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Assessing the Burden of Suicide Death Associated With Nonoptimum Temperature in a Changing Climate

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IMPORTANCE Few studies have projected future suicide burden associated with daily temperatures in a warming climate.

OBJECTIVES To assess the burden of suicide death associated with daily nonoptimal temperature and to project the change of suicide burden associated with nonoptimal temperature in different regions and seasons under various climate change scenarios.

DESIGN, SETTING, AND PARTICIPANTS Between January 1, 2013, and December 31, 2019, we conducted a time-stratified, case-control study among more than 430 000 individual suicide decedents from all counties in mainland China.

EXPOSURES Daily meteorological data were obtained from the European Centre for Medium-Range Weather Forecasts Reanalysis Fifth Generation (ERA5) reanalysis product. Historical and future temperature series were projected under 3 scenarios of greenhouse-gas emissions from 1980 to 2099, with 10 general circulation models.

MAIN OUTCOMES AND MEASURES The relative risk (RR) and burden of suicide death associated with nonoptimal temperature (ie, temperatures greater than or less than minimum-mortality temperature); the change of suicide burden associated with future climate warming in different regions and seasons under various climate change scenarios.

RESULTS Of 432 008 individuals (mean [SD] age; 57.6 [19.0] years; 253 093 male [58.6%]) who died by suicide, 85.8% (370 577) had a middle school education or less. The temperature-suicide associations were approximately linear, with increasing death risks at higher temperatures. The excess risk was more prominent among older adults (ie, ≥75 years; RR, 1.71; 95% CI, 1.46-1.99) and those with low education level (ie, middle school education or less; RR, 1.46; 95% CI, 1.36-1.57). There were 15.2% suicide deaths (95% estimated CI [eCI], 14.6%-15.6%) associated with nonoptimal temperature nationally. Consistent and drastic increases in excess suicide deaths over this century were predicted under the high-emission scenario, whereas a leveling-off trend after the mid–21st century was predicted under the medium- and low-emission scenarios. Nationally, compared with the historical period (1980-2009), excess suicide deaths were predicted to increase by 8.3% to 11.4% in the 2050s and 8.5% to 21.7% in the 2090s under the 3 scenarios. The projected percentage increments of excess suicide deaths were predicted to be greater in the South (55.0%; 95% eCI, 30.5%-85.6%) and in winter (54.5%; 95% eCI, 30.4%-77.0%) in the 2090s under the high-emission scenario.

CONCLUSIONS AND RELEVANCE Findings of this nationwide case-control study suggest that higher temperature may be associated with the risk and burden of suicide death in China. These findings highlight the importance of implementing effective climate policies to reduce greenhouse gas emissions and tailoring public health policies to adapt to global warming.

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Supplemental content

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Climate change is a growing global crisis that is already massive in scale and will continue to grow with inaction.[1] A number of studies have well-documented various physical health risks associated with nonoptimum ambient temperature and climate change.[2,3] Climate warming can also exacerbate many social and environmental risk factors for mental health and psychosocial well-being, which may contribute to emotional distress, the development of new mental disorders, and a worsening situation for people already living with these illnesses.[4,5] However, these adverse effects have received far less attention than those on physical health. Because mental disorders are a major contributor to the global burden of disease and disability, it is of great significance to explore the impact of nonoptimum temperature on mental health under climate warming.[6]

As the severest form of mental disorders, suicide is recognized as a critical public health problem worldwide.[7,8] According to the Global Burden of Disease Study,[9] more than 0.7 million people died from suicide in 2019, and 77% of suicides occurred in low- and middle-income countries. Higher temperature has been recently identified to be a risk factor of suicide.[10-15] However, most evidence was derived from ecological time-series or case-control studies that used aggregate data of suicide,[16-19] making it difficult to control for individual-level confounding factors. Although 2 case-control studies[20,21] had evaluated the association between ambient temperature and suicide at the individual level, they were conducted at a single center with a very small sample size, consequently attenuating the generalizability and robustness of the results.

Furthermore, quantifying the burden of suicide associated with nonoptimum temperature and projecting the magnitude and patterns of change in suicide burden under climate warming are essential for public policy formulation to prevent suicide. A previous study has projected that unmitigated climate change would lead to a combined 9000 to 40 000 additional suicides across the US and Mexico by 2050.[22] Another US study found that warming of 1 to 6 °C would result in an annual increase of 283 to 1660 additional suicide cases, corresponding to a population attributable fraction of 0.7% to 4.1%.[23] However, these projection studies were conducted at the monthly level and used a uniform relative risk (RR) per unit temperature increase. In addition, the magnitude of climate warming could vary considerably by season, and the effect of seasonal heterogeneity on changes in suicide burden remains unknown.

Using a national death registry of China, we conducted this individual-level, case-control study to assess the burden of suicide death associated with daily nonoptimum temperature. Potential outcome modifications by sex, age, and education level were also assessed. We further projected the change of suicide death burden associated with nonoptimum temperature in different regions and seasons under various climate scenarios.

Key Points

Question How is nonoptimum temperature associated with suicide death in a warming climate?

Findings In this case-control study of 432 008 of individuals, the temperature-suicide associations were found to be approximately linear, with increasing death risks associated with higher temperature, and 15.2% of suicide deaths were associated with nonoptimal temperature nationally. It is projected that there will be consistent and drastic increases in excess suicide deaths over this century under the high-emission scenario.

Meaning Results of this nationwide case-control study suggest that higher temperature may be associated with an increase in the risk and burden of suicide death; further, results suggest a comprehensive picture of the suicide death burden under climate warming in China.

Methods

Historical Death and Temperature Data

The detailed descriptions on the overall study design were provided in eMethods 1 in Supplement 1. The institutional review board at the School of Public Health, Fudan University, deemed the study exempt from review and waived the requirement for informed consent because the study involved analysis of deidentified data. We obtained individual records of suicide deaths from the China Cause of Death Reporting System,[24] which is the most representative national death registry in China. It collects the causes of deaths and the sociodemographic information for all decedents occurring in the whole of mainland China that covers 2844 county-level administrative units.

For this study, we extracted anonymous individual records for all suicide deaths from the China Cause of Death Reporting System between January 1, 2013, and December 31, 2019. Deaths from suicide were defined as those having an underlying cause named intentional self-harm, which was coded by the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* codes X60-X84.9, Y10-Y10.3, and Y87.0. Information on the date of death, demographics (ie, sex, age, and education level), and geocoded residential address was also obtained. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

The meteorological data (ie, temperature, relative humidity, precipitation, cloud cover, wind speed) were obtained from the European Centre for Medium-Range Weather Forecasts Reanalysis Fifth Generation (ERA5) reanalysis product with 0.1° × 0.1° spatial and hourly temporal resolutions.[25] The hourly meteorological data were extracted from the nearest grid cell in the ERA5 data set, and for each grid cell, the mean of all 24-hour estimates over the day was calculated as the daily mean meteorological data.

Projected Temperature Data

We obtained daily mean temperature series projected by 10 general circulation models (GCMs) for the period 1980 to 2099 from the National Aeronautics and Space Administration Earth Exchange Global Daily Downscaled Projections data set (eTable 1 in Supplement 1). We selected 3 shared socioeconomic pathway (SSP) scenarios of SSP126, SSP145, and

SSP585.[26] The detailed information on the climate change scenarios is provided in eMethods 2 in Supplement 1. We extracted simulated daily temperature series for each county by associating the coordinates with the corresponding cells of the grid. The resulting series was then calibrated with the ERA5 data using the bias-correction method developed within the Inter-Sectoral Impact Model Intercomparison Project.[27]

Statistical Analysis

Estimation of the Temperature-Suicide Association

The association between daily temperature and suicide death at the national level and regional level (eFigure 1 in Supplement 1) was estimated by an individual-level, time-stratified, case-control approach.[28] The detailed descriptions on the approach were provided in eMethods 3 in Supplement 1. We truncated the temperature distribution from the 1st to the 99th percentiles at the national or regional level to reduce the statistical uncertainty at temperature extremes.

We applied conditional logistic regression models to analyze the data. To explore possible nonlinear and lagged association with temperature, we incorporated a distributed lagged nonlinear model (DLNM) into the conditional logistic regression model.[29] Specifically, we introduced a cross-basis function of daily temperature built by the DLNM, which includes a quadratic B spline with 3 internal knots placed at the 10th, 75th, and 90th centiles of national or region-specific daily temperature distributions. We explored the lag response curves with a natural cubic B spline with an intercept and 3 internal knots placed at equally spaced values in the log scale, with a maximum lag up to 10 days (ie, from 0- to 9-day lag).[29-31] In addition, our main model included natural cubic B splines with 3 degrees of freedom of relative humidity, precipitation, cloud cover, wind speed, and a categorical variable of the holiday to control for their potential confounding effects.[28,32] We estimated the cumulative RR in subsequent analyses over a duration of lag days until the RR approached 1.0. To better interpret the RR associated with nonoptimum temperature, we chose a reference temperature that corresponds to the lowest risk (ie, minimum-mortality temperature) in the exposure-response curve and reported the RRs of suicide death and their 95% CI at the extremely high temperature (the 99th percentile) compared with the reference temperature. To facilitate the comparison with previous findings, we additionally provided the percentage change in death risk of suicide per 1 °C increase within the range between the extreme high temperature and the reference temperature at both national and regional levels, under a linear association assumption. To explore potential effect modifications, we further performed stratified analyses at the national level by age (≤64, 65-74, and ≥75 years), sex (male vs female), and education level (middle school or less vs high school or more).

Fractions of Suicide Death Associated With Nonoptimum Temperature

We quantified the burden of suicide death associated with nonoptimum temperature using the backward method proposed by a previous study.[33] This method could provide more accurate estimates of disease burden by accounting for the potentially complex lag patterns in the temperature-associated risks.[32,33] We calculated the attributable fraction (AF) at the national level and regional level. We calculated the empirical CIs (eCIs) of AF through Monte Carlo simulations.[33,34] The detailed calculation procedures can be found in eMethods 4 in Supplement 1.

Projections of Suicide Burden Associated With Future Climate Warming

We projected suicide death burden associated with climate warming using the modeled daily series of temperature under the assumption of no adaptation or population changes.[35] Briefly, for each county, we first used corresponding exposure-response association curves for specific regions to obtain the overall cumulative risks associated with each day's mean temperature relative to the referent temperature, and we then computed the excess deaths associated with the present-day nonoptimum temperature in the following lag days. Afterward, we summed the excess suicide deaths associated with daily nonoptimum temperature in each county.

We calculated the excess deaths separately for each county and for each combination of GCMs and SSPs. We then computed the excess deaths as GCM-ensemble averages by county, decade, and SSP. We aggregated the county-specific excess suicide deaths to derive the regional and national projections. We used Monte Carlo simulations to obtain 95% eCIs, so as to quantify the uncertainty in both the estimation of the exposure-lag-response associations and climate projections across GCMs. Then, we calculated the differences of projected excess suicide deaths in each decade of the scenario period (the 2010s, 2020s, through to the 2090s) compared with those in the historical period (ie, the mean of excess suicide deaths in each decade between 1980 and 2009). Finally, we assessed the burden of suicide death associated with future climate warming as the percentage change from the historical period.

We also calculated the AF of suicide death associated with nonoptimum temperature at the county, regional, and national levels. Finally, we calculated the differences of AFs in each decade of the scenario period compared with those in the historical period. Detailed descriptions can be found in eMethods 5 in Supplement 1.

All statistical analyses were performed using R software, version 3.6.1 (R Project for Statistical Computing) with the dlnm and survival packages. All analyses were 2-sided with an alpha of .05. The cutoff for statistical significance was $P < .05$.

Results

Descriptive Data

We evaluated a total of 432 008 individuals who died by suicide (mean [SD] age; 57.6 [19.0] years; 253 093 male [58.6%]; 178 915 female [41.4%]), of whom 85.8% (370 577) had a middle school education or less (eTable 2 in Supplement 1). The mean (SD) annual temperature at all locations of deaths was 13.6 (11.2) °C with the lowest in the Northeast (6.2 [14.1] °C) and the highest in the South (21.6 [6.1] °C). Nationally, the daily mean temperature ranged from −17.4 °C (the 1st percentile) to 30.9 °C (the 99th percentile).

Spatiotemporal Trend in Projected Annual Mean Temperatures

eFigure 2 in Supplement 1 shows consistently increasing trends of projected annual-mean temperatures relative to the historical period under various climate change scenarios, but the magnitude of increases differs by region with larger increments in the Northeast, Northwest, and North. Future climate warming was more prominent in the SSP585 scenario (increase of 5.5 °C by the 2090s) than in the SSP245 scenario (3.0 °C) and the SSP126 scenario (2.0 °C) nationally (eTable 3 in Supplement 1). The differences of projected temperatures among the 3 scenarios become more apparent after the 2050s (eTable 3 in Supplement 1).

Temperature-Suicide Association and the Burden Due to Nonoptimum Temperature

Figure 1 depicts the lag pattern for the RRs of suicide death associated with extreme high temperatures at the national and regional levels. The pattern is similar for various regions of China. Specifically, the RR was strongest on the present day (ie, the day of exposure to nonoptimum temperature [lag day 0]), attenuated drastically until lag day 3, and became nonsignificant thereafter. Accordingly, we derived the association between temperature and suicide death cumulated over lag 0 to lag day 3 in subsequent analyses and used this cumulative lag in disease burden assessment.

As shown in **Figure 2**, the shape of the exposure-response curves were largely similar across different regions. They were approximately linear, with increasing risks for higher temperature. For all regions, the minimum-mortality temperatures were around the extreme low temperature (the 1st percentile), which were thus used as the reference temperatures in subsequent analyses.

The **Table** presents the RRs and the AFs of suicide death associated with nonoptimum temperature at both national and regional levels. The nationwide RR comparing the extreme high temperature (30.9 °C) to the minimum-mortality temperature (−17.4 °C) was 1.44 (95% CI, 1.34-1.54). This indicates that a per 1 °C increase in daily temperature was associated with a 0.91% increase in risk of suicide death under a linear association assumption. The RRs in the Northeast, Northwest, Southwest, North, and South were higher than the national estimate. In total, there were 15.2% (95% eCI, 14.6%-15.6%) of suicide deaths attributable to nonoptimum temperature nationally, with higher AF in the East and the Southwest than the national estimate.

Figure 3 demonstrates the results of stratified analyses by age, sex, and education level. The RRs associated with extreme high temperature were considerably higher for decedents 75 years or older (RR, 1.71; 95% CI, 1.46-1.99) and those with lower education level (RR, 1.46; 95% CI, 1.36-1.57). Male decedents showed slightly larger RR than female decedents (RR, 1.47; 95% CI, 1.35-1.60 vs RR, 1.39; 95% CI, 1.25-1.55).

Suicide Death Burden and Future Climate Warming

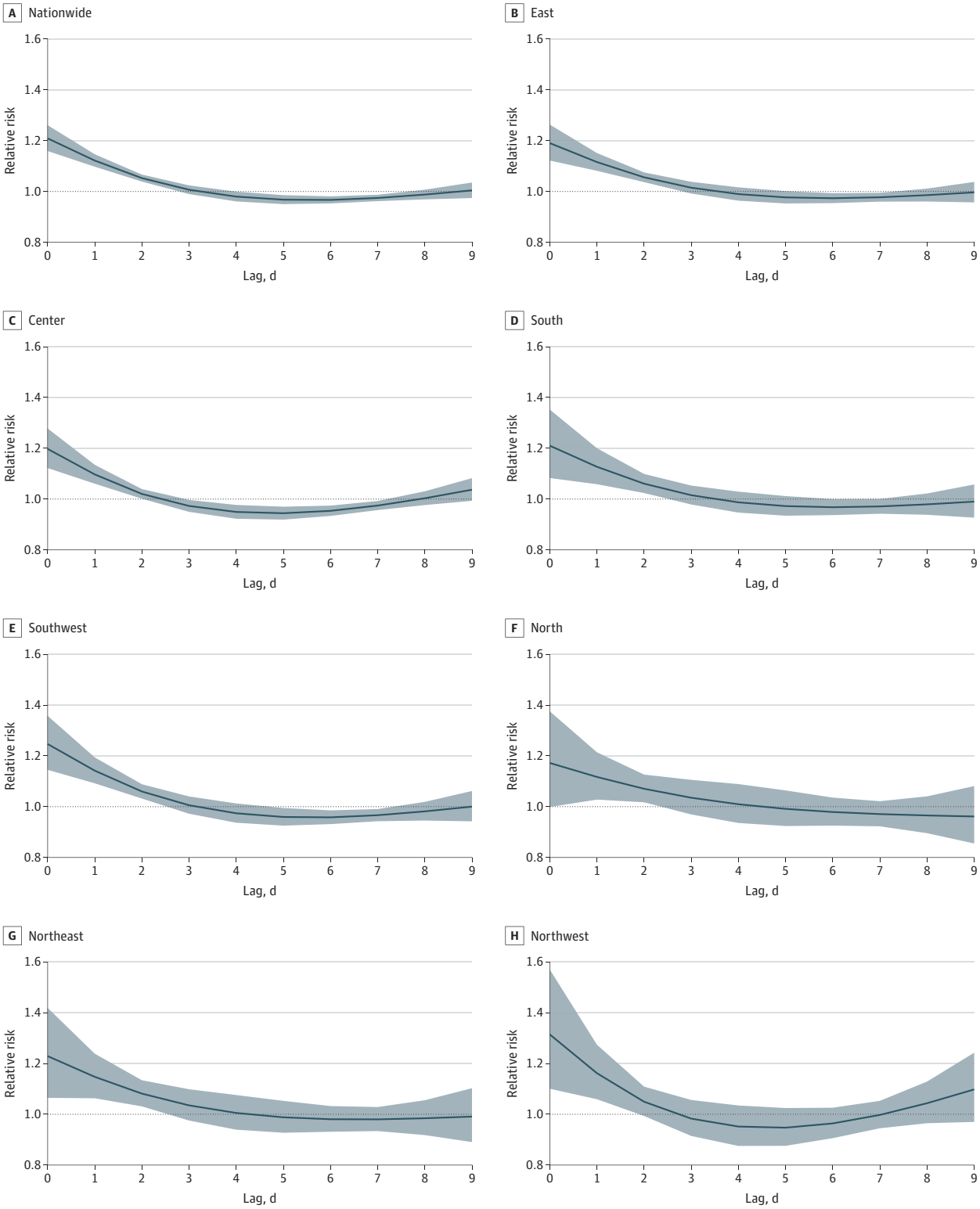
Figure 4 shows increases in future suicide deaths associated with nonoptimum temperature relative to the historical period at national and regional levels under 3 climate scenarios. Specifically, there was a consistent and drastic increase over this century under the SSP585 scenario, whereas there was a leveling-off trend after the middle of the century under the SSP126 and SSP245 scenarios. Nationally, compared with the historical period, excess suicide deaths will increase by 2.3% to 2.6% in the 2010s, 8.3% to 11.4% in the 2050s, and 8.5% to 21.7% in the 2090s under the 3 scenarios (eTable 4 in Supplement 1). It is noteworthy that the model projected 21.7% more suicide deaths due to climate warming at the end of the 21st century under the high-emission scenario relative to the historical period. In the 2090s, the number of excess suicide deaths will increase by 9429 (95% eCI, 4453-15 697) under SSP126, 13 731 (95% eCI, 7501-21 160) under SSP245, and 24 214 (95% eCI, 12 859-36 302) under SSP585 (eTable 5 in Supplement 1). eFigure 3 in Supplement 1 depicts the decadal differences in the predicted fractions of suicide deaths associated with nonoptimum temperature compared with the historical period. Nationally, the AF will increase by 0.5% in the 2010s, 1.6% to 2.3% in the 2050s, and 1.6% to 4.4% in the 2090s under the 3 scenarios (eTable 6 in Supplement 1).

The magnitude of projected increases in excess suicide deaths differs by region. The percentage increases will be greater in the South (55.0%; 95% eCI, 30.5%-85.6% during the 2090s under SSP585) than those in other regions (Figure 4; eFigure 4 and eTable 4 in Supplement 1). The season-specific projections revealed that the percentage increment in excess suicide deaths will be the highest in winter in the 2090s under the high-emission scenario (54.5%; 95% eCI, 30.4%-77.0%) (eFigure 5, eTable 7, and eTable 8 in Supplement 1). Nationally, the decade average number of excess suicide deaths associated with nonoptimum temperatures was significantly lower in winter (13 639) than in other seasons (spring, 28 476; autumn, 28 960; summer, 40 176) during the historical period. Compared with the historical period, excess suicide deaths were predicted to increase by 54.5% in winter, 22.1% in autumn, 19.3% in spring, and 11.9% in summer in the 2090s under SSP585 nationally (eTable 7 in Supplement 1).

Discussion

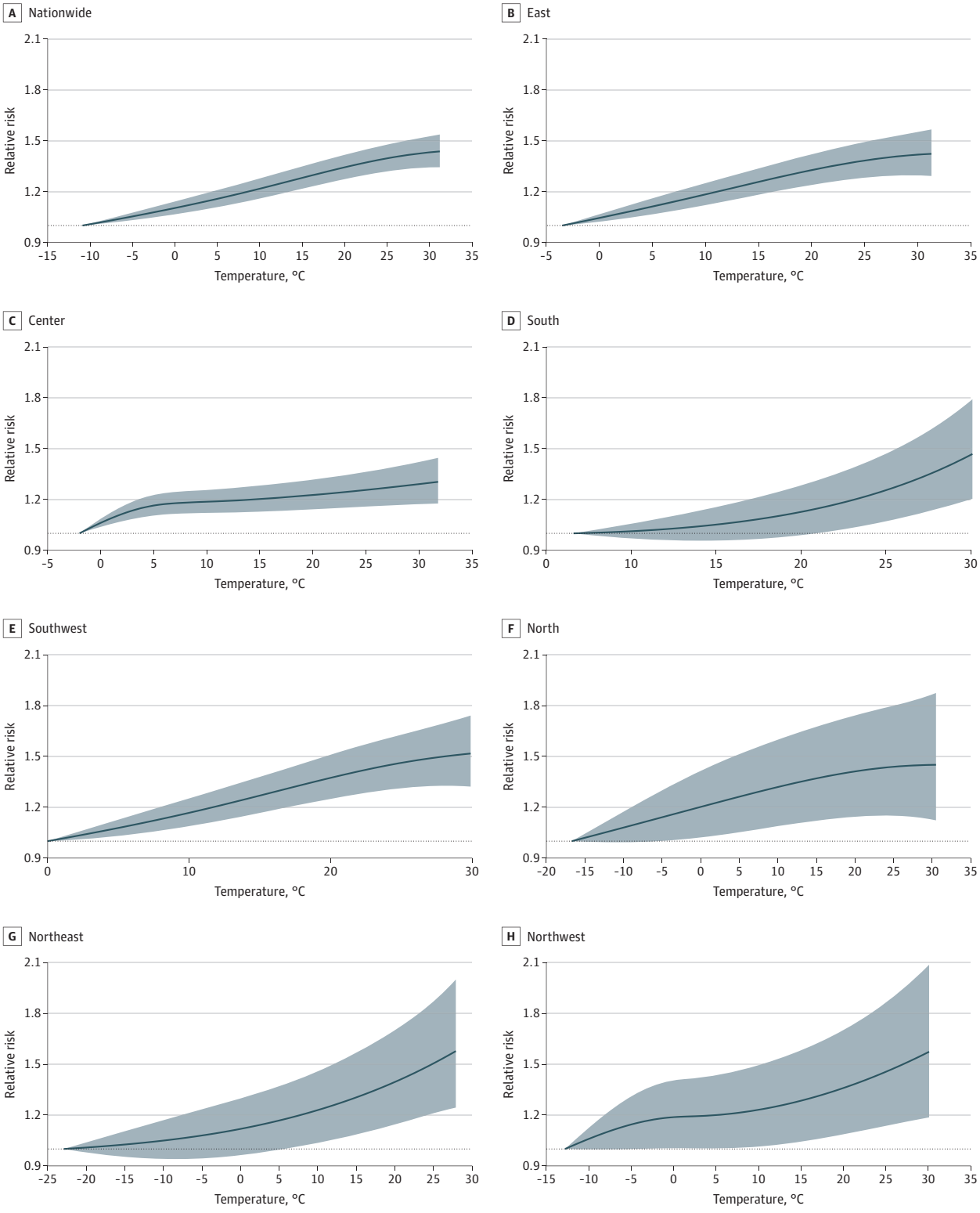
In this national individual-level, case-control study, we observed significant and approximately linear associations between daily mean temperature and suicide deaths, with increasing risks with higher temperature. The excess associated risk was more prominent among older adults and those with low education level. We further assessed the burden of suicide death associated with nonoptimum temperature, taking into consideration the spatial heterogeneity and the slightly nonlinear temperature-suicide association. We projected that the excess suicide deaths will increase with the warming climate, characterized by a consistent and drastic increase over this century under the high-emission scenario. The percentage increments of excess suicide deaths will be greater in the South and in winter. This nationwide study used a solid data set from the most representative death registry of China and an individual-level, time-stratified, case-control approach to analyze the association between daily temperature and suicide death, thereby ensuring the representativeness of our results.

Figure 1. Lag-Response Curves for the Relative Risk of Suicide Deaths Comparing Extreme High Temperatures (the 99th Percentile) to the Minimum-Mortality Temperatures (the First Percentile) in Different Regions of China



The solid lines are mean risk estimates, and the shaded areas are their 95% CIs.

Figure 2. Exposure-Response Curves for the Association Between Daily Temperature and Suicide Deaths in Different Regions of China



The associations were presented as the cumulative relative risks comparing a given temperature with the minimum-mortality temperature over a 0- to 3-day lag. The solid lines are mean risk estimates, and the shaded areas are their 95% CIs.

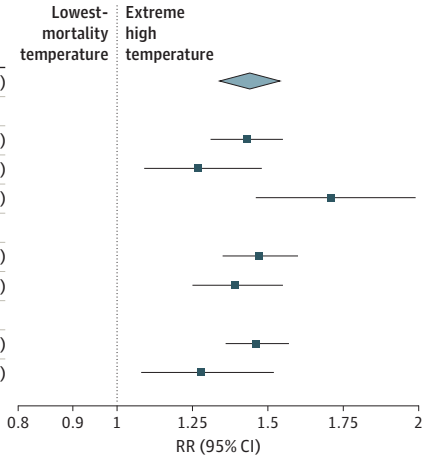
Table. Relative Risk and Attributable Fraction of Suicide Deaths Associated With Nonoptimum Temperature Over a 0- to 3-Day Lag, Classified by Region

Region	Mean (95% CI)		
	Relative risk[a]	Percentage changes per 1 °C increase[b]	Attributable fractions, %
Nationwide	1.44 (1.34-1.54)	0.91 (0.70-1.12)	15.2 (14.6-15.6)
East	1.42 (1.29-1.57)	1.23 (0.85-1.67)	17.8 (17.5-18.0)
Center	1.30 (1.18-1.45)	0.87 (0.52-1.31)	12.3 (11.8-12.7)
South	1.47 (1.20-1.79)	1.93 (0.82-3.24)	15.1 (14.0-16.0)
Southwest	1.52 (1.32-1.74)	1.15 (0.71-1.64)	16.0 (15.5-16.2)
North	1.45 (1.12-1.87)	0.94 (0.25-1.81)	14.4 (13.4-14.8)
Northeast	1.58 (1.24-2.00)	1.13 (0.47-1.94)	15.1 (13.9-15.8)
Northwest	1.57 (1.19-2.09)	1.19 (0.40-2.29)	11.5 (10.2-12.2)

[a] The relative risk of suicide death associated with extreme high temperature compared with the lowest-mortality temperature.

[b] The percentage change in death risk of suicide per 1 °C increase was calculated under a linear assumption within the range between the extreme high temperature and the lowest-mortality temperature.

Figure 3. National Cumulative Relative Risk (RR), Mean, and 95% CI of Suicide Deaths Associated With Extreme High Temperature Over a 0- to 3-day Lag, Stratified by Age, Sex, and Education



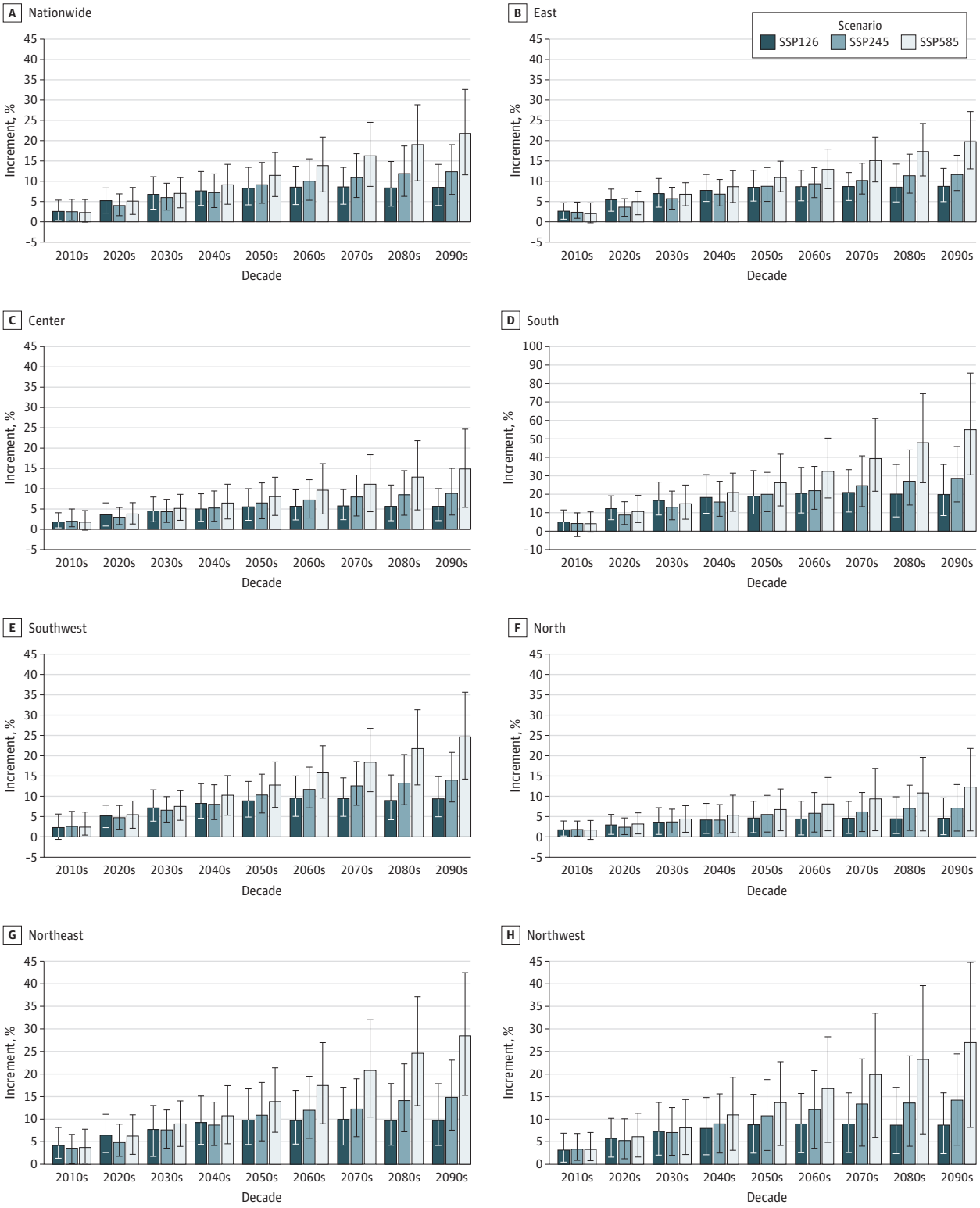
Subgroup	No. (%)	RR (95% CI)
Overall	432 008 (100)	1.44 (1.34-1.54)
Age, y		
<65	260 979 (60.4)	1.43 (1.31-1.55)
≥65 to <74	88 513 (20.5)	1.27 (1.09-1.48)
≥75	91 540 (21.2)	1.71 (1.46-1.99)
Sex		
Male	253 093 (58.6)	1.47 (1.35-1.60)
Female	178 915 (41.4)	1.39 (1.25-1.55)
Education		
≤Middle school	370 577 (85.8)	1.46 (1.36-1.57)
≥High school	57 933 (13.4)	1.28 (1.08-1.52)

Our results suggest that higher temperature was associated with an increased risk of suicide death with an approximately linear relationship, which is consistent with previous studies.[13,17,18,22] For example, a multicountry analysis indicated that higher ambient temperature was associated with increased risks of suicide death, with the country-specific RRs ranging from 1.31 in the US to 1.61 in South Korea,[19] which is comparable to our estimate (RR = 1.44). We observed that the risk was the strongest on the present day, which suggested the necessity of prompt precaution of suicide risk when encountering extremely hot days or heat waves. Furthermore, for the first time to our knowledge, we estimated a considerable proportion (15.2%) of suicide death that could be associated with nonoptimum temperature, which could contribute to the development of public policies for suicide prevention. We found that nonoptimum temperature was associated with greater risks for older adults and those with lower education levels, which may be explained by the potential physical and socioeconomic vulnerability of these subgroups. This finding is important for the development of evidence-based health protection plans to address adverse mental health risks associated climate warming.

The underlying mechanisms for the association between higher temperature and suicide, albeit uncertain, are somewhat plausible. Heat may exacerbate preexisting mental health problems and lead to suicide attempts through several pathways. One possible biological pathway is the suppression of the neurotransmitter 5-hydroxytryptamine release by high temperatures, which may trigger impulsive, aggressive, and suicidal behaviors.[36] Another potential etiological mechanism is the disrupted sleep or daytime discomfort during periods of high ambient temperatures,[37,38] which may result in hopelessness, maladaptive anxiety, stress, and other poor mental health conditions.[39-41] In addition to the excess risks associated with higher temperature, climate warming could also lead to more frequent and intense extreme events, such as elevated sea levels, intensified and prolonged droughts, floods, and wildfire seasons.[42] These consequences will change agricultural practices and natural landscapes, destroy food and water resources, erode infrastructure, exacerbate financial and relational stress, increase violence and aggression, and displace entire communities,[43,44] all of which will in turn increase the risks of suicide.[5]

Although several epidemiological studies have documented the increased risks of suicide associated with higher ambient temperature, few projection studies have estimated future suicide burden in a warming climate. In contrast to the previous projection study based on the association between monthly average temperature and monthly aggregate suicide deaths,[22] we made projections using the association between

Figure 4. Projected Percentage Increments of Suicide Deaths Associated With Nonoptimum Temperatures Under Different Climate Scenarios (Shared Socioeconomic Pathway [SSP]126, SSP245, and SSP585) Compared With the Historical Period (1980-2009), Classified By Region and Period



The height of columns denotes the mean estimate and the vertical black lines represent their empirical 95% CIs computed from Monte Carlo simulations (1000 samples). The upper limit of y-axis for the South is different from that for other regions.

daily mean temperature and suicide death from an individual-level, case-control analysis. Unlike the previous studies using a uniform risk estimate per unit temperature increase for different temperature levels,[22,23] we derived varying RRs at different daily temperatures according to the specific referent temperatures. These analysis methods could improve the accuracy of our projections on suicide burden. Our study findings suggest that future climate warming may further aggravate the burden of suicide, especially when no adequate climate policies are adopted. These results also highlight the necessity of implementation of effective climate policies in mitigating global warming and the associated public health challenges.

Another contribution of the present study is that we found significant spatial and seasonal heterogeneity in future suicide burden change under climate warming. We projected that the percentage increases will be greater in the South than those in other regions. This kind of spatial differences could be attributed to the regional differences in baseline temperature-suicide associations and magnitude of future warming. The spatial heterogeneity is also influenced by local factors, including socioeconomic characteristics, population vulnerability, and climate features.[45,46] Meanwhile, climate warming will amplify regional differences in temperature and climate conditions, which will eventually result in larger spatial heterogeneity.[47] We found that winter will experience the largest percentage increments in excess suicide deaths. This finding could be interpreted by the following possible reasons. First, there are significantly fewer excess suicide deaths associated with nonoptimum temperature in winter (decade average: 13 639) than in other seasons (spring: 28 476; fall: 28 960; summer: 40 176) during the historical period. Second, people in winter tend to be more sensitive to abnormal temperature increases because of the weakened ability of heat adaptation in this season.[14] Third, future warming is likely to be more prominent in winter than in the other seasons.[48,49] Therefore, our results support more tailored strategies according to different locations and seasons to reduce the mental disease burden associated with climate change.

Limitations

The limitations of our study should be acknowledged. First, although our study covers all areas in mainland China, the results may not be easily generalizable to other countries with different socioeconomic characteristics. Second, exposure errors are inevitable as we could only measure ambient but not personal temperature levels. Third, our projections of future suicide death burden are virtually based on the current socioeconomic conditions, population structure, and level of vulnerability.[50,51] Future work should take into account these population differences and the effects of demographic change, urbanization patterns, and population migration/dynamics on mental health risks from climate change. We were not able to explore the possible mediation roles of other types of extreme weather events (floods, droughts, etc) in the observed association of temperature increase with suicide death due to the lack of data.

Conclusions

Results of this nationwide, individual-level, case-control study suggest that higher temperature could increase the risk and burden of suicide death. Findings further suggest that climate warming may lead to significant increases in future burden of suicide death associated with nonoptimum temperature, especially in the high-emission scenario. In addition, our study reveals significant spatial and seasonal heterogeneity in future suicide burden under climate warming with the most prominent percentage increments in the South and in winter. Overall, this study could contribute ample and reliable scientific knowledge to the broad field of climate and mental health.

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Drafting of the manuscript: Y. Zhou, Gao, Kan.
Critical revision of the manuscript for important intellectual content: Yin, He, Liu, M. Zhou, Chen.
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