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Research Article

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Posted Date: February 24th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1368052/v1>

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Effective Interventions on Health Effects of Chinese Rural Elderly under Heat Exposure

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23 **Abstract:**

24 **Background:** Due to climate change, the heatwave has become a more serious public
25 health threat with aging as an aggravating factor in recent years. There is a pressing
26 need to detect the most effective prevention and response measures. However, the
27 specific health effects of interventions have not been characterized on an individual
28 scale.

29 **Method:** In this study, an intervention experiment was designed to explore the health
30 effects of heat exposure at the individual level and assess the effects of different
31 interventions based on a comprehensive health sensitivity index (CHSI) in Xinyi, China.
32 Forty-one subjects were recruited randomly, and divided into one control group and
33 three intervention groups. Interventions included education (Educate by lecturing,
34 offering relative materials, and communication), subsidy support (offer subsidy to
35 offset the cost of running air conditioning), and cooling-spray (install a piece of cooling-
36 spray equipment in the yard).

37 **Results:** Results showed that systolic blood pressure (SBP) and deep sleep duration
38 (DSD) were significantly affected by short-term heat exposure, and the effects could be
39 alleviated by three types of interventions. The estimated CHSI indicated that the
40 effective days of the education group were longer than other groups, while the lower
41 CHSI of the subsidy group showed lower sensitivity than the control group.

42 **Conclusions:** Education and subsidy support can help reduce the effect of heat
43 exposure efficiently. These findings provide feasible implementation strategies to

44 optimize Heat-health action plans and evaluate the intervention performance.

45 **Keywords:** high temperature, health effect, comprehensive evaluation, intervention,

46 rural elderly

47

1. Introduction

Along with global climate change, the average surface temperature has increased more than 1°C above the pre-industrial level continuously [1-3]. Heatwave is a typical extreme temperature issue and has become a potential risk to public health [4-7]. Heatwaves not only lead to death but also raise the morbidity of respiratory-diseases and cardiovascular diseases, which contribute to the increment of mortality [8-11]. Based on researches with different spatial scales, it was found that the frequency of global heatwaves increased by 2.7 times every ten years (1981-2010), while the amount of extreme warming events in China increased by 6.79 days/decade (1961-2017)[12, 13]. It is convinced that the number of high-temperature days shows a decreasing trend in central and an increasing trend in northwest and southeast, based on an analysis of high-temperature characteristics over fifty years in China[14, 15]. Though there are periodical fluctuations, the frequency, intensity, duration, and area of heatwave show a climbing trend by and large[16].

The elderly have been recognized as the most vulnerable people to heatwave [17-19]. In the past decades, the heat-related mortality of the elderly (≥ 65 years) has increased by 53.7% [20]. Particularly, the heat exposure of the elderly in China has come up to 2.2 million person-days, representing some 13 additional days of heatwaves experienced[20, 21]. When exposed to high temperatures, people will take steps to cool themselves through sweating automatically [22]. However, the elderly's poor

temperature regulation ability results in an increase in their sweating threshold[18].
Owing to income and chronic diseases, rural residents are more likely to be affected[23].
In addition, it is difficult for older people to accept the heat-related recommendations,
especially for those who are over 75 years old and low-educated[24]. Thus, it is a
considerable challenge to alleviate the heat health risks of the elderly.

Evidence suggests that the heat health warning system and education can reduce
heat-related death rates by improving residents' risk perception[25-28]. The
effectiveness of an intervention is mainly measured by the reductions in high
temperature-related morbidity and mortality, or by the improvement in public response
behavior [29-31]. However, there are no researches that have measured the potential
impact or benefit of the actions in reducing the incidence of high temperature-related
morbidity. Heart rate and blood pressure are essential signals when the human body
becomes disordered. Thus, they are used to partly explain the mechanism of
temperature-related cardiovascular admission/death[32, 33]. Though the long-term
relationships between temperature change and heart rate or blood pressure have been
figured out in previous studies, the effect of interventions on individual health is still
unclear.

Along with the threat of global warming and population aging, it is challenging to
struggle with high temperatures. The usage of air conditioning can reduce subjective
thermal discomfort, but contributes to more global greenhouse gas emissions
simultaneously [34]. Therefore, there is a pressing need to explore sustainable and

effective intervention measures. However, the previous intervention, like the warning system, fails to evaluate the effect at individual scale[35]. To the best of our knowledge, there have been few reports on the relationships between interventions and health indicators about the elderly in a realistic condition. Additionally, various heat-related influences on physical indicators make it challenging to assess the effectiveness by one metric. Thus, it is necessary to explore individual-based interventions and evaluate the effectiveness through a proper approach. We conducted an intervention experiment involving the Chinese rural elderly in 2019. Though we have explored the intervention effect on behavior and perception in previous research, the relationship between physical metrics and intervention is unclear[36]. Specifically, the objectives of this research are 1) to characterize six metrics' variation under heat exposure; 2) to evaluate the protective effect of three interventions with a comprehensive index; 3) to explore the possibility of a sustainable intervention method. Based on the research, the governments and institutions could develop and improve a more targeted implementation to reduce heat-related health risks for the rural elderly.

2. Material and Methods

2.1 Study Design

Xinyi (Figure 1) is an inland area located in the north part of Xuzhou, Jiangsu Province, one of the provinces that suffered heatwaves with the highest frequency and intensity typically observed in China [36-38]. Based on previous studies, the heat health

risk of residents is considerably higher in rural than in urban areas [39]. We conducted the survey in the rural area of Xinyi city. There are over eight hundred elderly people in the selected area. With the support from the local Chinese Center for Disease Control and Prevention (China CDC), we selected one hundred elderly people by simple random sampling. Eighty of the one hundred elderly expressed the willingness to attend this study. We excluded thirty-seven elderly people with primary diseases such as hypertension, diabetes, and other chronic diseases, which make it difficult to identify the main factors of health metrics' changes. Forty-four elderly people were recruited for the following intervention study. After controlling the variation in basic characteristics, the participants were randomly divided into control group, education group, subsidy support group, and cooling-spray group. Three participants dropped out for personal reasons during the survey and forty-one were left for finally analyses. For education intervention, participants took lectures (July 21st), read heat-related materials (July 22nd), and communicated with our team members (July 23th), respectively. Participants of the subsidy support group received 10 yuan (based on local electric charge, average cost on air-conditioning use for one day is about 10 yuan) each day to offset the cost of air conditioning use for five consecutive days. Cooling-spray equipment was installed in the yard of each participant from the cooling-spray group. The equipment was set to spray 5 min every half hour from 9.am to 5.pm to cool the external environment house. The more specific information about the intervention experimental design and device in use has been described by Lou et al. (2021).

This study used the 90th percentile temperature as a relative threshold to define a heat wave[40, 41]. The 90th percentile temperature in Xinyi is 32°C. The survey lasted from 17th July, 2019 to 25th July, 2019. To characterize the variation after the intervention, we defined the period before intervention (17th July - 20th July) as period 0, and each day of intervention from 21st July to 25th July as day 1, day 2, day 3, day 4, and day 5, respectively. The data in period 0 represented the baseline of the participants. Three intervention groups were assigned to receive the education, subsidy, and cooling-spray from day 1 to day 5, while the control group did not undergo any intervention measures throughout this survey. The content of the study design and statistical analysis is shown in Figure 2.

Figure 1 Study area

Figure 2 The flowchart of the methodology

2.2 Health Outcome and Exposure Measures

A wrist blood pressure monitor was used to measure the blood pressure and heart rate of the participant. The participants would sit for 3-5 minutes before monitoring to decrease the effects of activity status. Each metric was measured three times every morning during the whole period. Daily sleep duration was monitored by a smart band worn by the participant on his/her hand. The sleep duration had been divided into total sleep duration (TSD), deep sleep duration (DSD), and light sleep duration (LSD) for describing different sleep states

A portable temperature and humidity sensor (Renke, COS-04, 73*53*27 mm) was placed upper chest and used to measure individual temperature and humidity exposure data every five seconds. The sensor has a temperature accuracy of ± 0.3 °C and a measurement range from -20 °C to $+65$ °C. The relative humidity accuracy of the sensor is $\pm 2\%$ RH (<https://www.renkeer.com/>). Participants were required to wear the equipment all day (0:00-24:00) from July 17th to July 25th.

2.3 Statistical Analysis

Multiple measurements of the same object in different periods bring out the autocorrelation between repeated measurement data. The linear mixed-effects model overcomes the weakness that cannot be analyzed when the response variable has the characteristics of non-independence and heteroscedasticity. The random effect term was introduced to expand the application range of the linear model.

$$Y = X\beta + Z\Gamma + \varepsilon \quad (7)$$

where Y is the dependent variable, X is the matrix of the fixed-effect independent variable, β is the parameter vector of the independent variable, Z is the design matrix of random effects, Γ is the parameter vector of the random effect, and ε is the residual random error vector.

In this study, the "lme4" software package in R software was used to construct a mixed effect model to evaluate the impact of an intervention on outcome variables, including blood pressure, heart rate, and sleep duration. We fitted the models with or without these variables respectively and compared the fit using the Akaike Information

Criterion (AIC). Health metric values were dependent variables, group (control group, education group, subsidy-support group, cooling-spray group), period (before the intervention, each day of intervention) and the interaction items between group and period were fixed effects, and personal temperature exposure, relative humidity, BMI, whether drinking, whether smoking were covariates. Variables were controlled, and the participant's id was set to a random effect. The changes of health metrics among days were calculated based on the results of the linear mixed-effects model. The "emmeans" package in the R software was used to compare the value of metrics between intervention groups and control groups from day 1 to day 5, and calculate the differences.

2.4 Comprehensive Health Sensitivity Index (CHSI)

Each physical metric could reflect the body's adjustment to temperature change. However, most physical metrics, like blood pressure, have a threshold in medicine [42]. When the metrics are within the threshold, a person is considered at a low risk to get an unhealthy outcome. When extreme weather events such as heatwaves occur, the metrics will fluctuate due to the regulation of the body, even beyond the threshold range. All changes should be taken into consideration when choosing a better intervention. Therefore, we attempted to characterize the sensitivity level of residents to temperature changes through the fluctuation of metrics, defining it as a comprehensive health sensitivity index (CHSI). When the health index fluctuates greatly, it is considered that the residents' health sensitivity is high. In this study, CHSI was made up of heart rate,

blood pressure, and sleep duration.

The specific steps are as follows:

(1) Non-dimensionalization data processing metric:

$$x_{i,j}' = \frac{|x_{i,j} - x_{i,0}|}{x_{i,0}} \quad (1)$$

The variable $x_{i,j}$ represents the average data of the i^{th} metric for each group on the j^{th} day of the intervention. $x_{i,0}$, which is the mean value of the i^{th} metric in period 0. $x_{i,j}'$ represents the data of the i^{th} metric on the j^{th} day during intervention after non-dimensionalization processing.

(2) Calculating weights for each of the components of the CHSI, Y_i

We aggregate the metrics for the first time (Equation 2), in which the weight Ω_i is determined by the AHP (Analytic Hierarchy Process). The time vector w_j was calculated by Equation 3. The second aggregation was performed by inducing the TOWA operator in terms of time (Equation 4) [43, 44]. Then Equation 5 was used to calculate the metric's weight Y_i .

$$b = \sum_{i=1}^5 x_{ij}' \Omega_i \quad (2)$$

$$\left\{ \begin{array}{l} \max \left[- \sum_{i=1}^n w_i \ln w_j \right] \\ \lambda = \sum_{j=1}^n \frac{n-j}{n-1} w_j \\ \sum_{j=1}^n w_j = 1 \\ w_j \geq 0, n = k \end{array} \right. \quad (3)$$

$$X_{ij} = F(< 1, X_{i1} >, < 2, X_{i2} >, \dots, < 5, X_{i5} >) = \sum_{j=1}^5 w_j b \quad (4)$$

$$Y_i = \frac{\Omega_i \sum_1^5 w_j x_{ij}'}{X_{ij}} \quad (5)$$

where b is the evaluation value of each evaluation object in the specific period; Ω_i is the subjective weight of the i^{th} metric; λ is the "time degree"; $W = (w_1, w_2, \dots, w_5)^T$ is the time weight vector; X_{ij} is the result of the second aggregation;

(3) Calculation of CHSI

$$CHSI_j = \sum_{i=1}^5 x_{i,j} Y_i \quad (6)$$

where $CHSI_j$ represents the comprehensive result of each day during the intervention period.

3. Results

Table 1 showed a detailed summary of all participants. The age of each group ranged from 57.9 to 60.1, and the proportion of air conditioning users was higher than 80% in each group. No significant differences have been observed in baseline characteristics among groups as shown in Table 1 (p-value > 0.05). The maximum air temperature ($AT_{\max}$) in each period and the average individual exposure temperature of each group were in Table S1, and the air temperature range has been showed in Figure S1. The $AT_{\max}$ of the intervention period (July 21st to July 25th) were higher than 32°C, which means that the intervention was conducted during a heat wave. Compared with the control group, a decreasing trend has been observed in personal average temperature in intervention groups during the heatwave.

Table 1 Baseline characteristics of the study population by groups

Characteristics	Control Group	Education Group	Subsidy Support Group	Spray-cooling Group	p-value
Number	10	10	11	10	—
Sex					
Male	4	3	5	4	0.910
Age	57.9±6.57	58.4±6.42	68.8±6.66	60.1±7.40	0.881
Education					
Low level	6	6	8	6	0.917
Medium level	4	4	3	4	
Family annual income per capita(yuan)	15 330±9777	15 690±8442	13 982±4020	15 050±7920	0.967
Air-conditioning ownership					
Yes	8	9	10	8	0.825
No	2	1	1	2	
Physical condition					
Moderate	3	4	3	4	0.894
Healthy	7	6	8	6	
BMI	24.30±3.56	24.11±1.75	24.94±3.36	21.97±2.62	0.160
Smoking					
YES	6	4	4	6	0.600
NO	4	6	7	4	
Drinking					
YES	1	2	2	3	0.750
NO	9	8	9	7	

The format of data in the table is Mean ± standard deviation. “Moderate” physical condition means slightly worse than healthy.

3.1 Control Group

The changes in blood pressure have been displayed in Figure 3 (a and b). The Diastolic Blood Pressure (DBP) of the control group showed an insignificant increase in the first 4 days and the maximal level was 3.73 mmHg. The Systolic Blood Pressure (SBP) in the control group significantly increased on day 1 and day 2, rising by 5.62

mmHg (95 % CI: 1.77-9.46; p=0.01) and 5.33 mmHg (95 % CI: 1.05-9.60; p=0.02), respectively. After day 3, the changes of SBP became more moderate.

The Heart Rate (HR) level kept rising across the intervention, with the daily increase ranging from 0.35 beats/min to 1.47 beats/min (Figure 3, c). The increase was the greatest on day 1 while the highest daily ambient temperature increased sharply from 31.6°C (July 20th) to 34.7°C (July 21st). However, there was no significant difference between groups or periods.

Total sleep duration (TSD), made up of deep sleep duration (DSD) and light sleep duration (LSD), decreased slightly during the intervention period, with a daily decline of 0.07 hours to 0.27 hours (Figure 3, d). DSD changed significantly in the first 3 days from -0.49 hours (95%CI: -0.75, -0.23; p=0.00) to -0.38 hours (95%CI: -0.67, -0.08; p=0.02) and -0.25 hours (95 % CI: -0.49, -0.01; p=0.05). LSD showed a slight and insignificant upward trend during the intervention period.

Figure 3 Changes in Different Health Metrics of Control Group from Baseline (period 0)

(* p<0.05, **p<0.01, ***p<0.001, compared with period 0, the error bars represent estimate value±SE)

3.2 Intervention Groups

The DBP of the education group changed slightly during the whole period, while the DBP of the cooling-spray group and the subsidy support group had a similar increasing trend as the control group (Figure 4). There was no significant difference observed in DBP in these three groups during the intervention. In the education group and the subsidy support group, SBP stayed at a relatively stable level throughout the entire period. The trend of SBP of the cooling-spray group was similar to that of the control group. There was a significant increase of 3.14 mmHg (95%CI: 0.19, 6.09; $p=0.04$) on day 1 in SBP for the cooling-spray group. The SBP level then gradually declined and became steady. Figure 5 shows the differences in blood pressure between the control group and different intervention groups. Compared with the control group, SBP of the education group was 8.04 mmHg (95%CI: -12.90, -3.18; $p=0.01$) and 8.34 mmHg (95%CI: -13.20, 3.48; $p=0.01$) lower on day 1 and day 2, respectively.

Figure 4 Changes in Blood Pressure of Three Intervention Groups from Baseline (period 0)

(* $p<0.05$, compared with period 0, the error bars represent estimate value $\pm$ SE)

Figure 5 The difference in Blood Pressure between Intervention Groups and Control Group
(* $p < 0.05$, ** $p < 0.01$, compared with control group, the error bars represent estimate value $\pm$ SE)

The changes in HR in the cooling-spray group were consistently higher than baseline across all time points, but the trends were not consistent in the subsidy or education groups (Figure 6). The changes in HR in the subsidy group began to decrease after day3. Differences in HR between the control group and intervention groups ranged from -5.21 beats/min (cooling-spray group on day 5) to -0.68 beats/min (subsidy support group on day 1) (Figure S2).

Figure 6 Changes in Heart Rate of Three Intervention Groups from Baseline (period 0)

(The error bars represent estimate value $\pm$ SE)

Changes in DSD of the education group and the subsidy support group even showed a slight increment (Figure 7). Changes in DSD of the cooling-spray group

fluctuated during the intervention period, with the largest reduction being -0.20 hours (95%CI: -0.40, 0.00; $p=0.06$) in day 2. Analyses of DSD difference between groups in each period (Figure S3) showed that the DSD levels of the education and subsidy support groups were higher than that of the control group in the five days of intervention. The DSD difference between the education group and the subsidy support group was statistically significant only on day 1.

Changes in LSD were minor in three intervention groups, ranging from -0.11 hours to 0.04 hours in the education group, from -0.03 hours to 0.04 hours in the subsidy support group, and from -0.12 hours to -0.18 hours in the cooling-spray group. As a result, changes in TSD of the subsidy support group maintained a continuous increment, while changes in the education group and the cooling-spray group rose in the first few days and then declined. When comparing TSD between groups, TSD in the cooling-spray group was lower than the control group, while TSD in the education and subsidy support group were much higher. However, no significant between-group difference was observed in TSD and LSD during the experiment.

Figure 7 Changes in Sleep Duration of Three Intervention Groups from Baseline (period 0)

(the error bars represent estimate value $\pm$ SE)

3.3 Comprehensive Health Sensitivity Index (CHSI)

Weights of health metrics have been listed in Table 2. On day 1, the score of CHSI in control group (6.93) was significantly higher than education group (3.72, $p<0.05$), subsidy support group (3.50, $p<0.01$) and cooling-spray group (4.22, $p<0.05$), which showed that control group had the highest health sensitivity at the start of the heatwave (Figure 7). However, CHSI in control group declined over time. The score of CHSI decreased from 6.92 to 3.43 on day 5, indicating the human internal environment in control group had gradually reached a balance. On the second day of the intervention, the scores of the education group and the subsidy support group were still significantly lower than that of the control group ($p<0.05$). Though there was no significant difference between control group and cooling-spray group observed, the sensitivity

level of cooling-spray group was lower than control group during experiment.

Table 2 Weights of health metrics

Metrics	HR	DSD	SBP	LSD	DBP
Weight	0.3267	0.2346	0.1402	0.1402	0.1191

Figure 7 Variations in comprehensive sensitivity Index in four groups along with intervention time (* $p < 0.05$, ** $p < 0.01$, compared with the control group, the error bars represent estimate value $\pm$ SE)

4. Discussion

Based on the comparison between period 0 and high-temperature periods in the control group, health metrics fluctuated greatly when exposed to short-term heat. There was a significant variation in SBP and DSD, which was similar to some previous findings, suggesting that the high-temperature exposure contributed to higher blood pressure and thermal comfort was an essential factor affecting sleep quality[45-47].

Several studies showed that poor sleep quality might result in increased night-time blood pressure[48]. Nevertheless, the relationship between daily blood pressure and sleep quality needs further study. When exposed to high temperatures, individuals will increase cardiac output and turn on sweat glands to regulate body temperature, which will contribute to blood pressure variation[22]. However, aging is associated with the degenerated ability of cardiovascular adjustments and fluid regulation, resulting in that the elderly might take a higher risk of cardiovascular disease than young adults[18]. Because of the effects of human aging on organs and tissues, the elderly have blunted vascular responses and reductions in sweat production, which leads to a limitation of heat dissipation. Trouble falling or staying asleep is another mainly heat-related physical symptom[2]. Findings from other studies also firmed that sleep duration decreased significantly because of the heat exposure[33, 49]. The changes in each metric reflected that the body could be stabilized gradually, consistent with the experiment conducted by Meade[18]. The result of metric weight showed that HR played an essential role in the comprehensive assessment. The studies conducted by Madaniyazi et al (2016) and Carrillo et al (2019) also concluded that heart rate was correlated with heat exposure. Though an increasing trend was observed during the heatwave, there was no significant variation in this study, which was possibly due to the short duration of the experiment.

CHSI indicated that education could control the health sensitivity from day 1 to day 4. In a previous study, it is convinced that there is some mediating effect between

heat exposure and heat-protection action[28]. Being educated, individuals had a higher risk perception on perceived controllability, perceived concern, perceived effect, perceived familiarity[36]. The promotion of risk perception leads to a variety of alternations in heat-protection actions like increased frequency in using cooling equipment, more concern about weather changes, and reduction of the time exposed to sunlight directly. These behaviors enhanced the ability of adaptation to heatwave from psychological and physical aspects and relieved the influence of heatwave[28]. Besides, a study in Licheng showed that education could be considered a worthwhile investment for rural areas than urban areas in the prevalence of heat-related illness[51]. These studies were content to our results, improving the reliability of CHSI.

The results of CHSI showed the effectiveness of subsidy support as well. It was found that rural individuals preferred to use fans than air conditioning because of economic issues, which can be solved by subsidy support to a great extent[36, 52]. Previous study has shown that subsidy support group was more likely to do home cooling practices after intervention when comparing adaptive behavioral responses in groups[36]. In this circumstance, the willingness and the frequency of using air conditioning increased. As a result, the individual ambient temperature had been reduced to a comfortable level by the usage of air conditioning, which brings about a declined effect of the heatwave on health. However, the effects of subsidy support were significant in the first two periods. One of the reasons could be the limited effects on perception. It is reported that the subsidy support had no significant effect on perceived

effect[36]. Besides, we did not conduct an inquiry of the willingness to pay before the experiments. Therefore, the amount, frequency, and form of the subsidy might be further explored to break the limits.

Compared with education and subsidy support, the intervention effect of the cooling-spray is relatively limited. The reasons could be speculated as follows: 1) limited coverage area. The equipment was installed in the resident's yard, which means it would be useless when the resident leaves home. 2) limited effect. The outdoor temperature reduction was difficult to be conveyed to indoor. Therefore, the effect of indoor temperature reduction, as well as human thermal comfort, will be limited, when the resident stays in the house. 3) ventilation. Because of the material and the structure of the wall, the yard's ventilated condition was limited. It is reported that fans can be effective as air-conditioning, particularly in humid conditions [22]. Thus, the third reason is that we did not create any wind in the yard, though the humidity had been increased by the equipment. Despite the fact that the air conditioning has an excellent temperature reduction ability, the environmental problems caused by the equipment cannot be regardless [20]. Therefore, it is necessary to explore another economical and environment-friendly method to fight heatwaves.

There are still several limitations in our study. First, the number of subjects in our sample group is relatively small, resulting in a limited number of socioeconomic and demographic categories for analysis. From the perspective of verifying the health effects of an intervention, ten subjects in each group are sufficient[53]. For fundamental

research, a larger number of subjects are required for future experiments. Secondly, the information on occupation and air conditioning use was not collected in the questionnaire; therefore, we cannot further analyze the effect of these two factors on physical metrics. Thirdly, the selected participants connected with the local CDC before might be more concerned about their health. Besides, they have been screened by healthy conditions, limiting the sample's representativity. Next, metrics in period 0 represents the average level of metrics without heat exposure, which means that the potential variations during period 0 might have been ignored. Meanwhile, it is difficult to link intervention with specific health endpoints because of the time limitation. Though these metrics are significantly associated with heat-related diseases, further studies should be conducted to confirm the clinically relevant outcomes of interventions.

5. Conclusions

This study explored effective intervention methods on an individual scale, which supplements the intervention effect from physiological dimension and further validates the results of our previous research. It was found that short-term heat exposure would make effect on blood pressure, heart rate, and sleep duration. Under high temperatures, SBP and DSD were significantly affected in the first two days. For rural elderly, these effects could be efficiently reduced by education, subsidy support, and cooling-spray. Though cooling-spray was not the best method to prevent heat health risk due to its limitation in coverage area and effects, it is deserved to optimize the equipment for its

low carbon emission. A comprehensive health sensitivity evaluation method was proposed to assess the effectiveness of interventions. Compared with previous studies, CHSI was identified as a more practical and propagable approach in health effect assessment. The results indicated that older people should pay more attention to their blood pressure and sleep to prevent themselves from heat-related illnesses. Education and subsidy support made it possible for government and community to provide the vulnerable groups with more targeted help. These findings will provide references for researchers who further investigate the optimal strategies to reduce the health risk of human heat exposure.

Ethics approval and consent to participate

The research protocol was reviewed and approved by National Institute of Environmental Health Chinese Center for Disease Control and Prevention. All participants provided written informed consent prior to participation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the National Key Research and Development Program of China [2020YFC1807502]; and the Chinese Natural Science Foundation [41822709].

Authors' contributions

Yujia Huang performed the data curation and wrote the original manuscript. Ting Zhang was a major contributor in writing the manuscript. Jianing Lou was a major contributor to investigation. Peng Wang helped revise the manuscript. Lei Huang was a major contributor in writing the manuscript and acquired fundings. All authors read and approved the final manuscript.

Acknowledgements

This work was supported by the National Key Research and Development Program of China [2020YFC1807502]; and the Chinese Natural Science Foundation [41822709].

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