Projections of Heat-Related Illnesses due to Increases in Obesity and Temperature

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INTRODUCTION

Background:

- Obesity prevalence is on the rise in the US. Obesity is defined as Body Mass Index (BMI) >= 30kg/m^2.
- Obesity is a risk factor in heat-related illnesses.
- Global mean temperatures are rising.
- There is an established positive association between temperatures and heat-related illnesses.

Objectives:

1. To **quantify the number of heat-related illnesses** due to increases in adult obesity and increases in temperatures.
2. To provide an example of how to **evaluate climate change effects on human health** by combining climate models and health models.

COMPONENTS OF THE MODEL

Component 1: the relationship between temperature and heat-related illnesses.

The incidence rate of heat-related illnesses is exponentially dependent on temperature for temperatures above 15.6ºC (Lippmann, 2013). Incidence rate increase rapidly at temperatures beginning at 30ºC.

$$IR(T) = IR(T_0)1.43^{(T-To)}, \text{ where } T > 15.6^oC$$

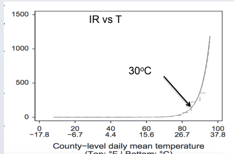


Figure 1. Incidence rates (IR) as a function of daily mean temperature (T). IR is defined as the number of emergency department visits per 100,000 person per year. Lippmann et al. (2013).

Component 2: the risk factor of obesity in heat-related illnesses. Donaghue and Bates (2000) analyzed miners working in deep underground mines to find the relationship between heat exhaustion cases and miners' BMI. They found **the obese are 3.63 more likely to get heat exhaustion than lean** (those not obese), defined as an odds ratio:

$$r_{odds} = IR_{obese}/IR_{lean} = 3.63$$

Combine models: develop incidence of heat related illness as a function of temperature and obesity.

Using the models above, we derive an equation for the incidence rate for the total population (IR) as a function of temperature (T) and fraction of population that is obese (obesity percentage, p_{obese}), assuming temperature and obesity to be independent.

$$IR(T,p_{obese}) = IR_{obese}(T_1)\,(p_{obese}(r_{odds}-1)+1)\,1.43^{(T-To)}$$

where $IR_{obese}(T_1) = \dfrac{IR(T_0)\quad 1.43^{(T-To)}}{(p_{obese}(T_1)(r_{odds}-1)+1)}$, $T1=35^oC$, $p_{obese}(T_1)=0.2$ (Donaghue and Bates, 2000)

PROJECTION OF FUTURE SCENARIOS

Projections of the incidence of heat-related illnesses are calculated using inputs of projected temperatures from climate models and inputs of projected obesity from health models.

1. Temperature projections: Table 1 shows the projected annual mean temperature increase is dependent on emissions scenarios in the Eastern North America. (IPCC: Christensen et al., 2013).

Temperature change (ΔT) between 1985-2005 for Eastern North America	RCP2.6	RCP6.0	RCP8.5
2016 - 2034	1.0ºC	0.9ºC	1.2ºC
2046 - 2065	1.4ºC	1.7ºC	2.8ºC

Table 1: Median area-mean temperature projections by CMIP5 models over Eastern North America for the RCP2.6, RCP6.0 and RCP8.5 scenarios (IPCC, 2013).

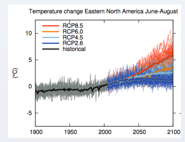


Figure 2 : Observed and projected temperature change over Eastern North America relative to 1986 - 2005. (IPCC, 2013).

PDF of Projected Daily Temperature in North Carolina: Daily mean temperature probability density function is generated from observations of daily mean temperature for North Carolina from 1989-2008 (Livneh et al., 2013). We will assume for a first approximation that **a future increase of temperature will have the same probability density profile as from 1989-2008 but shifted ΔT (ºC).**

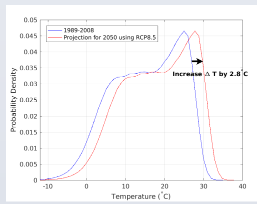


Figure 3. Probability density function of daily mean temperature observations for a year, blue line year (Livneh et al., 2013). The probability density function projected for RCP8.5 at 2050 with ΔT=2.8ºC, red line.

2. Obesity Projections: Obesity projections are constructed using linear and logit regression from observed data: US National Health and Nutrition Examination Study (NHANES) and US Behavioral Risk Factor Surveillance System (BRFSS).

1. Finkelstein et al. (2012): Logit regression model using 1990-2008 BRFSS data.
2. Linear trend projection using 2005-2015 BRFSS data for North Carolina.
3. Wang et al. (2008): Linear regression model using1970s-2004 NHANES data.

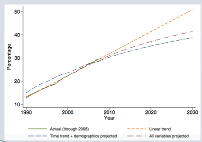


Figure 4. From Finkelstein et al. (2012). Obesity prevalence for: observed (green line), projected linear trend (orange dashed line) and projected using logit regression (purple dash-dot line).

RESULTS

1. Dependence of Heat-Related Illnesses on temperature and obesity: Incidence rates are more sensitive to temperature than obesity. By 2050 the temperatures are high enough to amplify incidence rate regardless of obesity level.

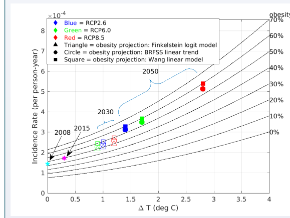


Figure 5. Incidence of heat-related illnesses area-averaged North Carolina as a function of change of temperatures from 1989-2008 and obesity. The area-average temperature for North Carolina for 1989-2008 is 14.9ºC.

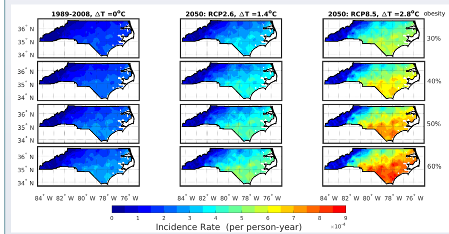


Figure 6. Incidence rates for heat-related illnesses for 1989-2008 temperatures (left), 2050 projected temperatures for RCP2.6 (middle) and RCP8.5 (right) and obesity levels of 30%, 40%, 50% and 60%.

2. Determining regions of vulnerability to heat-related illnesses

(i) The areas vulnerable to heat-related illnesses are dependent on temperature. **Vulnerable areas are regions in which daily mean temperatures are above a threshold temperature of 30ºC**. The threshold temperature is the temperature at which the incidence rate of heat-related illnesses begins increases rapidly with increasing temperature (Fig 1).

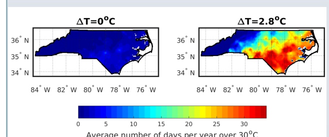
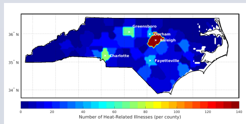


Figure 7. Average number of days per year over the threshold temperature of 30ºC for the observed time period of 1989-2008 (left) and for ΔT=2.8 (right).

(ii) The areas vulnerable to heat-related illnesses are dependent on population. **The number of heat-related illnesses are dominated by counties with high population.**

Figure 8. Number of heat-related illnesses per county in 2008. The number of heat-related illness was calculated by multiplying the incidence rate with county-level population. Annual county-level population data from North Carolina State Data Center.



DISCUSSION

- Both obesity and temperature have an effect the incidence of heat-related illnesses. **Temperature has an exponential effect on incidence of heat-related illnesses, obesity has a linear effect.** This incidence rate is especially significant at temperatures over 30ºC when the rate increases rapidly for increasing temperatures.
- Our model applied to North Carolina at 2050 shows that the **projected temperature changes produce much greater incidence rate increases than projected increases in obesity rate.**
- **Vulnerable areas to heat-related illnesses are dependent on spatial variation in temperature and population.** Vulnerable areas to heat-related illnesses are primarily regions with high temperatures.
- **This study is an example of how we can use models from multiple disciplines to quantify effects of climate change on human health.** Similar approaches can be used for other studies on climate impacts on public health.

FURTHER WORK

- **Spatial variation of obesity is important.** This model slightly overestimates the number of observed heat-related illnesses in North Carolina. This is likely to be due to a uniform obesity rate over North Carolina, whereas the observed obesity rate is 6% lower in populated urban areas than rural areas (Befort et al., 2012). Consistent with this explanation, Lippmann et al. found incidence of heat-related illnesses to be greater in rural than urban counties. **Future studies for using better spatial resolution of obesity data along with population data, will be needed to determine areas most vulnerable to heat-related illnesses**.
- Include a more comprehensive heat index that takes into account of humidity and temperature, i.e. wet-bulb temperature, to calculate dependence of incidence rate of heat-related illnesses could potentially allow us to generalize to regions beyond North Carolina.

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