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# Association between air temperature and self-perceived health status in Southern Germany: Results from KORA FIT study

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| Abstract: | Background: Short-term exposure to low and high air temperatures can cause serious harmful effects on human health. Existing literature has mostly focused on associations of ambient air temperature with mortality and the need for health care in population-level studies. Studies that have considered self-perceived health status as an outcome when examining the effects of air temperature on health are scarce. In this study, we explored the short-term association of daily mean air temperature with various measures of self-perceived health status. Methods: This cross-sectional analysis is based on the Cooperative Health Research in the Region of Augsburg (KORA) FIT study conducted in 2018/2019 and included participants from the Augsburg region of Southern Germany. Health-related quality of life (HRQOL) was evaluated by using the 5-level EuroQol Five Dimension (EQ-5D-5L) questionnaire, including the EuroQol visual analog scale (EQ-VAS). Self-rated health (SRH) and comparative self-rated health (CSRH) were each assessed using a single question. Daily mean air temperature data was estimated using a spatiotemporal model and assigned to participants' home addresses at a resolution of 1× 1km. Regression models with a Distributed Lag Non-linear Modeling (DLNM) approach were used to investigate the associations between daily mean air temperature and self-perceived health measures. Results: We found no association of heat or cold with the HRQOL, SRH or CSRH. Nevertheless, there was a significant protective association of low air temperature with the EQ-5D-5L dimension “usual activities.” Conclusion: There was no evidence of daily mean air temperature adversely affecting participants' self-perceived health status. |
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Cover Letter

International Journal of Hygiene and Environmental Health
Editorial Office

Dear Editor,

We hope you will consider the enclosed manuscript entitled "Association between air temperature and self-perceived health status in Southern Germany: Results from KORA FIT study" for publication in Environmental Research.

Temperature changes are well known to increase morbidity and mortality. Traditionally, clinical diagnoses or results of physiological measurements have been used to indicate morbidity in studies on the health effects of air temperature. However, these do not represent the individual's perception of their life and health. Clinicians usually overlook subjective self-reported scales since they are considered less reliable than objectively evaluated health measures. The research has shown that self-perceived health measures are a reliable indicator of premature mortality. The information about the effects of temperature on self-perceived health measures is scarce. In this research article, we used methods of environmental epidemiology to investigate the effect of low and high temperatures on self-perceived health measures in the Augsburg region of Southern Germany during the year 2018-2019. As an outcome measure, we assessed Health-Related Quality of Life (HRQoL), self-rated health, and comparative self-rated health. We checked the sensitivity of the results by varying lag structure, knot locations, and different effect modifiers such as age, sex, comorbidity, and self-reports on green spaces.

We believe that our study design and results are of wider interest to the scientific community. With the changing climate and weather conditions, the temperature-associated health burden is increasing worldwide. Our research provides much-needed quantitative information on the association of temperature with subjective health measures. This knowledge is also crucial to understanding the individual's own perception of health and well-being. These results could possibly help in designing further studies using a similar methodology.

This is an original work; it has not been previously published in whole or in part, and it is not under consideration for publication elsewhere. All the authors have read the manuscript, agree that it is ready for publication, and accept responsibility for the manuscript's contents. The authors declare they have no actual or potential competing financial interests.

Yours sincerely,

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# Association between air temperature and self-perceived health status in Southern Germany: Results from KORA FIT study

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**Abstract:**

Background: Short-term exposure to low and high air temperatures can cause serious harmful effects on human health. Existing literature has mostly focused on associations of ambient air temperature with mortality and the need for health care in population-level studies. Studies that have considered self-perceived health status as an outcome when examining the effects of air temperature on health are scarce. In this study, we explored the short-term association of daily mean air temperature with various measures of self-perceived health status. Methods: This cross-sectional analysis is based on the Cooperative Health Research in the Region of Augsburg (KORA) FIT study conducted in 2018/2019 and included participants from the Augsburg region of Southern Germany. Health-related quality of life (HRQOL) was evaluated by using the 5-level EuroQol Five Dimension (EQ-5D-5L) questionnaire, including the EuroQol visual analog scale (EQ-VAS). Self-rated health (SRH) and comparative self-rated health (CSRH) were each assessed using a single question. Daily mean air temperature data was estimated using a spatiotemporal model and assigned to participants' home addresses at a resolution of 1× 1km. Regression models with a Distributed Lag Non-linear Modeling (DLNM) approach were used to investigate the associations between daily mean air temperature and self-perceived health measures. Results: We found no association of heat or cold with the HRQOL, SRH or CSRH. Nevertheless, there was a significant protective association of low air temperature with the EQ-5D-5L dimension "usual activities." Conclusion: There was no evidence of daily mean air temperature adversely affecting participants' self-perceived health status.

Keywords: EQ-5D, self-rated health, self-perceived health, HRQOL, ambient air temperature

# Introduction

Climate change and changing weather conditions have become a serious public health concern. Extreme high and low air temperatures are known to increase morbidity and mortality (Basu, 2009; Green et al., 2019; Gronlund et al., 2018). As air temperature is increasing globally (IPCC, 2018), temperature-associated health burden demands even more scientific research to investigate potential health risks (Lee et al., 2019).

The effect of non-optimum ambient temperatures on human health is considered a key research priority worldwide (Deschenes, 2013). Exposure to high air temperatures affects the body's natural mechanism to regulate its internal temperature leading to heat stress, hyperthermia, heat stroke, and ultimately causing death (Marcus Sarofim et al., 2016). Likewise, exposure to low air temperatures can cause increased blood pressure, vasoconstriction, blood viscosity, and plasma fibrinogen, which may lead to adverse cardiovascular events (Raven et al., 1970). Low air temperature can also induce bronchoconstriction, suppress immunological mechanisms, and increase respiratory infection risk (Eccles, 2002).

Health-related quality of life (HRQOL) is a multidimensional concept describing an individual's health in different live domains and has been used in many previous studies (Dorr et al., 2006; Mapes et al., 2003; Tsai et al., 2007). HRQOL can be measured using tools like the 5-level EuroQol five dimensions questionnaire (EQ-5D-5L) (Stolk et al., 2019). This questionnaire covers five domains related to physical and mental health. In addition to EQ-5D, self-rated health (SRH) and comparative self-rated health (CSRH) are further measures to investigate self-perceived health status. Self-perceived health is a widely used subjective health concept that covers all aspects of health following the definition of the World Health Organization (WHO), i.e., an individual's biological, social, and mental well-being (Stanojevic et al., 2017). Clinicians usually overlook subjective self-reported scales since they are considered less reliable than objectively evaluated health measures (Desalvo and Muntner, 2011; Puvill et al., 2017; Sternhagen Nielsen et al., 2008). However, existing literature has shown that subjective health scales can strongly predict mortality (Jylhä, 2009; Karen DeSalvo et al., 2006) and effectively represent the individual's perception of his/her daily life quality and health (E L Idler and Y Benyamini, 1997; Jylhä et al., 2006).

Traditionally, clinical diagnoses or results of physiological measurements have been used to indicate morbidity in studies on the health effects of air temperature. However, these do not represent the individual's perception of their life and health. To the best of our knowledge, only one study from

China has investigated the short-term association of ambient air temperature with HRQOL or self-rated health (Yang et al., 2022). They reported that exposure to high temperatures and temperature fluctuations decreased the self-rated health scores, which referred to body pain and impairments of usual activities due to physical or mental health reasons in the past month (Yang et al., 2022). Additionally, only three other studies have investigated the association of short-term indoor air temperature with self-rated health. These studies concluded that exposure to high or low indoor air temperatures could cause lower self-rated health scores (Li et al., 2020; Sutton-Klein et al., 2021; Van Loenhout et al., 2015). In this study, we therefore investigated whether non-optimum ambient temperature is associated with self-perceived health measures of participants in the Augsburg region of Southern Germany.

# Methods

## Study population

This cross-sectional study is based on data collected in the population-based Cooperative Health Research in the Region of Augsburg (KORA) cohort study, Germany (Holle et al., 2005). Four cross-sectional surveys of KORA (S1: 1984/1985, S2: 1989/1990, S3: 1994/1995, S4: 1999/2000) and multiple follow-ups have been conducted since 1984. The KORA FIT follow-up study was conducted from January 2018 to June 2019, comprising all KORA participants born between 1945 and 1964. We excluded KORA participants who were deceased, moved outside the study area, or moved to an unknown address before the KORA FIT examination, leaving 4748 individuals eligible for the KORA-FIT survey. Of these, 365 individuals could not be reached, 394 did not have time, and 930 were unwilling to participate. We re-examined the remaining 3059 participants in the KORA-FIT survey (64.4% of all eligible individuals).

Our study analyzed a subgroup of KORA FIT participants involved in the INGER project (N=2,624). The INGER project (Kraus et al., 2023) aimed to integrate sex/gender themes into environmental health research and collected data via a newly developed questionnaire with modules on diverse biological and social aspects of gender along with information on green spaces. We further excluded participants lacking geocoding information, having missing data in outcomes, or having missing data in covariates in the main model, resulting in 2,602 participants in this study. The exclusion process is shown in Figure 1.

Personal and clinical characteristics, medication intake, and disease history were collected through self-administrated questionnaires, interviews, and physical examinations at the study center. The ethics committee of the Bavarian Chamber of Physicians approved the study (KORA-Fit EC No 17040). All study participants gave written informed consent, and the study was performed in accordance with the Declaration of Helsinki.

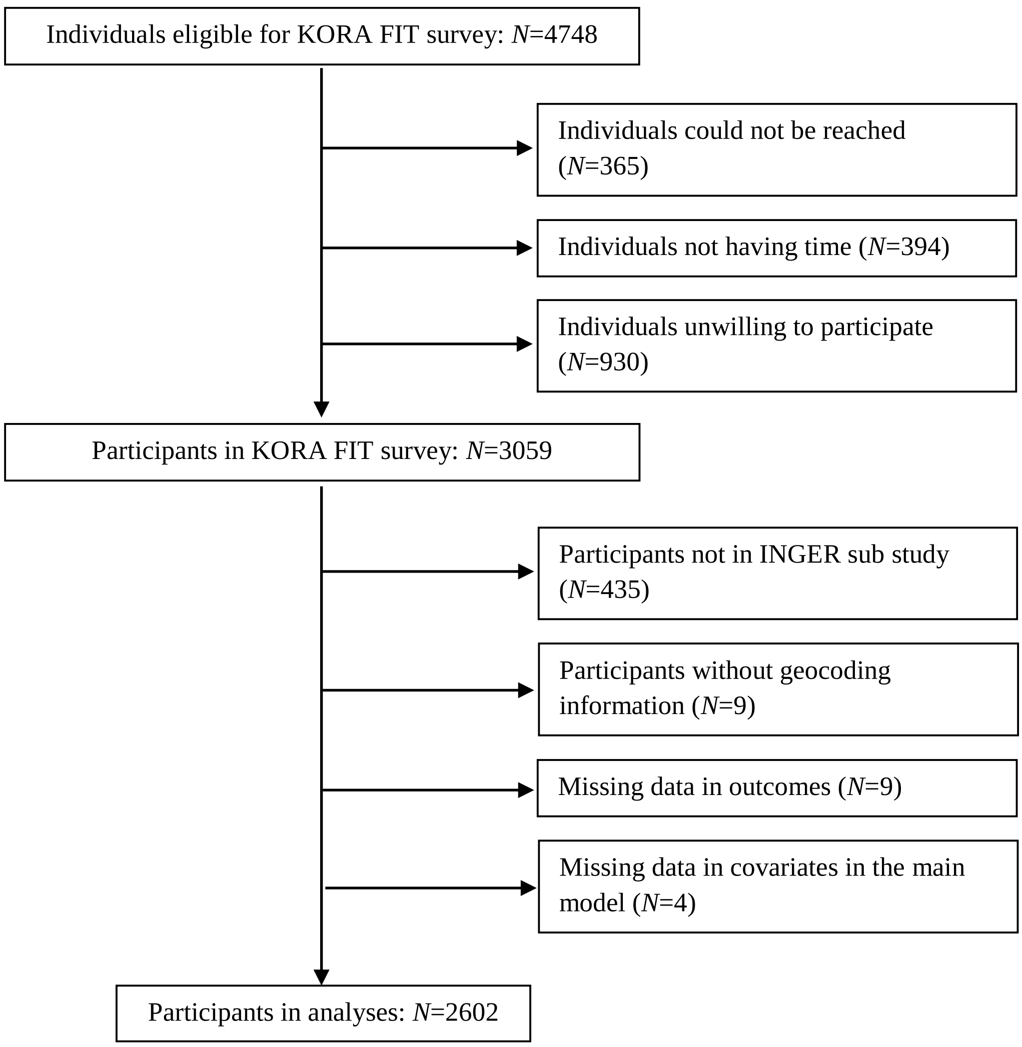


*Figure 1: Flow chart of number of participants in the KORA INGER Project*

## Outcomes

As an outcome measure, we assessed HRQoL using the EQ-5D-5L instrument (Janssen et al., 2013). It contains a descriptive system asking five key questions on mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, which were answered by the participants themselves. We used the EQ-5D-5L version, in which each dimension has five answer levels: no problems, slight problems, moderate problems, severe problems, and unable or extreme problems. An EQ-5D index value was calculated to represent the health status as a single number. The calculation of the index value was done using the German value set (Ludwig et al., 2018). The range of the index value in our study was +1.000 to -0.131 (a lower number indicates worse health status). The EQ-5D instrument also includes a measure of SRH: a visual analog scale (EQ-VAS), on which participants were asked to mark their current health status between 0 (worst imaginable health) and 100 (best imaginable health).

In the analyses using individual dimensions as outcomes, the five answer levels were dichotomized as "no problems" (level 1), and slight, moderate, severe, and unable or extreme problems (level 2 to level 5) were merged into "any problems" as per EQ-5D-5L user guidelines (EuroQol Research Foundation, 2019)

Self-rated health (SRH) was assessed using a single question, "How would you rate your current physical condition?" with responses on a 4-point scale: very good, good, less good, and bad. We dichotomized responses to 0 = good by merging very good and good and 1 = bad by merging less good and bad.

Comparative self-rated health (CSRH) was also assessed by a single question, "How would you rate your health in comparison to other people of your age?" with responses on a 4-point scale: better, worse, the same, I don't know. The response was dichotomized with the values 0=better by merging better, the same, and I don't know, and 1=worse as per EQ-5D-5L user guidelines.

## Exposure

In this study, our exposure of interest was daily mean ambient air temperature. The daily mean air temperature was estimated at a resolution of 1 × 1 km using a spatio-temporal model and assigned to participants' home addresses. Daily mean air temperature was estimated using a multi-stage regression-based approach and a combination of satellite land surface temperature data, ground-based air temperature measurements, and various remote sensing spatial predictors (Nikolaou et al., 2023).

Especially for the Augsburg region, our study area, the mean air temperature model was extensively validated against an independent and dense monitoring network of 82 stations and achieved very good performance ($R^2$ = 0.99 and Root Mean Square Error = 1.07ºC).

## Covariates

Previous literature was used to obtain information about potential confounders. We used month, year, weekday age, sex, socioeconomic status, living with a partner, physical activity, BMI, history of diabetes, angina pectoris, asthma, fine particulate matter (PM2.5; aerodynamic diameter ≤ 2.5 μm), and Ozone ($O_3$) as covariates.

Age was used as a continuous variable. Sex was operationalized dichotomously with the categories "female" and "male" without further distinguishing between biological sex or gender being related to social and structural factors. Socioeconomic status was measured using the Helmert Index (low score shows poor socioeconomic status) (Helmert and Shea, 1994). Living with a partner was categorized as yes or no.

Physical activity was divided into four levels, i.e., regularly more than 2 hours a week, regularly about 1 hour a week, irregularly approximately 1 hour a week, and almost no or no physical activity. Body Mass Index (BMI) was included as a continuous variable measured in kg/m2.

Medical history variables included history of angina, diabetes, or asthma as binary variables i.e., yes or no.

Data on daily $NO_2$ concentrations were obtained from an urban background station (BourgesPlatz) located 2 km north of the city center. $O_3$ concentrations were measured at the monitoring station (LfU) located approximately 4 km south of the city center. Daily average $PM_{2.5}$ (PM2.5; aerodynamic diameter ≤ 2.5 μm) was obtained from an aerosol monitoring station (FH) located 1 km southeast of the city center. This monitoring station was established in 2004 and is considered a representative of the urban background in Augsburg.

## Statistical Analysis

We used regression models with the distributed lag non-linear modeling (DLNM) approach to explore the association of daily mean air temperature with EQ-5D index value and EQ-VAS. The DLNM uses a "cross-over basis" function to simultaneously define the shape of the association of the dependent variable with the independent variable and the time lag structure.

A lag period of 21 days was selected to capture the overall and delayed effect of temperature as well. For the cross-basis, we defined air temperature with a natural cubic spline having three knots placed at the $25^{th}$, $50^{th}$, and $75^{th}$ percentile. Natural cubic splines with three knots placed at equally spaced positions were used to investigate the lag structure. In the second analysis stage, we investigated the association of daily mean air temperature with individual dichotomized dimensions of EQ-5D-5L, as well as SRH and CSRH. Since the outcome variables were dichotomous, we incorporated a multiple logistic regression model with the DLNM approach to estimate the effects.

A stepwise forward selection method reducing the Bayesian Information Criterion (BIC) was used to select covariates from a large set of potential covariates. The selection process was done in four steps. In the first step, we ran the model with age, sex, living with a partner, education years, income, working status, and socioeconomic status offered for selection. In the second step, we offered BMI, physical activity, smoking status, and alcohol consumption. In the third step, a history of hypertension, diabetes mellitus, myocardial infarction, angina pectoris, COPD, and asthma were offered for selection. In the final step, we offered air pollutants such as PM10, PM2.5, O3, and NO2. The selection process was carried out with each of the outcomes. There was only one final model for all outcomes consisting of all the covariates resulting from outcome-specific selection processes. The final model included the following covariates: age, sex, socioeconomic status, living with a partner, physical activity in categories, BMI, Angina, Diabetes, Asthma, PM2.5, and Ozone (O3). In addition to these, month, year, and weekday covariates were also included in the final model to control time and seasonal trends.

All the analyses were performed using the R program for statistical computing (version 1.4.1106) with the packages "mgcv" and "dlnm" (Gasparrinia et al., 2010; Wood, 2006). Results were reported as absolute differences and odds ratios with 95% confidence intervals for moderate and more extreme heat and cold.

## Sensitivity Analyses

As sensitivity analyses, we varied the modeling parameters and used a 14-day lag period for daily mean temperature. Additionally, we ran the models by placing the knots for the exposure-response function at the $10^{th}$, $25^{th}$, $50^{th}$, and $75^{th}$ percentile. We also checked the robustness of our results by introducing $NO_2$ as a covariate in the model. As an additional sensitivity check, we investigated effect modification by incorporating an interaction term between the cross-basis of air temperature and the effect modifier in the regression model. The potential effect modifiers included age (<65 years vs. >= 65 years), sex (male vs. female), comorbidity (angina pectoris, asthma, and diabetes mellitus), and self-reports on green spaces (greenness of the participants' neighborhood and access of public green spaces) (supplementary file).

# Results

Tables 1 and 2 show the basic descriptive statistics of the study population and exposure variables. The mean age of the participants was 64 years, with 54.6% male and 45.4% female. Moreover, the average socioeconomic status of the participants was 14.9, which reflects a medium status as per the global Helmert index. The daily mean air temperature during the study period was 9.2± 7.9°C. The average daily concentrations of $PM_{2.5}$, $PM_{10}$, $O_3$, and $NO_2$ were 14.2, 19.7, 46.5, and 28.2 µg/m3, respectively.

*Table 1: Descriptive statistics of the study population (N= 2602) during the study period 2018-2019*

| Variable (unit) | Mean ± SD or N (%) |
|---|---|
| **Personal characteristics** | |
| **Age (years)** | 64.0 ± 5.4 |
| **Sex** | |
| Male | 1420 (54.6) |
| Female | 1182 (45.4) |
| **Live with a partner** | |
| Yes | 2058 (79.1) |
| No | 544 (20.9) |
| **Socioeconomic status** [c] | 14.9 ± 5.0 |
| **Physical activity** | |
| regularly more than 2 hours a week | 1015 (39.0) |
| regularly about 1 hour a week | 885 (34.0) |
| irregularly approx. 1 hour a week | 320 (12.3) |
| almost no or no physical activity | 382 (14.7) |
| **Body Mass Index (BMI, $kg/m^2$)** | 28.0 ±5.2 |
| **Disease history** [d] | |
| **Angina pectoris** | |
| Yes | 99 (3.8) |
| No | 2493 (95.8) |

| | |
|---|---|
| **Diabetes mellitus** | |
| Yes | 206 (7.9) |
| No | 2393(92.0) |
| **Bronchial asthma** | |
| Yes | 207 (8.0) |
| No | 2335(89.7) |
| **<u>Outcomes</u>** | |
| HRQOL: EQ-5D-5L index value [a] | 0.9 ± 0.1 |
| **Dichotomized EQ-5D-5L dimensions** | |
| • **Mobility** | |
| Problem in walking around | |
| | 725 (27.9) |
| • **Self-care** | |
| Problem in washing or dressing | |
| | 84 (3.2) |
| • **Usual activities** | |
| Problem in doing day to day activities | |
| | 364 (14.0) |
| • **Pain/Discomfort** | |
| Have pain or discomfort | |
| • **Anxiety/Depression** | 1612 (62.0) |
| Have anxiety or depression | |
| **HRQOL: EQ VAS scale [b]** | 705 (27.1) |
| **Self-rated health: physical health** | 79.2±14.6 |
| having a bad physical condition | |
| **Self-rated health: Comparative health** | 435 (16.7) |
| Worse in comparison to own age group | |
| | 210 (8.1) |

[a] EQ-5D-index value: +1 to -0.131 (lower numbers indicate poor health status)

[b] EQ-VAS: Scale from 0 to 100 (0 is the worst health)

[c] Individual socioeconomic status (SES) according to Helmert index

[d] Missing data: angina pectoris: 10 observations (0.4%), diabetes mellitus: 3 observations (0.1%), bronchial Asthma: 60 observations (2.3%)

*Table 2: Descriptive statistics of environmental variables during study period 2018-2019*

| Variable (Units) | Mean ± SD | Minimum | Maximum |
|---|---|---|---|
| | | | |
| Air temperature (°C) | 9.2± 7.9 | -12.3 | 27.3 |
| **Air pollutants (μg/m³)** | | | |
| $PM_{2.5}$ | 14.2±9.3 | 1.3 | 65.0 |
| $O_3$ | 46.5±23.8 | 0.4 | 102.9 |
| $NO_2$ | 28.2±11.0 | 5.8 | 60.4 |

We analyzed the association of daily mean air temperature with EQ-5D index value and the dichotomized EQ-5D-5L dimensions. The results of our analysis are shown in Table 3. The daily mean air temperature was not associated with the EQ-5D index value in any temperature range of our study. However, we found a significant effect of moderate cold (OR: 0.38, 95% CI: 0.18, 0.84) and extreme cold (OR: 0.13, 95% CI: 0.02, 0.93) with the dimension "usual activities." We did not report effect estimates for one EQ-5D-5L domain, i.e., "problem in taking care of yourself," as there were a very limited number of observations. Additionally, our results did not show any association of daily mean temperature with the EQ-VAS, SRH, or CSRH of participants.

*Table 3: Absolute changes (95%CI) in EQ-5D-index value and EQ-VAS and odds ratios (95% CI) of having any problems in EQ-5D-5L dimensions and of worse SRH and CSRH for the association with the 21-day lag of daily mean air temperature during the study period 2018-2019.*

| **Outcome** | **Moderate Heat[1]** | **Extreme Heat[2]** | **Moderate Cold[3]** | **Extreme Cold[4]** |
|---|---|---|---|---|
| **EQ-5D index value** | -0.010(-0.064, 0.045) | -0.039(-0.151, 0.074) | 0.000(-0.029, 0.030) | -0.019(-0.096, 0.058) |
| **EQ-VAS** | -2.389(-8.361, 3.582) | -4.401(-16.787, 7.985) | 2.253(-1.004, 5.510) | 7.025(-1.436, 15.485) |
| **Dichotomized EQ-5D-5L Dimensions** | | | | |
| **having problem in mobility** | 1.01(0.37, 2.74) | 1.64(0.21, 13.09) | 0.73(0.42, 1.29) | 1.20(0.28, 5.24) |
| **having problem in usual activities** | 1.07(0.29, 3.88) | 1.49(0.10, 21.67) | **0.38(0.18, 0.84)** | **0.13(0.02, 0.93)** |

| | | | | |
|---|---|---|---|---|
| **having pain/discomfort** | 0.96(0.38, 2.47) | 1.22(0.17, 8.54) | 0.84(0.51, 1.38) | 0.72(0.20, 2.60) |
| **having anxiety/depression** | 1.37(0.50, 3.78) | 2.08(0.25, 16.94) | 0.75(0.43, 1.32) | 0.68(0.16, 2.87) |
| **Self-rated health (SRH)** | 1.08(0.31, 3.83) | 1.24(0.09, 17.10) | 1.21(0.62, 2.35) | 1.69(0.30, 9.46) |
| **Comparative Self-rated health (CSRH)** | 2.15(0.38, 12.24) | 4.90(0.13, 180.07) | 0.77(0.31, 1.96) | 0.65(0.06, 7.05) |

[1]The 95th percentile of air temperature (21.2°C) relative to the 75th percentile of air temperature (16.0°C)

[2]The 99th percentile of air temperature (24.5°C) relative to the 75th percentile of air temperature (16.0°C)

[3]The 5th percentile of air temperature (-3.5 °C) relative to the 25th percentile of air temperature (3.1°C)

[4]The 1st percentile of air temperature (-7.3 °C) relative to the 25th percentile of air temperature (3.1°C)

We confirmed the robustness of our results with sensitivity analyses. Results have been provided in a supplementary file.

# Discussion

This study investigated the association of daily mean air temperature with self-perceived health status in the KORA FIT study in Augsburg, Germany. We did not find any increased risk of poor health-related quality of life, assessed by using the EQ-5D-5L questionnaire or self-rated and comparative self-rated health with heat or cold. However, a protective association of low temperature with the dimension "usual activities" was observed.

We hypothesized that low and high temperatures might be associated with poor self-perceived health. Our findings were contrary to our hypothesis. We found that daily mean temperature is not associated with the self-perceived health status of the participants. However, there has been only one study from China that investigated the association of ambient temperatures with the HRQOL or self-rated health score of the participants. They reported that the participants' self-rated health score decreased with high temperatures and temperature fluctuation (Yang et al., 2022). However, our results contrast with that study. A possible explanation for contradictory results could be because of differences in the use of health indicators.

Previous studies have shown that high ambient temperatures are correlated with indoor temperature during summertime (Nguyen et al., 2013; Zuurbier et al., 2021). Chen et al. reported that there is only a little air conditioning in residential buildings in Augsburg, which should make people more vulnerable to heat and high temperatures (Chen et al., 2019). In contrast to what could be concluded based on our results, studies have found high indoor temperature to be associated with decreased SRH. For example, a study from England investigated the association of indoor temperature with self-rated health (Sutton-Klein et al., 2021). SRH was assessed by asking a question, "How is your health in general" and participants reported through five answer options "very good, good, fair, bad or very bad". This study reported that high indoor temperatures cause worse self-rated health (Sutton-Klein et al., 2021). Another study from the United States investigated the association of indoor temperatures with self-reported mental health (Li et al., 2020). It was assessed by asking a question "Thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?". They reported that cooler days from the previous month reduce the likelihood of reporting bad mental health, while hotter days increase the probability (Li et al., 2020). A potential reason for not finding an association between ambient temperature and self-rated health could be that our study subjects were, in general, in good health, with only a few participants having a history of chronic diseases and not that old, as the mean age was 65 years. Moreover, participants with chronic diseases may have poor selfassessments of their health due to their diseases, and temperature effects might be too weak to be observed beyond that. Additionally, temperatures in our study were perhaps not high enough (Mean: 9.2, SD: 7.9 °C) to cause any potential harm to individuals' health.

We found no adverse association between high temperatures and the domain "usual activities". However, a protective effect of moderate and extreme cold on the domain "usual activities" of participants was reported. To the best of our knowledge, there are no previous studies on the association of temperature with the domain "usual activities." However, previous literature has reported that extreme temperatures can cause physiological effects, which may reduce the capacity to perform daily activities (Kjellstrom et al., 2009; Robert Bridger, 2008). For example, a study investigated the effect of air temperature on labor productivity in telecommunication offices (Niemelä et al., 2002). The study was conducted as a case-control study in two call centers. The intervention was conducted by installing an air conditioner in one call center. Results showed that the call center with no air conditioning and elevated temperature had significantly lower work productivity than the one with an air conditioning work environment (Niemelä et al., 2002).

Our results also suggested that daily low or high mean temperatures are not associated with the domain "pain or discomfort." However, we did not find any suitable previous studies to compare our findings. We also did not find any association of temperature with the domain "depression/anxiety." In contrast to our findings, previous literature has reported that low or high ambient temperatures could increase the risk of depression and mental health problems (Ning Jiang et al., 2022; Wang et al., 2014). As previously mentioned, our study participants were generally in good health. People with good health status can cope with stressful situations better, which could be a reason for not finding any association in our study.

This study has several strengths. To the best of our knowledge, only three other studies have evaluated the association of temperature with self-perceived health status. Moreover, this study is based on a well-explored and extensive study population. In addition, a wide range of participants' information is available from the survey, which allowed us to select the important potential confounders. However, there are some limitations in this study as well. Firstly, information about the participants was collected at a single time point for each individual, so causal relationships cannot be concluded. Secondly, self-rated health is an all-inclusive concept with various influencing variables that might not all have been adequately adjusted. Thirdly, there could be the possibility of reverse causation. We observed the protective effect of cold weather. One reason could be that in extremely cold weather, people are staying at home, which may improve the self-perceived health status of individuals. This could be a sign of reverse causations due to the cross-sectional nature of the study.

In conclusion, our study does not indicate any short-term effect of daily mean temperature on self-perceived health in the participants of the KORA FIT study in Southern Germany.

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