All the Good Stuff is in the Appendix

Appendicitis and Recent Temperature

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NIEHS Early Stage Investigator Webinar Series
Wednesday March 8th, 2022

Acute appendicitis is a common cause of acute abdominal pain

one of the most common general surgical emergencies

occurs >250,000 per year in the US

affects 7-8% of Americans during their lifetimes

Few well-documented risk factors

Age (most common 10-30)
Sex (slightly more common in males)
Diet (low fiber diets have higher risk)
Genetics
Decreased water consumption

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- Genetics
- **Decreased water consumption**

Appendicitis is more common in the summer

Hypothesis:

Temperature is causally associated with appendicitis risk

Truven Health Analytics Marketscan

- Commercial Claims and Encounters Database
- Medicare Supplemental and Coordination of Benefits Database

Truven Health Analytics Marketscan

Commercial Claims and Encounters Database

Medicare Supplemental and Coordination of Benefits Database

Insurance claims for health care utilization for ~200,000,000 people with an mean enrollment duration of ~3 years

Find cases of appendicitis diagnosis in either inpatient or outpatient settings by ICD-9 and ICD-10 diagnosis codes

ICD	Diagnosis	Long Description
9	540.0	Acute appendicitis with generalized peritonitis
9	540.1	Acute appendicitis with peritoneal abscess
9	540.9	Acute appendicitis without mention of peritonitis
9	541	Appendicitis, unqualified
9	542	Other appendicitis
10	K35.2	Acute appendicitis with generalized peritonitis
10	K35.3	Acute appendicitis with localized peritonitis
10	K35.80	Unspecified acute appendicitis
10	K35.89	Other acute appendicitis
10	K37	Unspecified appendicitis
10	K36	Other appendicitis

Daily number of cases = Number of unique people with a claim for appendicitis in a city for a given age and sex for each day

Daily number of people at risk = Number of unique people in the Truven database for a given age and sex for each day

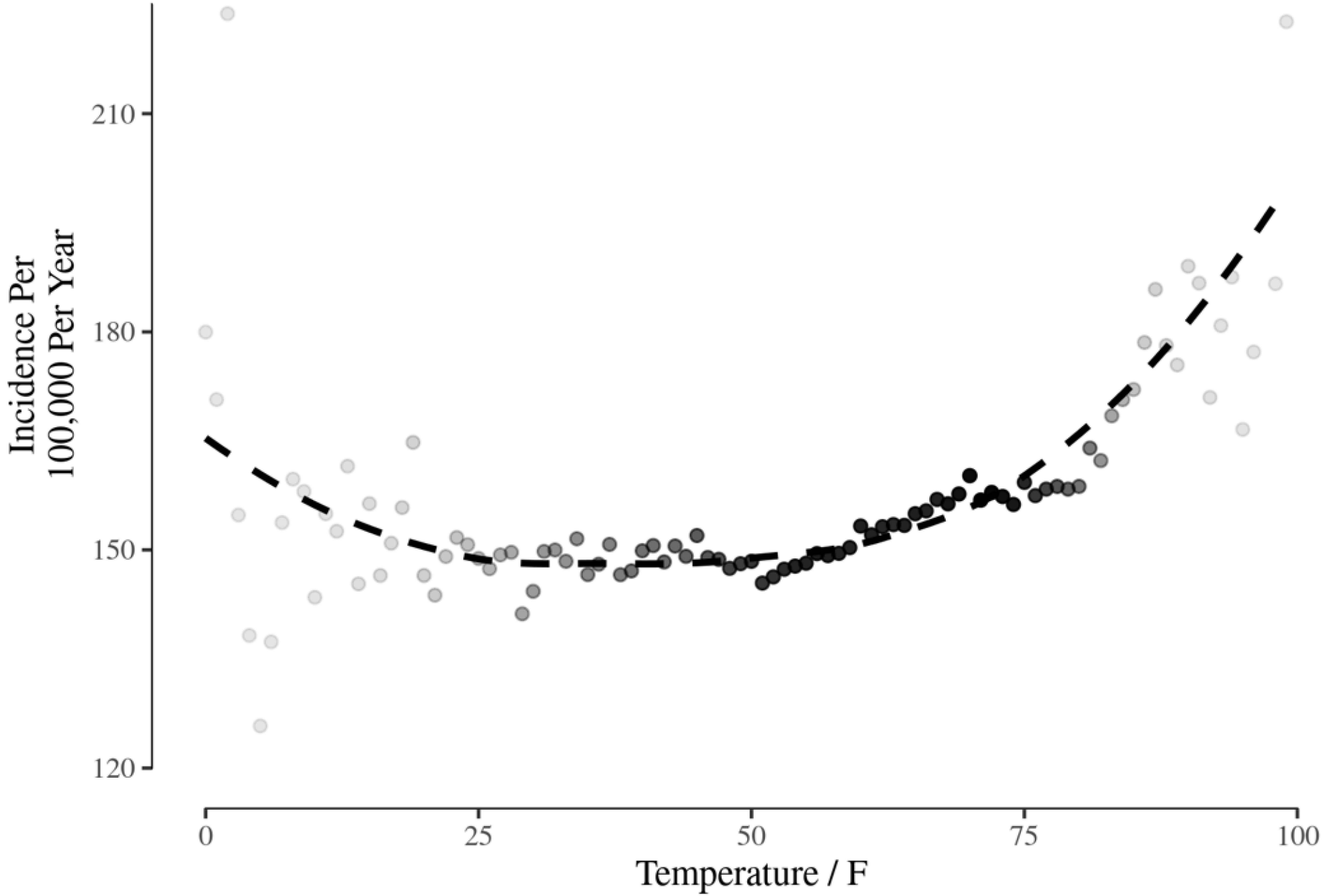
We assumed that people only ever get appendicitis once (obviously true if managed surgically) and so only retain the first diagnosis of appendicitis for a person as the event date

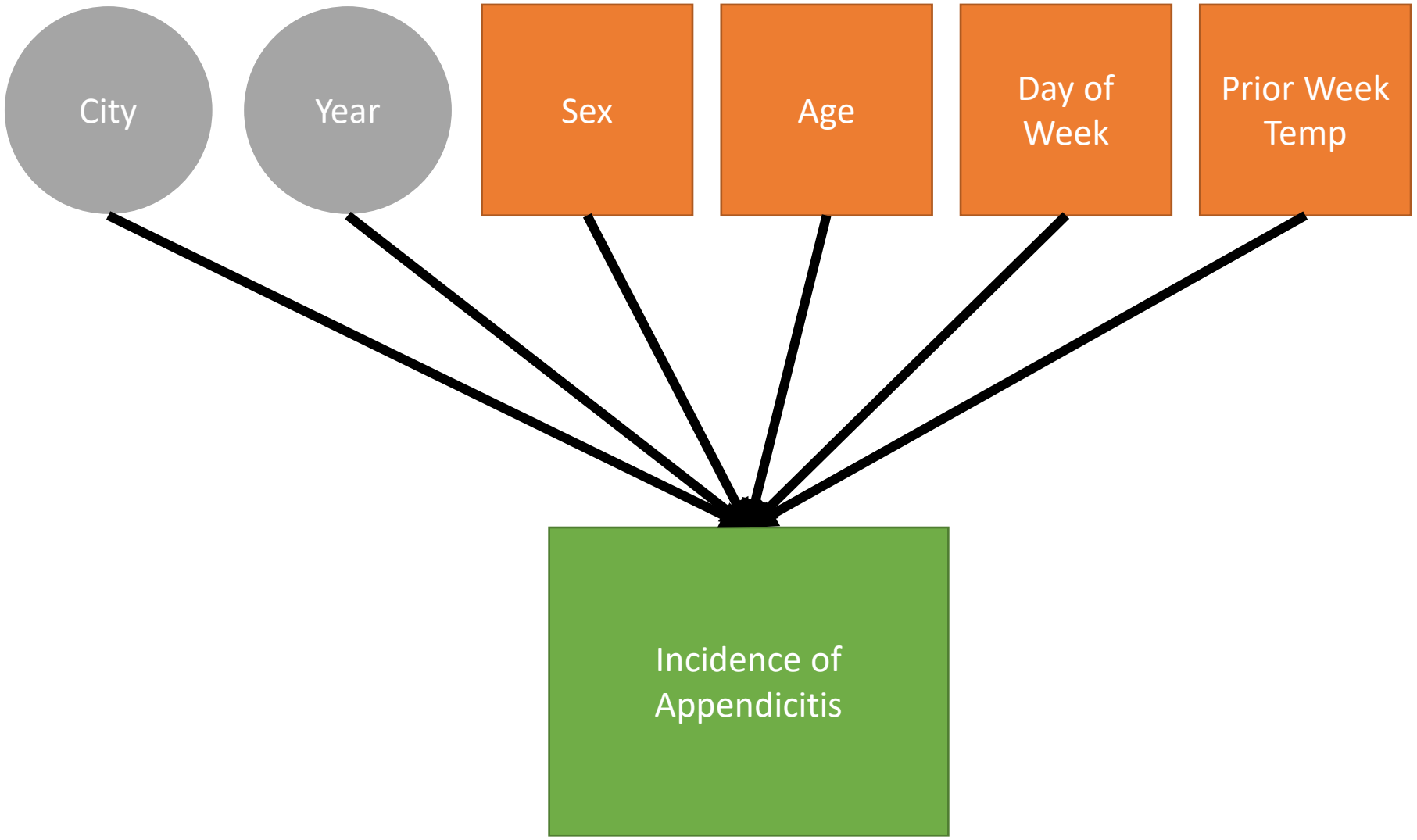
	Female Enrollees			Male Enrollees		
Age	Cases	Person-Years at Risk in 100,000s	Annualized Incidence Per 100,000	Cases	Person-Years at Risk in 100,000s	Annualized Incidence Per 100,000
0-5	3,365	130.5	25.8	4,306	136.9	31.4
6-10	15,110	137.3	110.1	22,156	143.3	154.6
11-15	27,137	152.1	178.4	38,968	158.5	245.8
16-20	36,918	159.8	231.0	42,472	165.2	257.0
21-30	59,764	293.1	203.9	60,093	270.1	222.5
31-40	58,002	333.0	174.2	55,515	297.9	186.4
41-50	56,699	390.1	145.4	50,374	349.0	144.3
51-60	51,523	397.2	129.7	42,110	350.2	120.3
61-70	22,424	205.3	10.92	20,583	184.6	111.5
71-80	7,349	84.9	86.6	7,376	69.9	105.5
81+	4,153	60.5	68.7	3,520	37.7	93.3

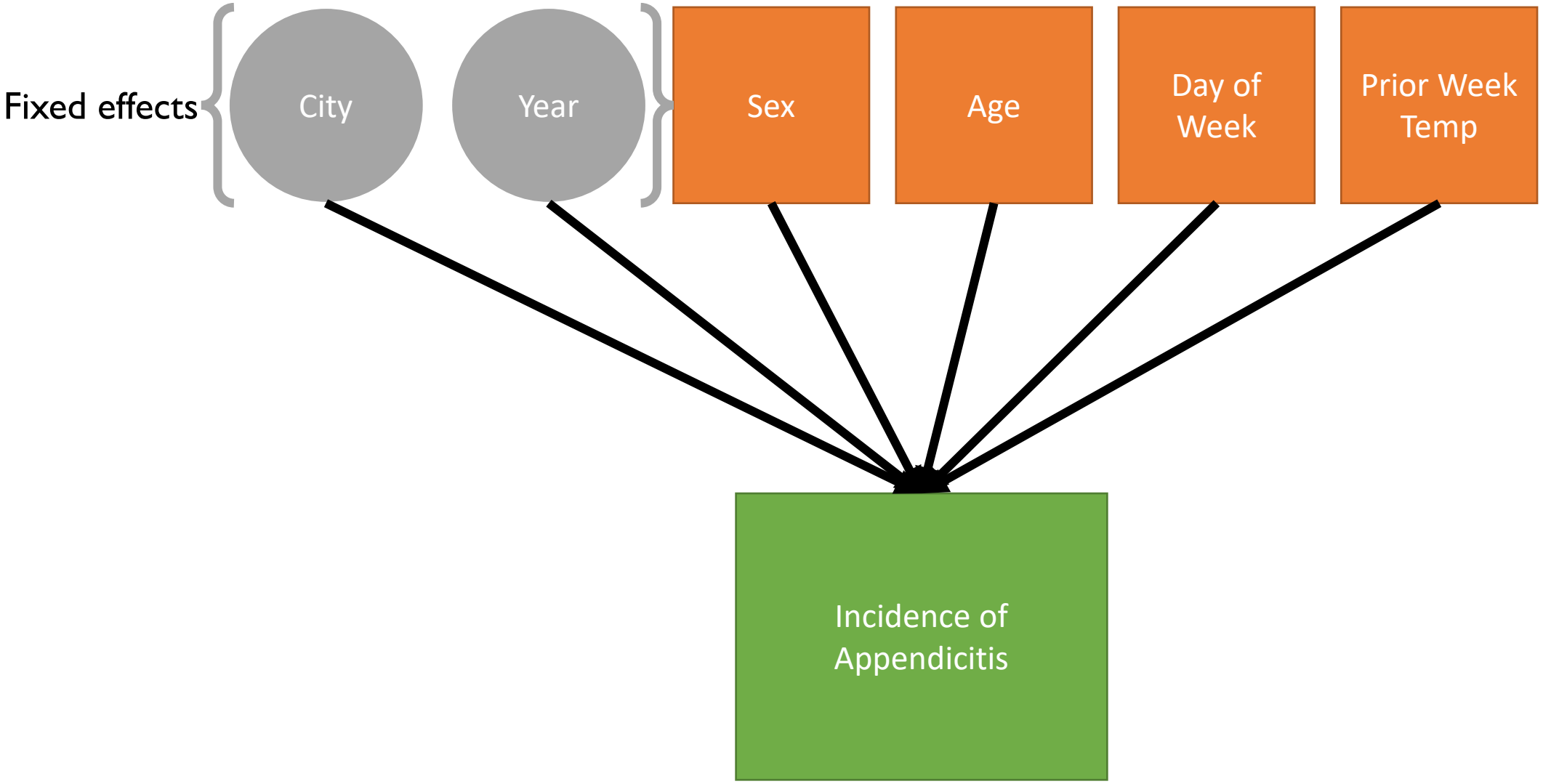
For each city, we found the recorded hourly temperature observations as reported by the National Centers for Environmental Information, part of NOAA, since 1980

This database has 1,000s of sites across the United States – mostly, but not exclusively, at airports

We used all weather stations within 100 km (62 miles) of a city's center to define the temperature experienced by people in that city

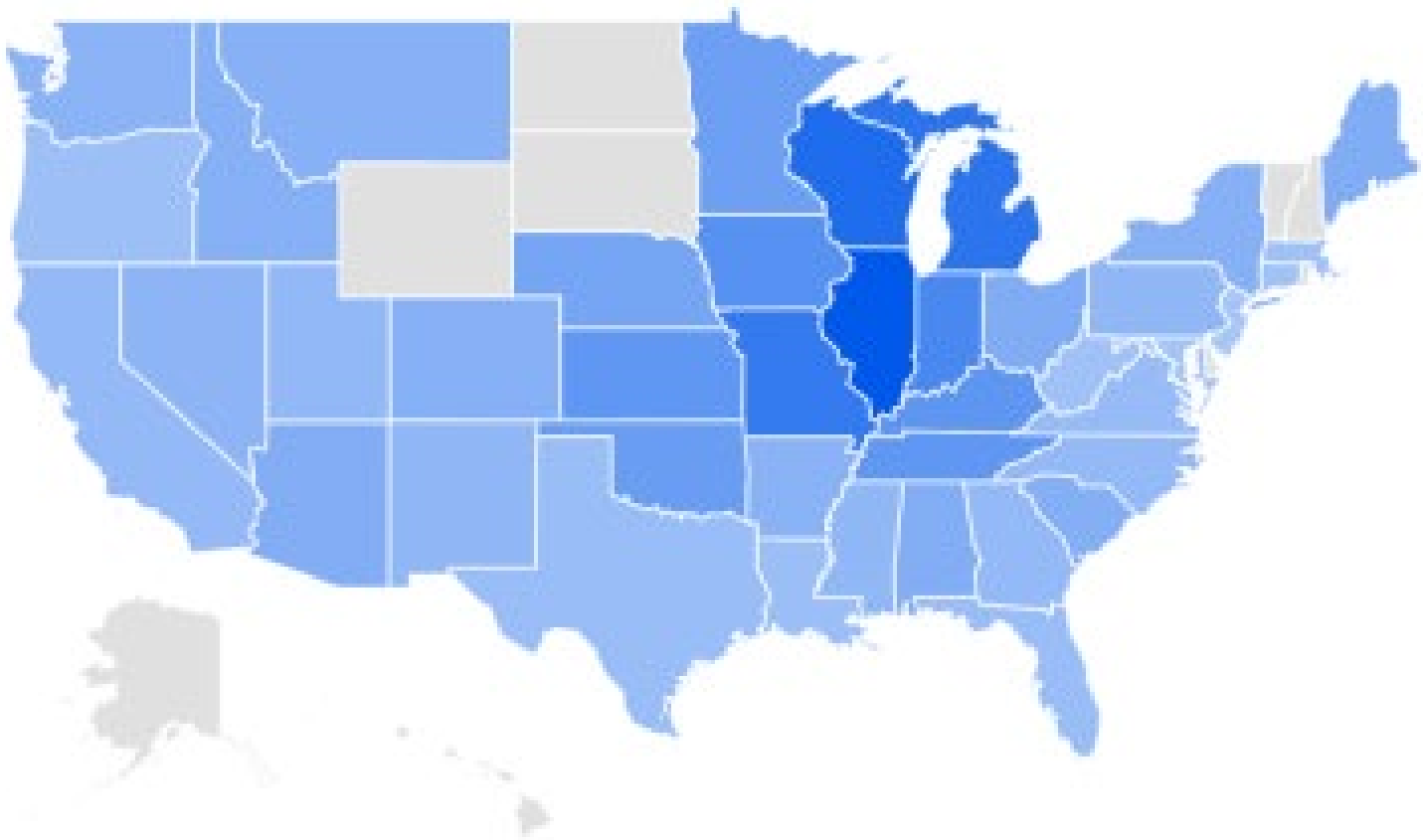

Incidence Per
100,000 Per Year
210
180
150
120
0
25
50
75
100
Temperature / F


City
Year
Sex
Age
Day of Week
Prior Week Temp
Incidence of Appendicitis


Fixed effects
City
Year
Sex
Age
Day of Week
Prior Week Temp
Incidence of Appendicitis

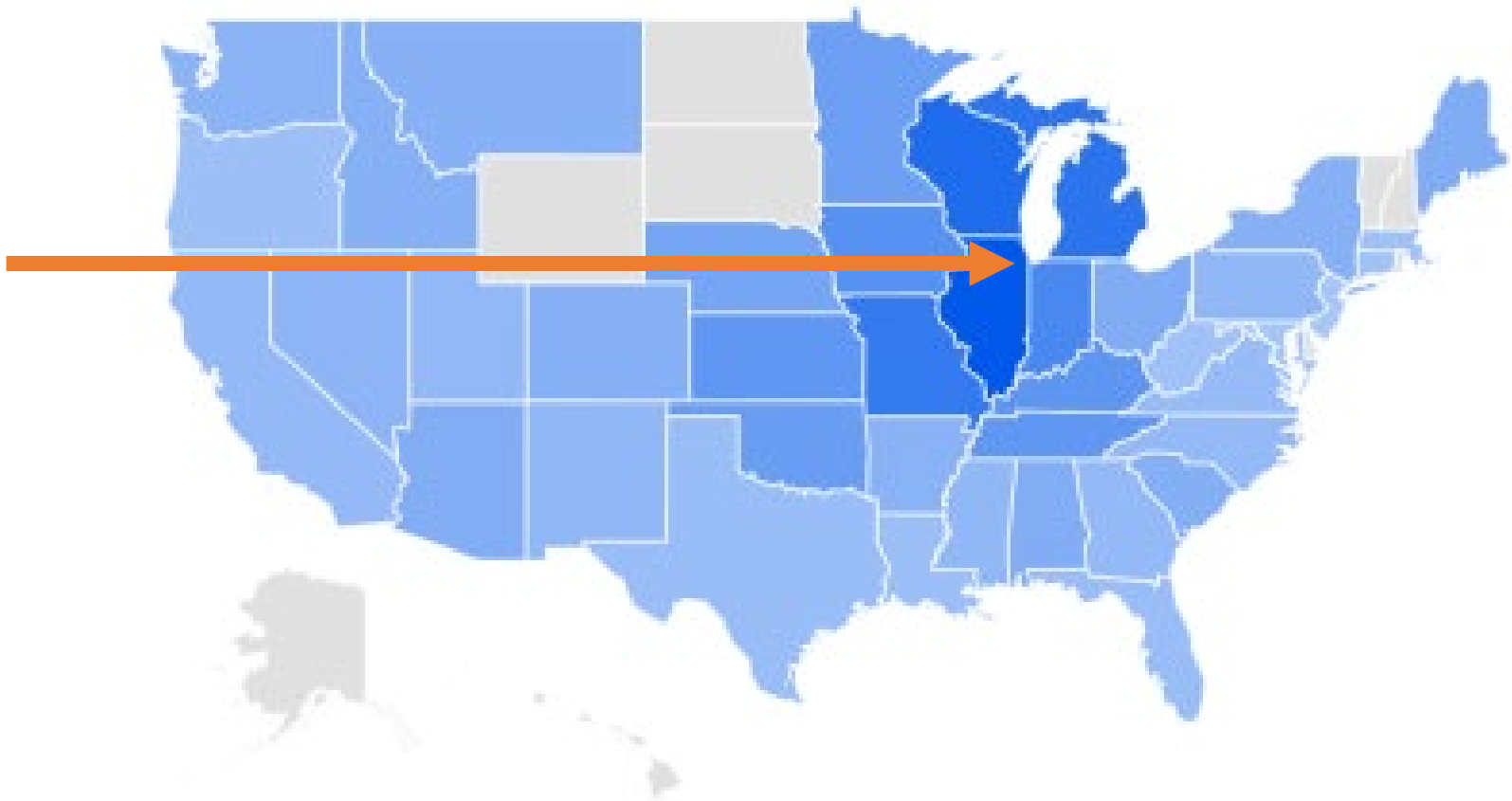
Suppose the humble Polish sausage is a risk factor for appendicitis

Google search volume for “Polish Sausage”



Google search volume for “Polish Sausage”

Eats lots of Polish Sausage



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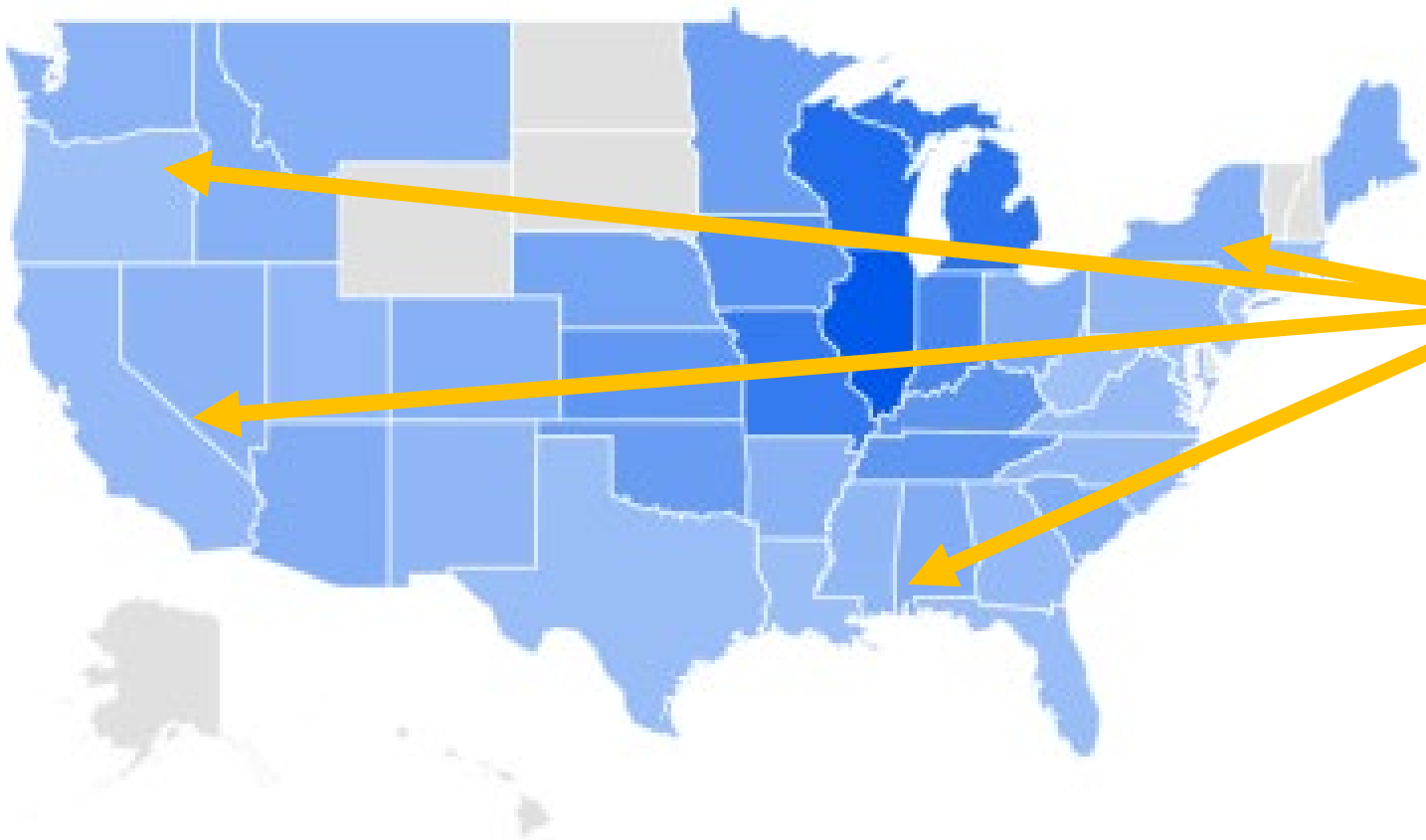
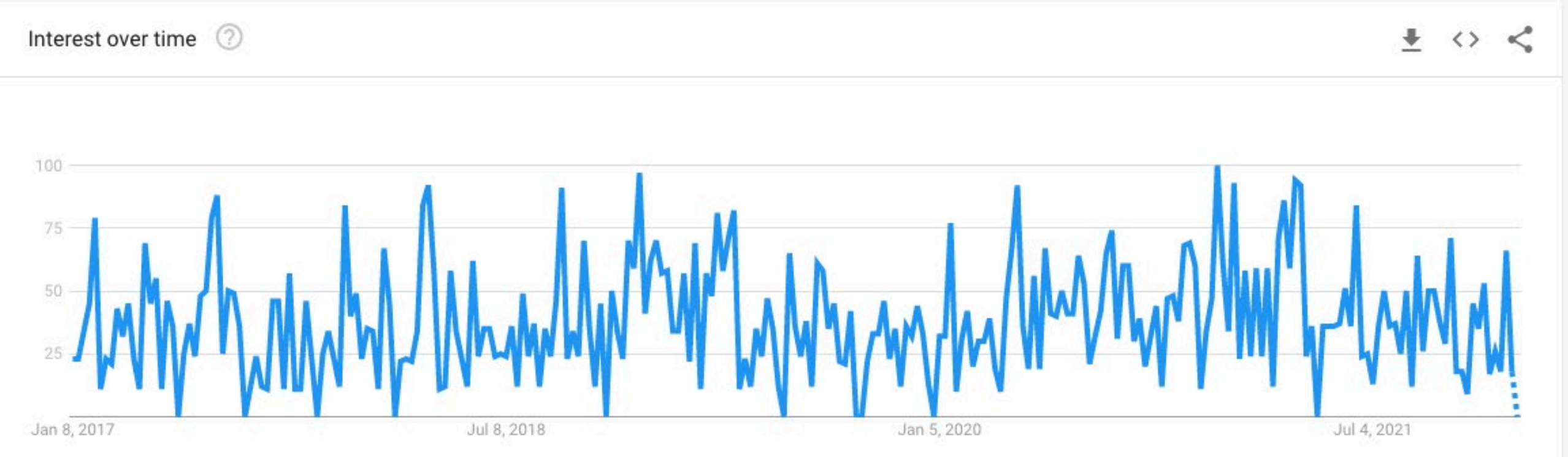


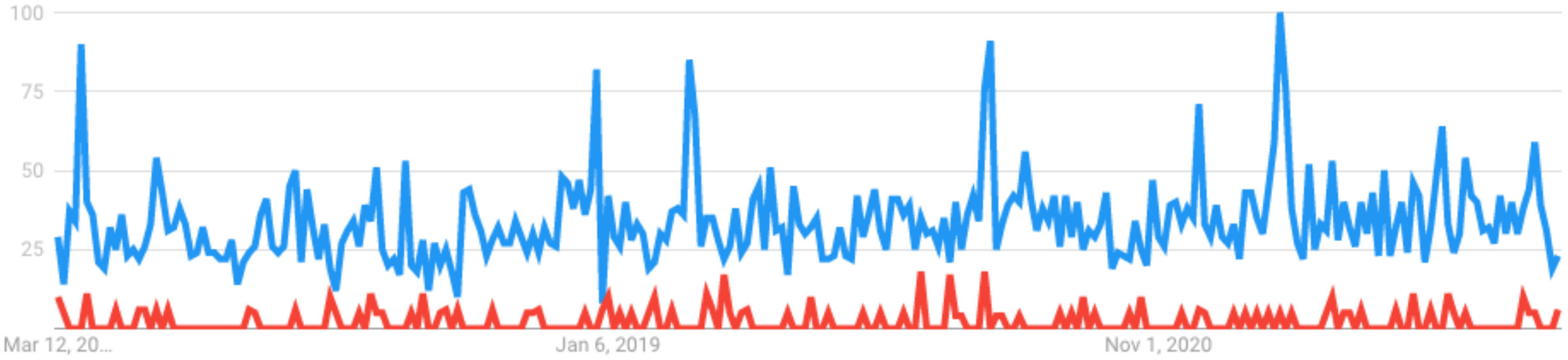
What’s Polish Sausage

Google search volume for “Polish Sausage” in Illinois for the last 5 years



Demand for Polish sausage will be the same year-to-year in Chicago

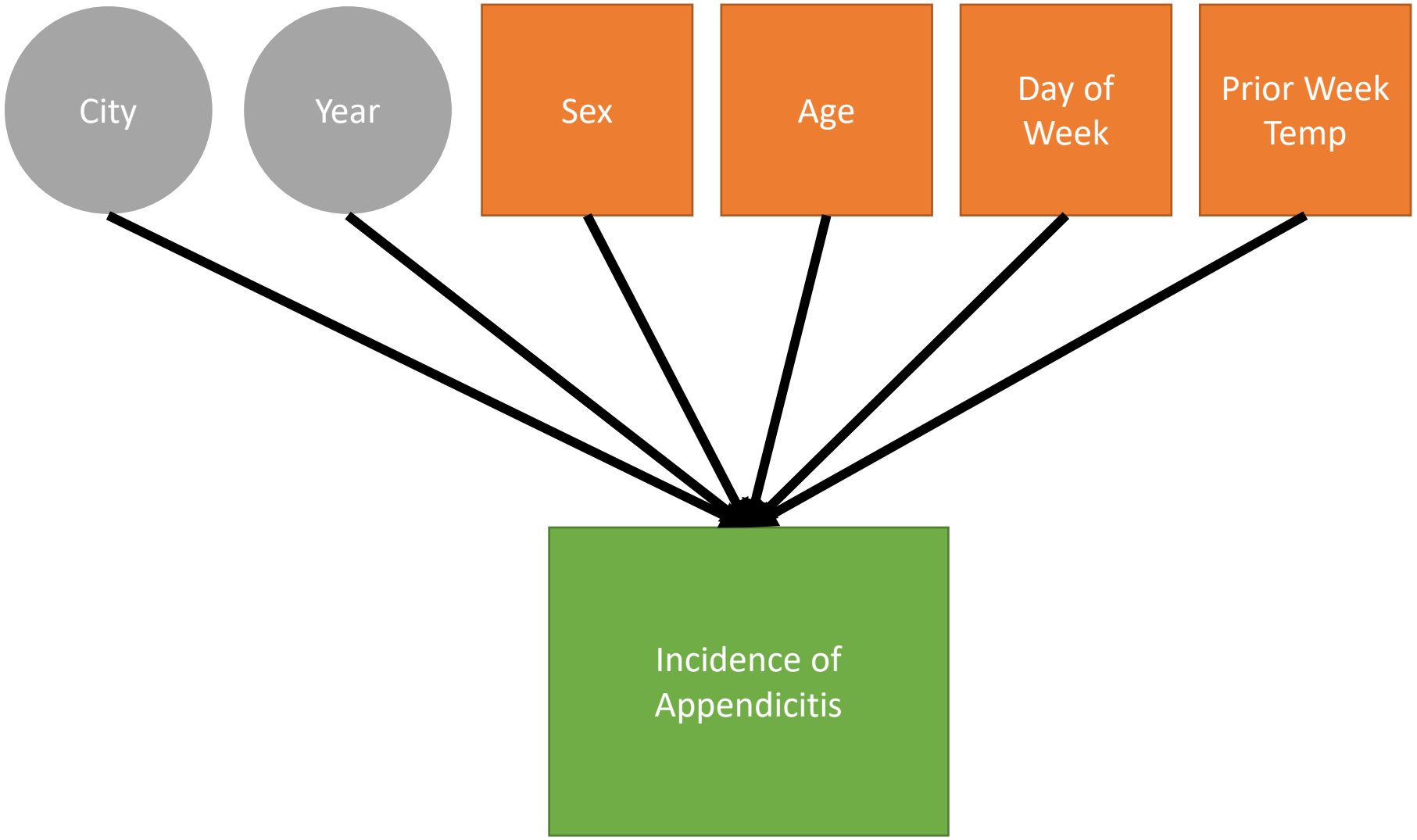
And the same is true (but much lower) in Miami



We do this for

Cities (a city is similar to itself year after year)

Year (each year has a similar effect on incidence across all cities)



Estimate this model with a negative binomial fixed effects regression

		95% CI (robust SE by clustered by MSA)	
	Incidence Rate Ratio	Lower Bound	Upper Bound
Prior Week Temperature (Per 10 Degrees)	1.012	1.007	1.016

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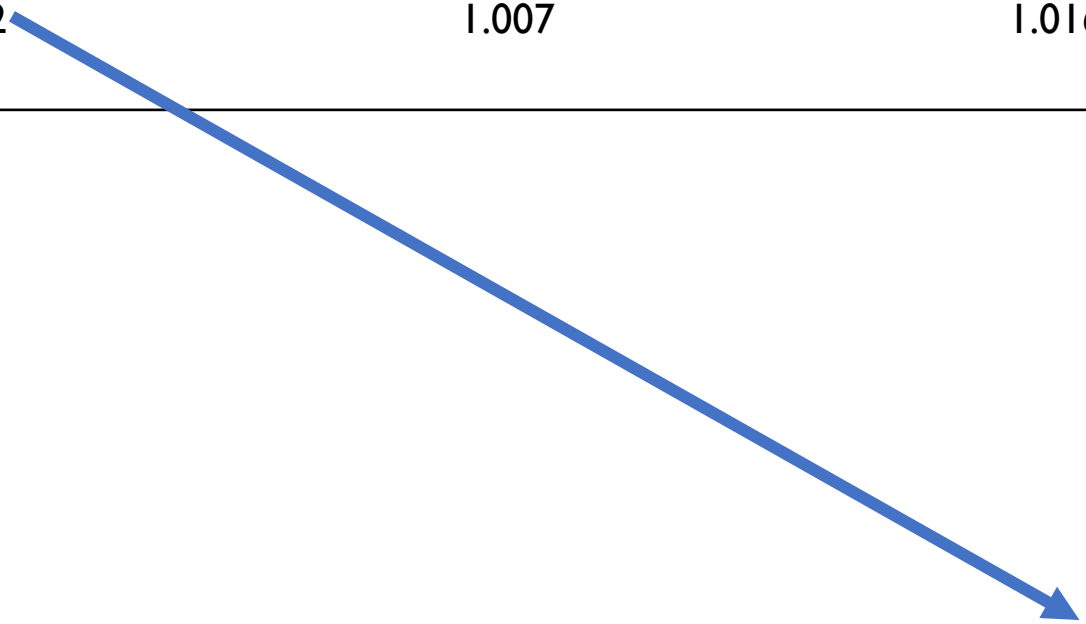

For every 10 degree increase in temperature when the temperature is below 53, there is a 1.2% increase

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	Incidence Rate Ratio	Lower Bound	Upper Bound
Prior Week Temperature (Per 10 Degrees)	1.012	1.007	1.016
Prior Week Temperature 53-73F			
Additional Change	1.018	1.009	1.027

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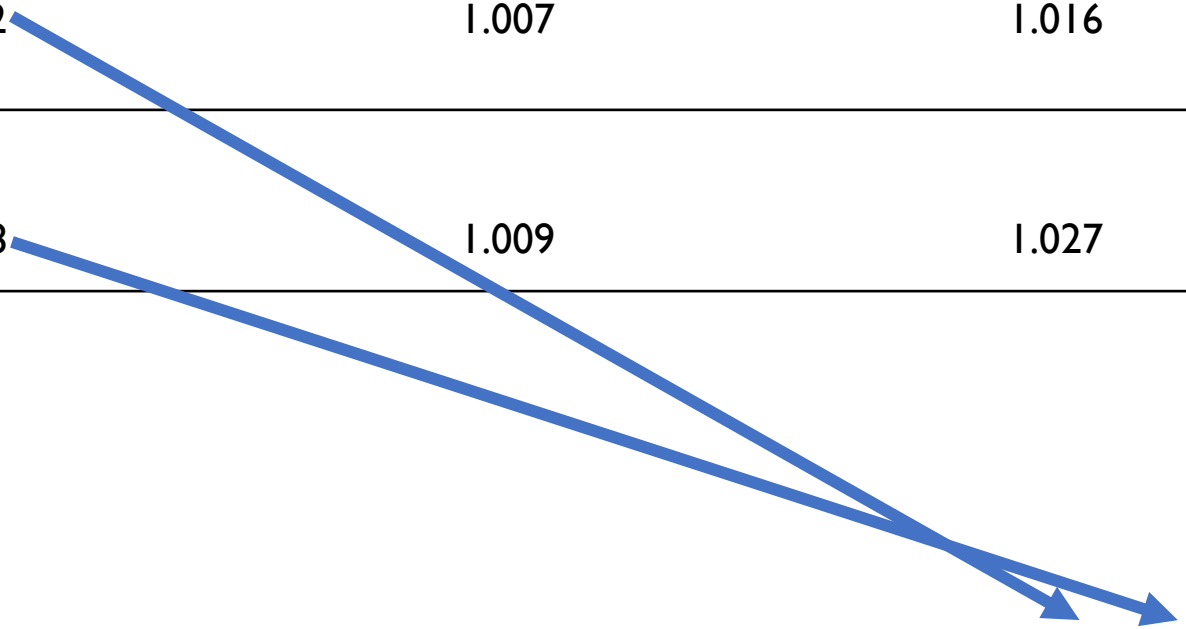

For every 10 degree increase in temperature when the temperature is 53-73, there is a **1.2*1.8 = 2.2%** increase

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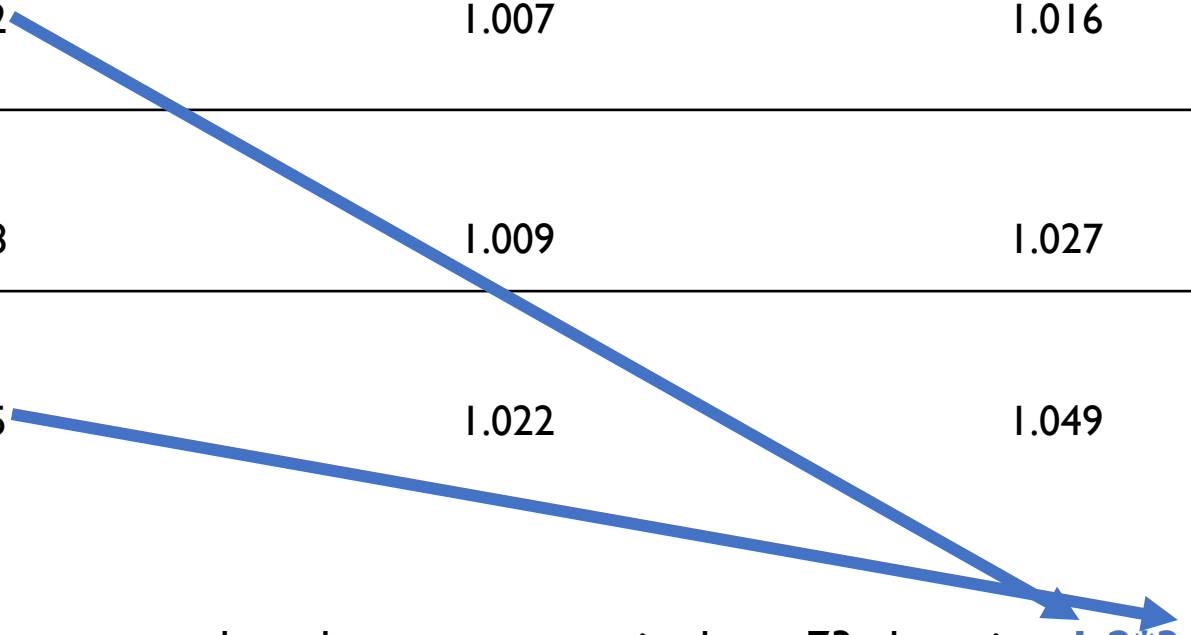
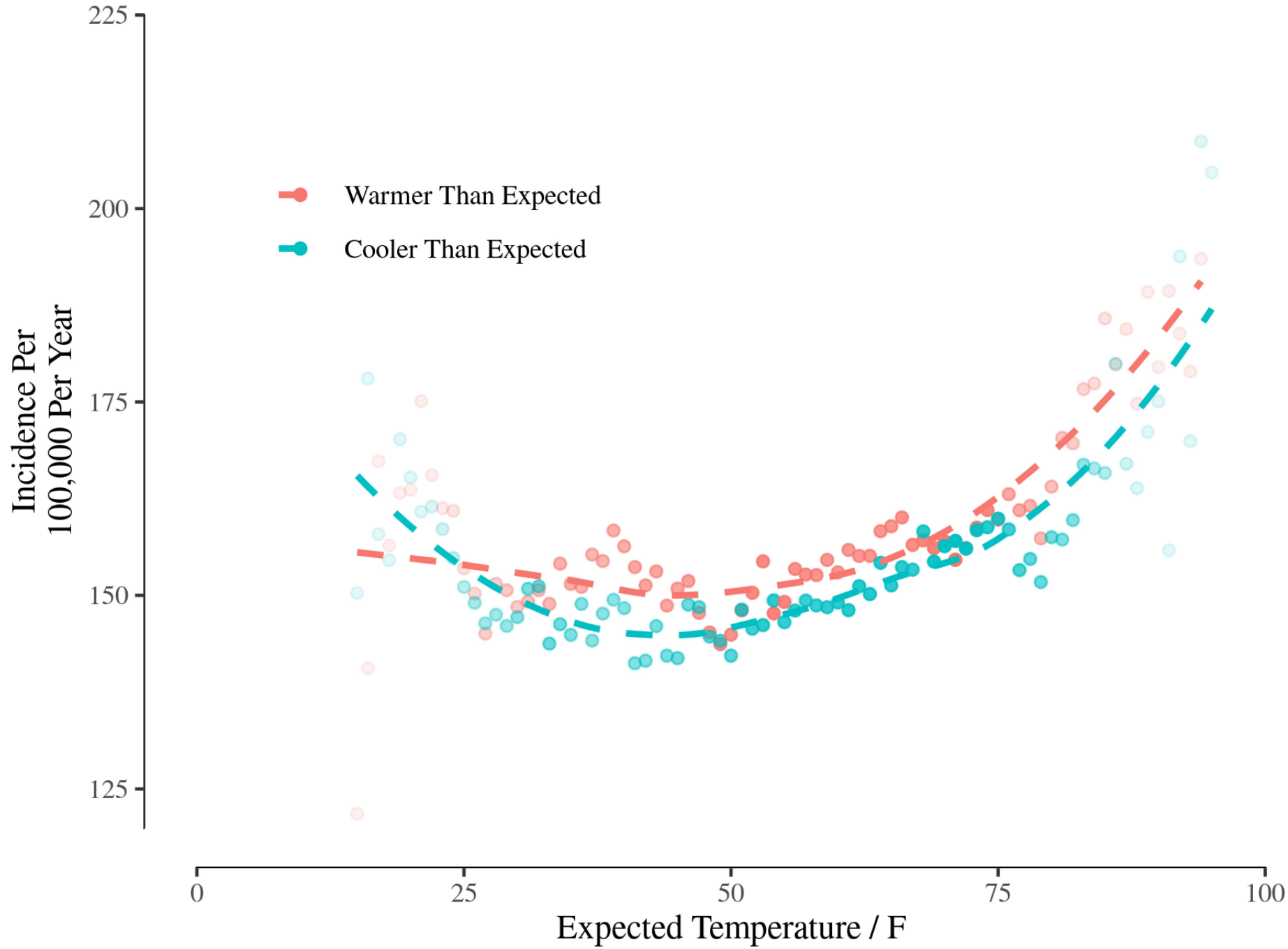


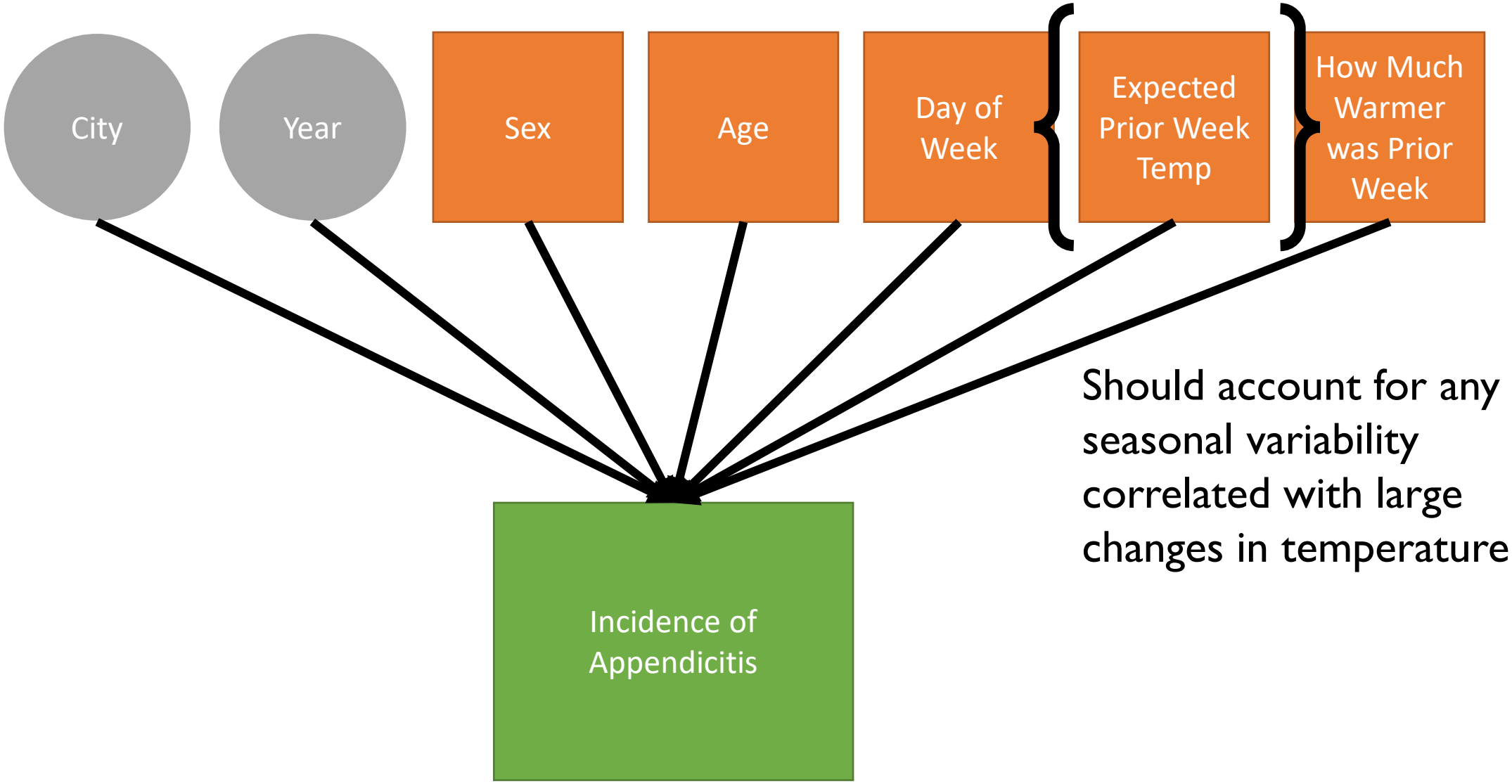
For every 10 degree increase in temperature when the temperature is above 73, there is a **1.2*3.5 = 4.2%** increase

		95% CI (robust SE by clustered by MSA)	
	Incidence Rate Ratio	Lower Bound	Upper Bound
Prior Week Temperature (Per 10 Degrees)	1.012	1.007	1.016
Prior Week Temperature 53-73F			
Additional Change	1.018	1.009	1.027
Prior Week Temperature >73F			
Additional Change	1.035	1.022	1.049

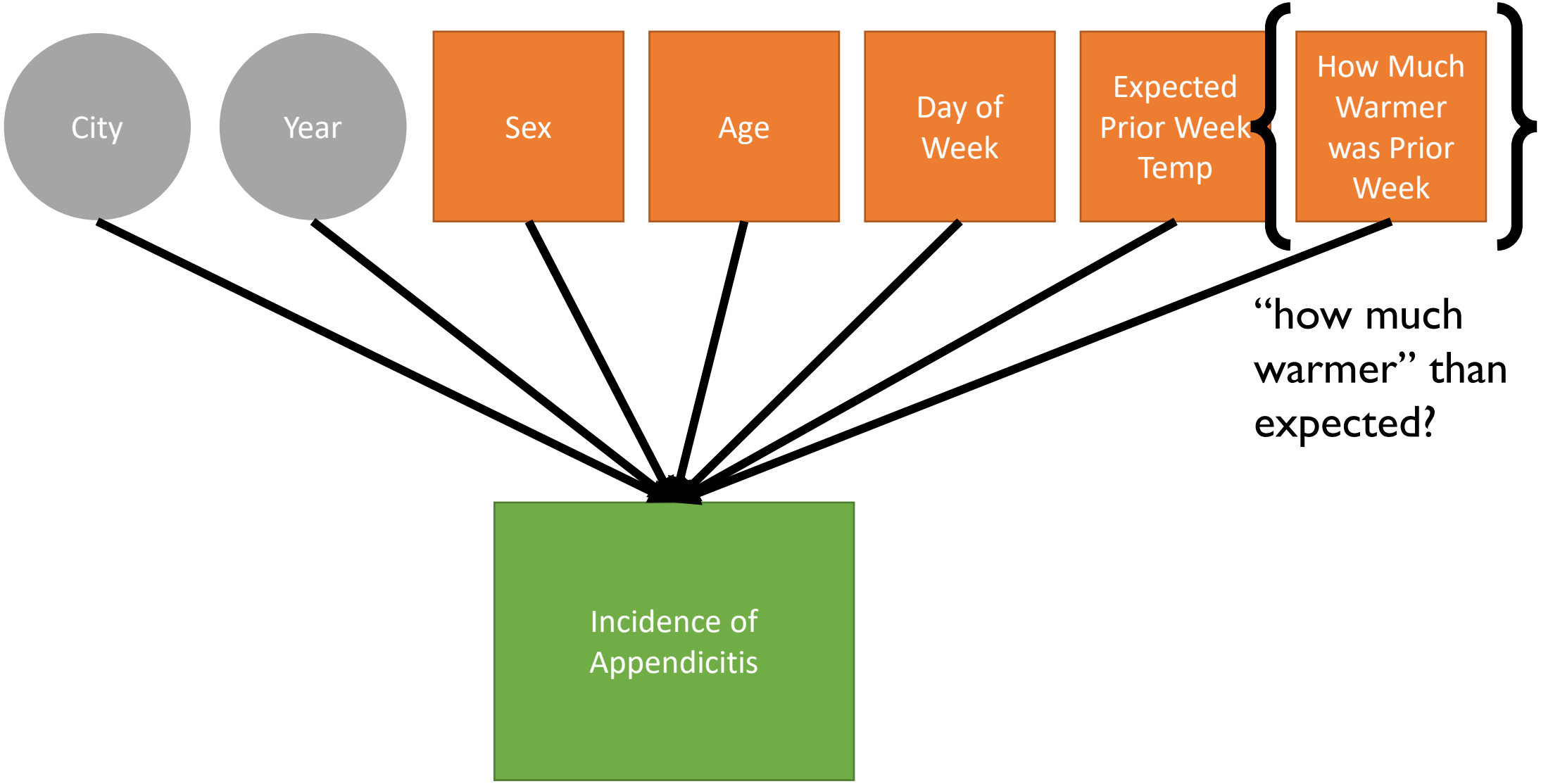
For every 10 degree increase in temperature when the temperature is below 53, there is a 1.2% increase in incidence
For every 10 degree increase in temperature when the temperature is 53-73, there is **1.2*1.8 = 2.2%** increase
For every 10 degree increase in temperature when the temperature is above 73, there is a **1.2*3.5 = 4.2%** increase

Warmer temperature had increased risk but maybe its due to confounding by omitted seasonality

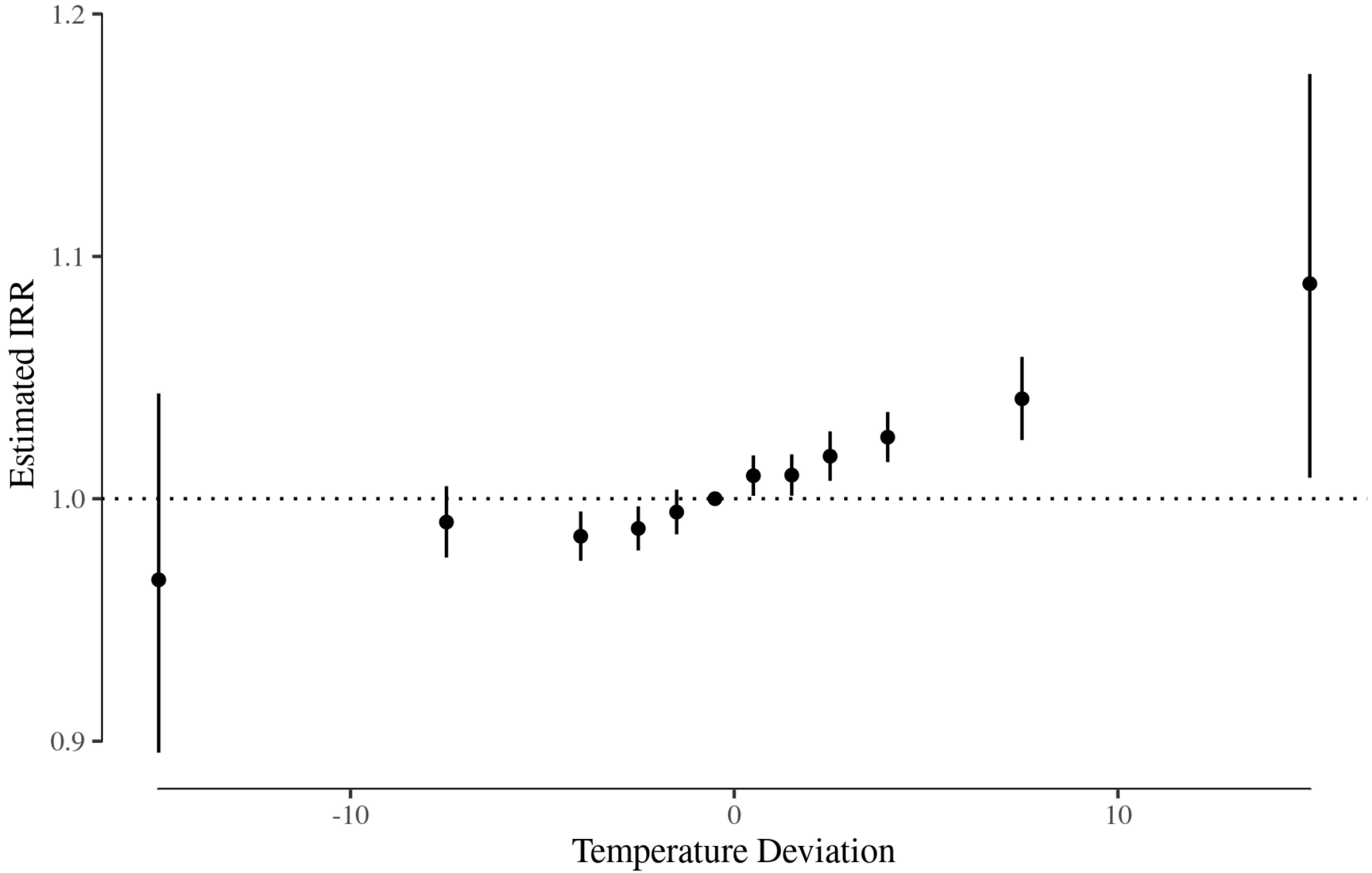

225
200
175
150
125
Incidence Per
100,000 Per Year
Warmer Than Expected
Cooler Than Expected
0
25
50
75
100
Expected Temperature / F

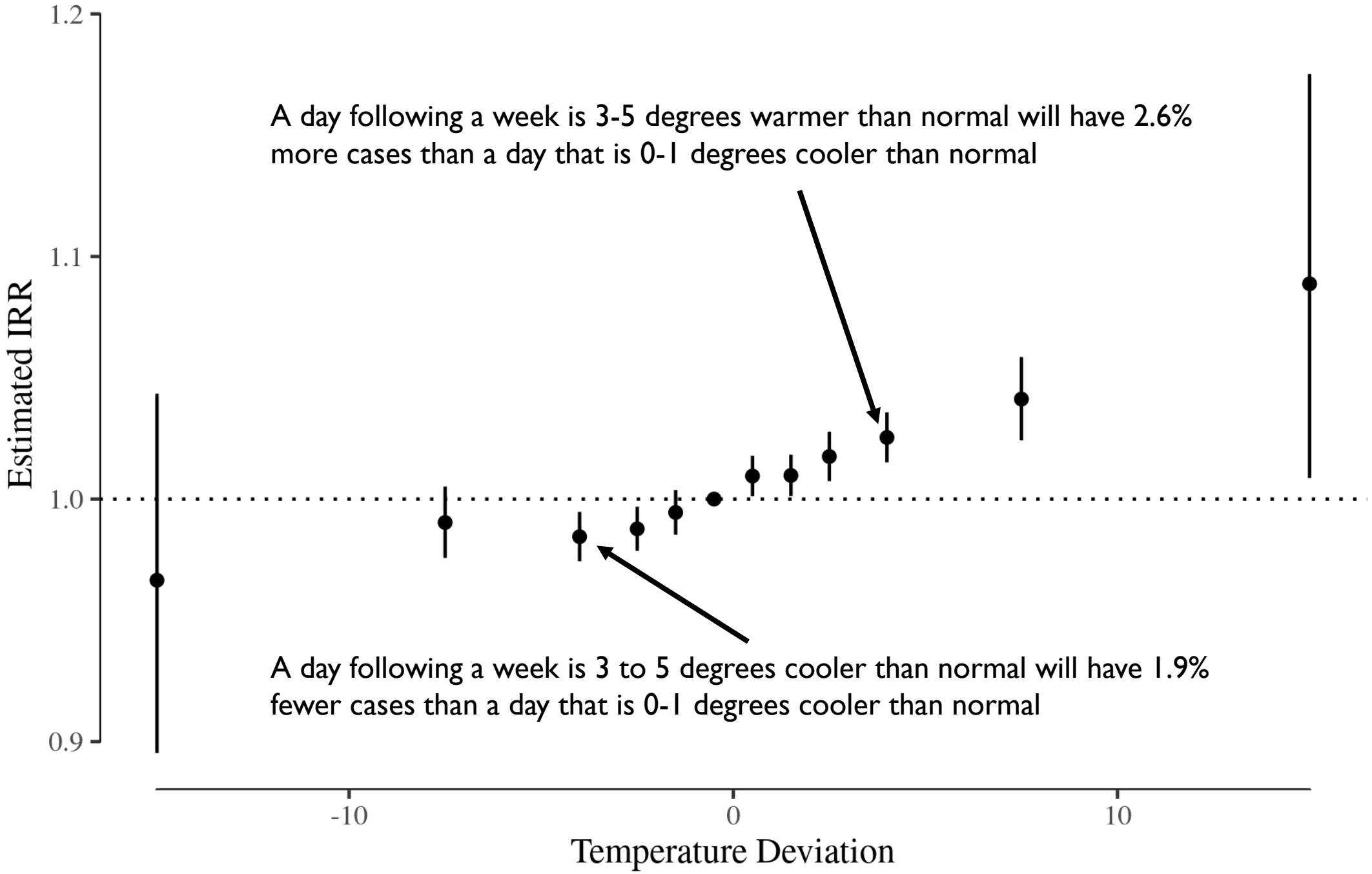


Should account for any seasonal variability correlated with large changes in temperature



"how much warmer" than expected?


1.2
1.1
1.0
0.9
Estimated IRR
-10
0
10
Temperature Deviation


A day following a week is 3-5 degrees warmer than normal will have 2.6% more cases than a day that is 0-1 degrees cooler than normal
A day following a week is 3 to 5 degrees cooler than normal will have 1.9% fewer cases than a day that is 0-1 degrees cooler than normal
Estimated IRR
1.2
1.1
1.0
0.9
-10
0
10
Temperature Deviation

1. Clinically significant increase in incidence of appendicitis during the warmer periods of the year

2. Incidence is associated with deviations in temperature after adjustment for expected temperature, suggesting a causal role for temperature

3. Effect is consistent between both severe and non-severe cases of appendicitis

4. Potential method to reduce recurrence following medical management

Changing Climate, Changing Diseases

Vector changes

- Lyme disease
- Zika
- Malaria
- West Nile Virus

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Influenza Like Illnesses

- RSV
- Influenzas
- Rhinoviruses
- Coronaviruses

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Clearly Heat Related

- Heat Stroke
- Heat Exhaustion
- Fluid Depletion

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New?
- Urinary tract infections
- Acute appendicitis