008**	**$>R_0$**	0.979	0.514	$>R_0$
	Lag (t-2)	1.551	1.411	$>R_0$	1.027	0.833	$<R_0$	0.362	0.310	$>R_0$	-	-	$>R_0$

Age	Time	RELIGIOUS HOLIDAYS: Hannukah IRR	RR	Hyp.	Muharram IRR	RR	Hyp.	SOCIAL HOLIDAYS: Superbowl IRR	RR	Hyp.	Mardi Gras IRR	RR	Hyp.	Valentine's Day IRR	RR	Hyp.
Age Group 3 (5-24 Years)	Lead (t+2)	**0.235**	**0.213**	**$<R_0$**	-	-	$>R_0$	**1.120**	**3.353**	**$>R_0$**	-	-	$>R_0$	0.917	0.927	$>R_0$
	Lead (t+1)	1.016	0.921	$<R_0$	1.200	1.270	$>R_0$	0.986	2.952	$>R_0$	**1.116**	**0.564**	**$>R_0$**	1.747	1.766	$>R_0$
	Holiday (t)	1.103	1.000	R_0	**0.945**	**1.000**	**R_0**	**0.334**	**1.000**	**R_0**	**1.980**	**1.000**	**R_0**	0.989	1.000	R_0
	Lag (t-1)	1.667	1.511	$>R_0$	**0.949**	**1.004**	**$>R_0$**	**0.844**	**2.527**	**$>R_0$**	**1.275**	**0.644**	**$>R_0$**	**0.780**	**0.789**	**$>R_0$**
	Lag (t-2)	**2.899**	**2.628**	**$>R_0$**	**0.907**	**0.960**	**$>R_0$**	**0.904**	**2.707**	**$>R_0$**	-	-	$>R_0$	**0.956**	**0.967**	**$>R_0$**
Age Group 4 (25-44 Years)	Lead (t+2)	**0.084**	**0.104**	**$<R_0$**	0.028	0.051	$>R_0$	-	-	$>R_0$	-	-	$>R_0$	0.853	0.897	$>R_0$
	Lead (t+1)	**0.091**	**0.112**	**$<R_0$**	-	-	$>R_0$	0.942	0.635	$>R_0$	**0.594**	**0.257**	**$>R_0$**	1.140	1.199	$>R_0$
	Holiday (t)	0.811	1.000	R_0	**0.548**	**1.000**	**R_0**	**1.483**	**1.000**	**R_0**	**2.307**	**1.000**	**R_0**	0.951	1.000	R_0
	Lag (t-1)	**0.294**	**0.363**	**$>R_0$**	-	-	$>R_0$	**0.118**	**0.080**	**$<R_0$**	**0.327**	**0.142**	**$<R_0$**	**1.224**	**1.287**	**$>R_0$**
	Lag (t-2)	0.331	0.408	$>R_0$	**0.878**	**1.602**	**$>R_0$**	**0.872**	**0.588**	**$<R_0$**	**6.128**	**2.656**	**$<R_0$**	**0.202**	**0.212**	**$>R_0$**
Age Group 5 (45-64 Years)	Lead (t+2)	-	-	$<R_0$	1.357	1.677	$>R_0$	-	-	$>R_0$	-	-	$>R_0$	0.89	-	$>R_0$
	Lead (t+1)	1.016	0.921	$<R_0$	5.599	6.921	$>R_0$	1.062	2.847	$>R_0$	**3.075**	**7.482**	**$>R_0$**	0.035	-	$>R_0$
	Holiday (t)	1.103	1.000	R_0	**0.809**	**1.000**	**R_0**	0.373	1.000	R_0	**0.411**	**1.000**	**R_0**	-	-	R_0
	Lag (t-1)	-	-	$>R_0$	**2.228**	**2.754**	**$>R_0$**	**0.203**	**0.544**	**$<R_0$**	**0.190**	**0.462**	**$<R_0$**	**0.720**	-	**$<R_0$**
	Lag (t-2)	-	-	$>R_0$	**0.723**	**0.894**	**$>R_0$**	**0.676**	**3.330**	**$<R_0$**	-	-	$<R_0$	**0.531**	-	**$<R_0$**

Note: The symbol (-) indicates insufficient cases in or around the time of a holiday to offer a credible prediction (e.g. no cases, too few cases to run a negative binomial regression, or a gross overestimate of incidence as a result of near zero cases). Each column is distinguished between hypothesis (predicted relative risk rato compared to the holiday in question), IRR (incidence rate ratio of influenza compared to all other days), and RR Ratio (the relative risk ratio between case counts and the holiday in question). All hypotheses (individually made for each age group) depict increased risk (>R0) compared to the holiday week(s) or decreased risk (<R0) compared to the holiday week(s). All bolded values depict significance with green indicating when the RR supports the expected hypothesis while red distinguishes those opposing the expected hypothesis.

FUTURE DIRECTIONS

While effectively exemplifying differences in individual holiday effects across age groups, further analysis will be taken to review variations across influenza serotype and strain. As the timing of peak case counts do not directly correlate across strains and serotypes, this more granular analysis will offer greater comparison of holiday effects across age groups. Future work will also attempt to analyze a longer effective data length using more recent records from the Milwaukee Health Department Laboratory.

From the results provided above, we recommend future influenza studies using time series analysis not aggregate holidays into single dichotomous variables measuring merely the presence and absence of any holiday. Instead, we suggest accounting for each holidays individually and tracking the occurrence of holidays across epidemiological weeks an annual basis, especially for floating or irregular holidays. Future applications of this study include the development of incidence risk ratios to estimate individual holiday effects for specific holidays. Such incidence rates can be used as weighting schema to that can adjust influenza forecasts to more accurate predict fluctuations of influenza case counts across age-specific subpopulations.

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