Original Article

Analysis of a Community-based Intervention to Reduce Heat-related Illness during Heat Waves in Licheng, China: a Quasi-experimental Study*

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Abstract

Objective To reduce health-related threats of heat waves, interventions have been implemented in many parts of the world. However, there is a lack of higher-level evidence concerning the intervention efficacy. This study aimed to determine the efficacy of an intervention to reduce the number of heat-related illnesses.

Methods A quasi-experimental design was employed by two cross-sectional surveys in the year 2014 and 2015, including 2,240 participants and 2,356 participants, respectively. Each survey was designed to include one control group and one intervention group, which conducted in Licheng, China. A representative sample was selected using a multistage sampling method. Data, collected from questionnaires about heat waves in 2014 and 2015, were analyzed using a difference-in-difference analysis and cost effectiveness analysis. Outcomes included changes in the prevalence of heat-related illnesses and cost-effectiveness variables.

Results Relative to the control participants, the prevalence of heat-related illness in the intervention participants decreased to a greater extent in rural areas than in urban areas (*OR*=0.495 *vs*. *OR*=1.281). Moreover, the cost-effectiveness ratio in the intervention group was less than that in the control group (US$15.06 *vs*. US$15.69 per participant). Furthermore, to avoid one additional patient, the incremental cost-effectiveness ratio showed that an additional US$14.47 would be needed for the intervention compared to when no intervention was applied.

Conclusion The intervention program may be considered a worthwhile investment for rural areas that are more likely to experience heat waves. Meanwhile, corresponding improving measures should be presented towards urban areas. Future research should examine whether the intervention strategies could be spread out in other domestic or international regions where heat waves are usually experienced.

Key words: Effectiveness; Intervention; Quasi-experimental; Heat waves; Difference-in-difference analysis; Cost-effectiveness analysis

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INTRODUCTION

'Warming of the climate system is unequivocal,' according to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 'changes in many extreme weather and climate events have been observed since about 1950'[1]. Of all severe weather events, heat waves often claim the largest number of fatalities[2]. In 2010, the crude daily death rate due to heat-related illness significantly increased by 33% in Québec, Canada[3]. During 2013 in Japan, 58,729 heat stroke diagnoses were reported[4]. A total estimated 679 extra heat-related illnesses occurred during three heat waves in 2013, in Ningbo city of China[5]. Moreover, in the past five decades of the 20th century, the frequency and duration of heat waves increased significantly in China, especially in the first decade[6]. Epidemiological studies have emphasized that higher mortality risks from heat waves are very likely to increase without no additional adaptations as more frequent, more intense, and longer heat waves will likely occur in the future[7-8].

To respond to the continuous threat of heat waves, adaptation or intervention projects have been implemented in many parts of the world, including Europe, Australia, USA, and Canada[7-10]. These strategies are implemented at different executive levels. For example, at the national level, the Heat Alert Response System and Heat-Health Watch/Warning System are conducted in five cities in Canada[9]. Moreover, heat health warning systems cover nearly half of Europe[10]. Although the names of the systems are different, their aims are similar.

In addition to the alert systems, several actions can be undertaken to avoid or at least reduce the negative impact of heat waves. At the region or community level, promoting educational programs is considered effective[11-12]. The best method for handling heat waves at the individual level may be through primary prevention by taking appropriate measures before, during, and after heat waves. It includes measures such as wearing cooler clothes, reducing outdoor physical activities and drinking sufficient water[13-18]. Although intervention measures regarding heat waves have been conducted in many countries, there is still a lack of evidence about the efficacy of the intervention, largely because it is difficult to evaluate large-scale public health programs as there are multiple factors involved[19-20]. Fortunately, an important recently publication has assessed the effect of a heat action plan on heat-related mortality[21]. However, we need more evidence to support the effectiveness of adaptation or intervention on heat waves. To develop statistically important evidence, the primary aim of this study was to provide evidence of the effectiveness of the Heat Wave Intervention Program (HWIP) in China by detecting changes in indicators regarding the prevalence of heat-related illness. A quasi-experimental design (before and after measurements made in both intervention and control areas) was implemented[22] to better infer causality[23]. Accordingly, this quasi-experimental study was developed to have sufficient power to detect significant changes in the prevalence of heat-related illness, as well as to enable modifications to improve the efficacy of the intervention program.

In addition, economic assessments of HWIP are also believed to be crucially important[24]. The cost effectiveness analysis (CEA), one of the economic analyses, is strongly advocated by the World Health Organization (WHO-CHOICE project) and is used to help governments set health care priorities in both developed and developing countries[25]. At present, research evaluating the overall cost-effectiveness regarding changing the behavior of health professionals has started to receive attention[24,26-27]. However, reports of cost-effectiveness regarding interventions are currently rare[28]. It is therefore important to use economic assessment to explore the effectiveness of interventions.

To help overcome these shortcomings, and in the context of the National Basic Research Program of China (973 Program) grant no. 2012CB955500, the Chinese Center for Disease Control and Prevention and Licheng Center for Disease Control and Prevention developed a HWIP, which aimed to reduce the adverse impacts of heat waves in Licheng District, China. Over time, the results from this program will provide evidence for interventions based on changes in the prevalence of heat illness and a cost-effectiveness analysis.

METHODS

Heat Wave Intervention Program (HWIP)

The HWIP research centers on a comparison of control and intervention groups. Furthermore, the HWIP is designed to improve public health via a series of intervention measures through city and township service providers under the direction of the local health departments. The objective of the HWIP project is to sufficiently capture the difference of the prevalence and cost between intervention and control groups. The control group will not take any additional measures, whereas the intervention group will follow four intervention measures:

I. Three-level health care networks: establishing three-level 'district-street-city/township' health care networks, in which all intervention measures are implemented.

II. Heat early warning and preparation: paying close attention to the weather forecast, before the expected heat waves pamphlets will be distributed by the community workers to ensure every household has one. The pamphlets provide educational information and preventive practices about heat waves.

III. 24 hours consulting services: setting up a telephone hotline and a WeChat (an app for instant message) service that are open 24 h per day, with one person assuming responsibility for this. This process is convenient for service providers and residents to communicate with each other.

IV. Heat-related training: providing training programs for doctors so that they will be capable to give professional advice as well as provide health care on high temperature days and during heat waves, especially to older individuals, children, and pregnant women.

Study Design and Objective

Licheng District is located in the southeast of Jinan City, with 1298.57 square kilometers area and 1.12 million people. The mean temperature in warm season (June to September) of 2014 and 2015 were 24.7 °C and 25.3 °C. There were no significant differences in the mean temperature between the year 2014 and 2015 (P=0.105). Multistage sampling was utilized to select a representative sample. In the first state, the study district was geographically divided into urban and rural areas. In the second stage, two streets were selected from each area with the similar demographic characteristics and economic status. Shanda (urban), Quanfu (urban), Baoshan (rural), and Wangsheren (rural) were selected into the study. A quasi-experimental approach was then executed that involved a two-group pre-post design with the intervention streets and control streets. The streets of Quanfu and Baoshan were randomly chosen as the intervention streets, and those of Shanda and Wangsheren as control streets. In the third stage, 600 households from each street were randomly selected at every cross-sectional investigation. Finally, all participants aged over 14 years who had been living in that area for at least 6 months were registered, and one eligible local resident in each household was selected using the Kish grid method[29].

Two cross-sectional surveys using the same questionnaire were conducted at the beginning (pre-intervention from September to October in 2014) and end (post-intervention from September to October in 2015) of the intervention, respectively (Figure 1). Intervention groups were assigned to receive the HWIP from May 1st, 2015, to August 30th, 2015, while the control group did not undergo any intervention measures throughout the survey.

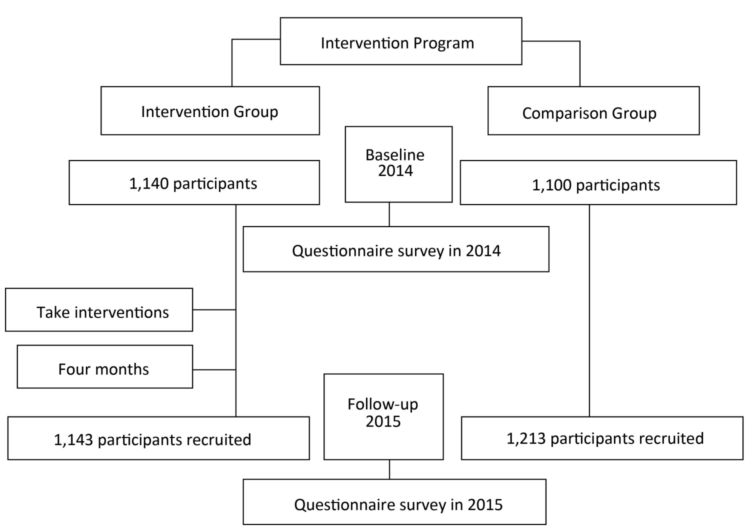

Figure 1. HWIP sample flow diagram.

During the project, actions were undertaken to ensure the quality of the surveys. All interviewers received systematic and intensive training before the survey. Moreover, 100 participants were recruited for a small-scale pilot study to test the validity and reliability of the questionnaire. Four senior researchers were present full-time during the survey to monitor and ensure the quality of the data collected.

Study Data

Questionnaire data were obtained from the two cross-sectional surveys, which mainly included socio-demographics, health behaviors and a range of health outcomes. The baseline data collected in 2014 consisted of information from 2,240 participants. The sample size in 2015 was 2,356. Program costs were also an important factor, since cost is a key factor to determine whether the intervention achieved cost-effectiveness. The program costs of HWIP are largely covered by government insurance, as well as additional costs incurred during intervention periods, such as administrative costs, health professional consultations and labor cost. Detailed costs are listed in Table 5.

Statistical Analysis

Two methods were used to measure the efficiency of the HWIP: a difference-in-difference analysis (DID) and CEA. The main outcome variable was the prevalence of heat-related illness which had been fully explained in another study by our team[19]. This outcome was binary (yes/no) and was analyzed as the percentage of respondents who responded in the affirmative. Differences in proportions were compared among different demographic groups using χ^2 test.

DID Analysis DID analysis is one of the most frequently used and informative study designs for evaluating the effect of interventions in social sciences. In the present study, DID estimation was used to assess the effect of interventions on the prevalence of heat-related illness while controlling for socioeconomic characteristics of subjects in the framework of a fixed effect logistic model. To DID analysis[17,30], an intervention program is provided at some time point between time *a* as year 2014 and time *b* as year 2015. There are only two groups (g=0 or 1), and the intervention group is given to 1. For an individual i with responses y_{ia} and y_{ib}, $E\ (y_{ia}\text{-}y_{ib}|g{=}0)$ includes only the time effect, whereas $E\ (y_{ia}\text{-}y_{ib}|g{=}1)$ includes both time and intervention effects. Thus,

$$\text{DID} = E\ (y_{ia}\text{-}y_{ib}|g{=}1) - E\ (y_{ia}\text{-}y_{ib}|g{=}0) \qquad (1)$$

This model identifies the desired intervention effect (or the net effect of policy reform). The DID estimator is the coefficient of the interaction term between time and group in a linear regression model with group, time, and their interaction as covariates. Because of the binary outcome variable in this study, the DID-logistic estimate was adopted to estimate the intervention impact using the above calculations.

CEA CEA can provide a clear, descriptive summary of the costs and consequences for decision-makers[20]. The analysis includes both the cost-effectiveness ratio (CER) and incremental cost-effectiveness ratio (ICER). The CER is calculated to compare the health benefits and costs between the intervention group and the usual care of the control group; all estimates are reported in U.S. dollars per person. The analysis also involves computing the ICER, which measures efficiency and estimates the additional expenditures required to gain additional health benefits when a more effective and expensive strategy is undertaken[25]. The ICER is calculated using the following formula:

$$\text{ICER}=(\Delta C_2\text{-}\Delta C_1)/(\ \Delta E_2\text{-}\Delta E_1) \qquad (2)$$

In this formula, C_2 was defined as the total cost of intervention group and C_1 as that of control group. E_2 and E_1 were changes in the number of cases in the intervention and control groups, respectively. To assess the influence of various cost parameters on the results, one-way deterministic sensitivity analyses were performed where input parameters varied one at a time while the remaining values were fixed at their baseline values.

Categorical variables were computed as a percentage of subjects with the perspective attribute. The differences in unordered categorical variables were calculated using χ^2 test. The ordinal categorical variables including age, education and income were calculated using *Mantel-Haenszel* test. All statistical analyses were performed using STATA (version 13), and *P* values <0.05 from two-sided tests were considered statistically significant.

Ethical Statement

Ethical approval was obtained from the Ethics Committee of the Chinese Center for Disease Control and Prevention (No.201214). Written informed consent was obtained from all the participants prior to the survey. All data obtained were anonymous.

RESULTS

Descriptive Analysis of Sample and Prevalence of Heat-Related Illness

Table 1 presents the sample results in different surveys and different areas. The response rate was 93.3% (2,240/2,400) in baseline survey and 98.1% (2,356/2,400) in intervention survey.

Table 2 reports the comparison of prevalence rate in different year of different groups and D-value in the comparison between control and intervention group. Of the seven aspects, only occupation status differed significantly between groups when comparing the prevalence of heat-related illness in 2014 to that in 2015 in the intervention group (P=0.009). In the control group, the percentage of those aged 35-44 years who experienced heat-related illness was 21.9% in 2014 and 17.8% in 2015, a non-significant difference of 4.1%. As for the intervention group, the prevalence of heat-related illness decreased significantly by 10.5% from 30.7% in 2014 to 20.2% in 2015 (χ^2=6.00, P=0.014). In 2014, the prevalence of heat-related illness in women was 19.5% in the control group and 25.9% in the intervention group; in 2015, the rate was 16.6% in the control group and 15.7% in the intervention group, a difference value (D-value) of 7.3 across years (P=0.022). It is noteworthy that the D-value with a monthly income of $322-483 was higher (14.6%) in the intervention group than that in the control group (4.0%), and the change in the prevalence of heat-related illness in the intervention group was significant.

Table 1. Number of Surveyed Participants in 2014 and 2015

Area	2014		2015	
	Intervention	Control	Intervention	Control
Total	1,140	1,100	1,143	1,213
Urban	462	571	510	599
Rural	678	529	633	614

Changes of the D-value and net D-value Regarding the Prevalence of Heat-Related Illness

Figure 2 shows the D-value and net D-value of demographic characteristics of heat-related illness prevalence in the intervention and control groups. The net D-value is equal to the absolute D-value of the intervention group minus the absolute D-value of the control group. Compared with the control group, the D-value of the intervention group was greater in most of the sub-groups. People who were divorced had the largest net D-value of the prevalence of heat-related illness (-58.3%), but there was no significant difference between the intervention and control groups. The net prevalence of heat-related

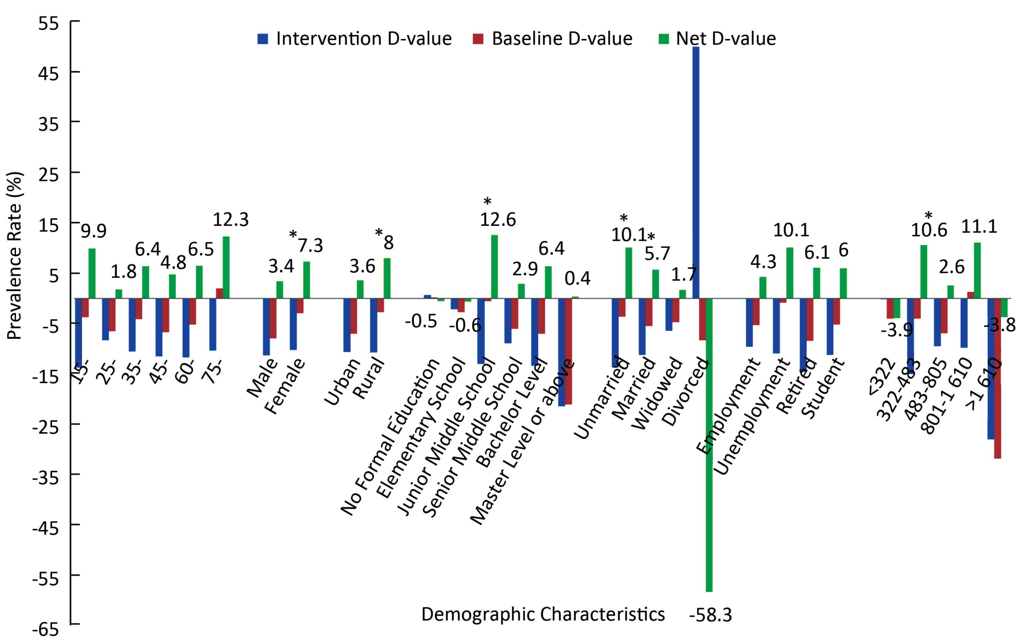

Figure 2. D-value between Intervention Group and Control Group, $^{*}P$<0.05.

Table 2. Comparison of Prevalence Rate and D-value in Control Group and Intervention Group

Characteristics	Control Group			Intervention Group			D-value (%)	
	2015 % (*N*)	2014 % (*N*)	*P*-value	2015 % (*N*)	2014 % (*N*)	*P*-value	Control (95% *CI*)	Intervention (95% *CI*)
Age (y)			0.33			0.234		
15-	14.4 (24)	18.1 (25)		11.8 (150)	25.4 (33)		3.7 (-4.6, 12.1)	13.6 (2.7, 24.5)*
25-	17.4 (56)	23.9 (64)		16.7 (53)	25.0 (74)		6.5 (-0.1, 13.0)	8.3 (1.9, 14.7)*
35-	17.8 (39)	21.9 (37)		20.2 (39)	30.7 (70)		4.1 (-3.9, 12.1)	10.5 (2.1, 18.9)*
45-	16.0 (43)	22.7 (60)		17.7 (50)	29.2 (83)		6.7 (0, 13.4)*	11.5 (4.6, 18.5)*
60-	16.5 (31)	21.7 (46)		13.8 (28)	25.5 (42)		5.2 (-2.5, 13.0)	11.7 (3.6, 19.7)*
75-	16.3 (8)	14.3 (7)		19.4 (12)	29.7 (11)		2.0 (16.6, 12.5)	10.3 (-7.1, 2.8)
Sex			0.166			0.106		
Male	16.5 (91)	24.4 (121)		18.0 (96)	29.3 (154)		7.9 (3.1, 12.8)*	11.3 (6.2, 16.4)*
Female	16.6 (110)	19.5 (118)		15.7 (96)	25.9 (159)		2.9 (1.3, 7.1)	10.2 (5.6, 14.6)*
Area			0.459			0.713		
Urban	15.0 (101)	22.0 (147)		17.2 (129)	27.8 (199)		7.0 (2.9, 11.2)*	10.6 (6.4, 14.9)*
Rural	18.5 (100)	21.2 (92)		16.1 (63)	26.8 (114)		2.7 (-2.3, 7.7)	10.7 (5.1, 16.3)*
Education			0.077			0.085		
No Formal Education	12.9 (9)	12.7 (7)		15.6 (10)	14.9 (7)		-0.2 (-12.1, 11.9)	-0.7 (-14.5, 13.1)
Elementary School	26.3 (26)	29.0 (31)		20.0 (22)	22.1 (21)		2.7 (-9.6, 15.1)	2.1 (15.3, 26.6)
Junior Middle School	20.6 (59)	21.1 (55)		16.0 (43)	29.1 (83)		0.5 (-6.3, 7.3)	13.1 (6.2, 20.1)*
Senior Middle School	15.8 (54)	21.8 (68)		19.9 (66)	28.8 (102)		6.0 (0, 12.0)*	8.9 (2.4, 15.3)*
Bachelor Level	13.6 (50)	20.6 (66)		13.8 (48)	27.2 (90)		7.0 (1.3, 12.5)*	13.4 (7.4, 19.4)*
Master Level or above	6.3 (3)	27.3 (12)		14.3 (3)	35.7 (10)		21.0 (6.2, 35.9)*	21.4 (-4.0, 46.8)
Marital Status			0.784			0.244		
Unmarried	17.3 (37)	20.9 (39)		9.6 (11)	23.3 (42)		3.6 (-4.1, 11.3)	13.7 (4.7, 22.6)*
Married	16.2 (151)	21.7 (186)		17.1 (163)	28.3 (259)		5.5 (1.9, 9.1)*	11.2 (7.4, 14.9)*
Widowed	18.8 (12)	23.5 (12)		22.5 (16)	28.9 (11)		4.7 (-10.4, 20.0)	6.4 (-10.9, 23.7)
Occupation			0.116			0.009		
Divorced	25.0 (1)	33.3 (2)		66.7 (2)	16.7 (1)		8.3 (-6.7, 8.4)	-50 (-127.4, 27.4)
Employment	17.8 (145)	23.1 (165)		19.2 (145)	28.8 (231)		5.3 (1.3, 9.3)*	9.6 (5.3, 13.8)*
Unemployment	14.5 (24)	15.3 (18)		13.6 (16)	24.5 (24)		0.8 (-7.6, 9.2)	10.9 (0.5, 21.3)*
Retired	13.5 (15)	21.9 (37)		11.8 (27)	26.3 (40)		8.4 (-0.9, 17.7)	14.5 (6.7, 22.2)*
Student	14.0 (17)	19.2 (19)		9.5 (4)	20.7 (18)		5.2 (-4.7, 15.0)	11.2 (-2.8, 25.1)
Monthly Income ($)			0.609			0.311		
<322	21.9 (58)	25.9 (76)		26.8 (45)	26.9 (74)		4.0 (-3.1, 11.1)	0.1 (-8.4, 8.7)
322-483	16.8 (77)	20.8 (85)		16.2 (61)	30.8 (127)		4.0 (-1.3, 9.1)	14.6 (8.6, 20.4)*
483-805	13.8 (47)	20.7 (61)		14.4 (64)	23.9 (72)		6.9 (1.1, 12.8)*	9.5 (3.9, 15.1)*
805-1,610	12.8 (16)	11.5 (10)		16.4 (22)	26.2 (33)		-1.3 (-10.3, 7.7)	9.8 (-0.2, 19.7)
>1,610	12.0 (3)	43.8 (7)		0.0 (0)	28.0 (7)		31.8 (5.1, 58.3)*	28 (7.3, 48.7)*

Note. *Control group compared D-value with that of intervention group, *P*<0.05. 95% *CI*, 95% Confidence Interval.

illness at the junior middle school-level was 12.6%, with a statistically significant difference between the groups. Meanwhile, the prevalence of heat-related illness significantly decreased among women, participants who lived in rural areas, participants who were married and those with a monthly income of $322-483.

Difference-in-Difference Fixed Logistic Regression Analysis

Table 3 presents the results of difference-in-difference fixed logic regression, which accounts for the interaction coefficient (group × time) on prevalence among different respondents. The group × time (difference-in-difference estimator) indicated the net effect of intervention program. Model 1 and model 2 showed similar patterns of the intervention effect without or with covariates in different populations. After one year, the degree of decrease in the prevalence of heat-related illness among the intervention group was greater than that of the control group (*OR*=0.745; *P*<0.01). After incorporating covariates, the intervention group showed 0.769 fewer heat-related illness than that in control group, bu this was not statistically significant (*P*>0.05). The effects of group × time were explored at the city and township levels. At the city level, the net effect of the intervention program was not significantly different between the intervention and control group (*OR*=1.281, *P*>0.05). In contrast, at the township level, there was a greater decrease in heat-related illnesses in the intervention group than that in the control group (*OR*=0.495, *P*<0.001).

Table 3. Effects of the Intervention Program on the *OR* of Heat-related Illness among Participants in Urban and Rural Areas

Independent Variable	Dependent Variable					
	Prevalence (total)		Prevalence (urban)		Prevalence (rural)	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Time	0.715** (0.581, 0.881)	0.727** (0.589, 0.898)	0.512*** (0.378, 0.693)	0.538*** (0.395, 0.734)	0.982 (0.732, 1.317)	0.974 (0.724, 1.310)
Group	1.363** (1.123, 1.654)	1.350** (1.110, 1.642)	1.058 (0.794, 1.408)	1.016 (0.757, 1.364)	1.698*** (1.295, 2.225)	1.756*** (1.333, 2.314)
Group × Time	0.745* (0.557, 0.997)	0.769 (0.573, 1.033)	1.209 (0.781, 1.869)	1.281 (0.820, 2.002)	0.493*** (0.331, 0.732)	0.495*** (0.331, 0.740)
Sex		0.859* (0.741, 0.997)		0.863 (0.690, 1.078)		0.848 (0.693, 1.036)
Age		1.094 (0.721, 1.659)		1.217 (0.637, 2.324)		1.054 (0.609, 1.824)
Education		1.105 (0.705, 1.731)		1.047 (0.616, 1.781)		1.223 (0.502, 2.979)
Hukou		0.952 (0.809, 1.119)		1.140 (0.873, 1.490)		0.871 (0.705, 1.074)
Marriage		1.228 (0.432, 3.497)		3.006 (0.681, 13.261)		0.560 (0.109, 2.853)
Occupation		0.915 (0.559, 1.496)		1.122 (0.567, 2.216)		0.723 (0.342, 1.526)
Income		1.141 (0.632, 2.064)		1.364 (0.641, 2.904)		0.932 (0.348, 2.491)
Constant	0.277*** (0.240, 0.320)	0.043 (0.000, 9.111)	0.310*** (0.255, 0.375)	0.001* (0.000, 0.835)	0.245 (0.197, 0.303)	2.028 (0.000, 8756.264)
N	4596	4596	2142	2142	2454	2454
R-square	0.012	0.024	0.011	0.035	0.014	0.025

Note. 95% Confidence Interval in brackets. *P<0.05, **P<0.01, ***P<0.001; *OR*: Odd Ratios.

Costs of the HWIP

After the interventions, the prevalence of heat-related illness was reduced by 10.7% in the intervention group and 5.1% in the control group (5.6% net D-value, *P*=0.039) (Table 4). In contrast, the sample population had no statistical significance between groups. Therefore, the mean of the sample population of the intervention and control groups were used to calculate the average cost per patient. The mean sample population was 1,140 and 1,150 in the intervention and control groups, respectively. The number of patients was multiplied by the total number of participants and the prevalence: 122 (1,140×10.7%) in the intervention group, and 59 (1,150×5.1%) in the control group.

The costs including personnel, materials, expert fees, staff training, labor and telephone bills for the project were listed in Table 5 on the basis of the actual cost. Intervention costs were estimated at a total of $1837.68. For the control group, the usual costs (government costs) were a total of $925.93. The upper and lower limit of total intervention costs were $918.84 and $3675.36, respectively, which was calculated by using one-half and twice the total intervention costs. Detailed data sources and descriptions are listed in Table 5.

Analysis for Cost Effectiveness and Sensitivity Analysis

Table 6 displays the CER and ICER between the control and intervention groups. The CER in the intervention group was lower than that in the control group (15.06 *vs*. 15.69). It indicated that the costs of reducing one heat-related patient were lower in the intervention group than that in the control group. Moreover, based on the ICER, it would cost $14.47 to reduce one extra heat-related patient in the context of HWIP.

Table 4. Net D-Value of the Prevalence of Heat Illnesses between Intervention and Control Group

Group	2015	2014	D-value	Net D-value
Intervention group	16.8% (1,143)	27.5%[a] (1,140)	-10.7%	-5.6%[c]
Control group	16.6% (1,213)	21.7%[b] (1,100)	-5.1%	

Note. [*]Means and standard errors were estimated using linear regression. D-value, difference value [a]*t*=-5.78, *P*<0.001; [b]*t*=-2.90, *P*=0.004; [c]*t*=-2.6, *P*=0.039.

Table 5. Cost of Intervention Program for 1,140 Participants during Heat Wave Periods in 2015

Resources	Details of Quantities and Values	Total Costs (US$[*])
Personnel	To assume the government's fixed investment, 0.81$/per participant	917.87
Materials		
Brochure	To ensure that everybody has a brochure, $0.13 each	146.86
Posters	Four during the intervention, $16.1 each	64.41
Others		
Expert fee	Experts give guidance before the intervention, $96.6/per consultation	289.86
Staff Training	To train the community service staff	128.82
Labor cost	To distribute related materials	128.82
Telephone	To open the hotline	64.41
others	Such as travel, table money	96.62
Total		1837.68 (918.84, 3675.36)

Note. [*]US$1=6.21 Yuan as of June 2015. Upper and lower limits in parentheses. Upper and lower limit of control group was 462.96 and 1851.86 $.

Table 6. Cost-Effectiveness Analysis

Group	Cost ($)	Effectiveness/Number of Participants	CER ($ per person)	ICER ($ per person)
Control	925.93	59	15.69	
Intervention	1837.68	122	15.06	14.47

Figure 3 displays the sensitivity analysis of CER and ICER between the intervention and comparison group. Government-cost (GC) was the fixed cost provided by the government to cope with heat waves and was $0.81/per person. The intervention-cost (IC) was the total intervention cost minus the GC. When the IC was doubled or the GC halved, the CER of the intervention group was higher than that of the control group. However, the ICER was $29.07 and $14.47, respectively. The ICER was much less than the GDP per capita. It is noteworthy that when the IC was halved, CER was $11.29 less than that in comparison group ($15.69), and ICER was only $7.17. Generally speaking, regardless of the parameter values of GC and IC, the intervention strategy was optimal.

DISCUSSION

There are a number of strengths in the present study. First, the study has sufficient power to potentially detect a significant change in the prevalence of heat-related illness in the total population and in rural population. Second, it enables cautious causal inferences to be drawn about the efficacy of the intervention program. To legitimately determine a cause-effect relationship between an intervention and heat-related illness, it is necessary to employ a quasi-experimental design[23]. Such an approach is commonly used to measure behavior in communities before and after an intervention[31]. Examples of studies include assessing the impact of street lighting[22], infrastructure improvements around schools[31] and active travel[22]. Evidence of a causal effect is indicated with a significantly greater behavioral change in the treatment group than that in the control group.

Contrary to expectations, the intervention had a smaller effect in urban areas, although urban residents possess a relatively greater heat wave-related knowledge level and may be more likely to take protective measures during extreme heat events, since the urban population may has more access to resources and is usually well educated[17]. However, there may be several reasons regarding more limited effects in urban areas. First, the most effective intervention measures are those that promote risk perception and encourage people to assume more protective behaviors during heat waves. Furthermore, the intervention measures of the current study may not have been sufficient and effective for individuals in urban areas due to the impact of the urban heat island (UHI) effect, a by-product of urban development. The UHI effect results in higher temperatures in urban areas than in places with less population density and more vegetation, such as rural or suburban areas[32]. Much recent research has examined the relationship between UHI and the significantly greater risk of death on hot days in heat island areas[2,23-33]. Therefore, in response to the negative influence of

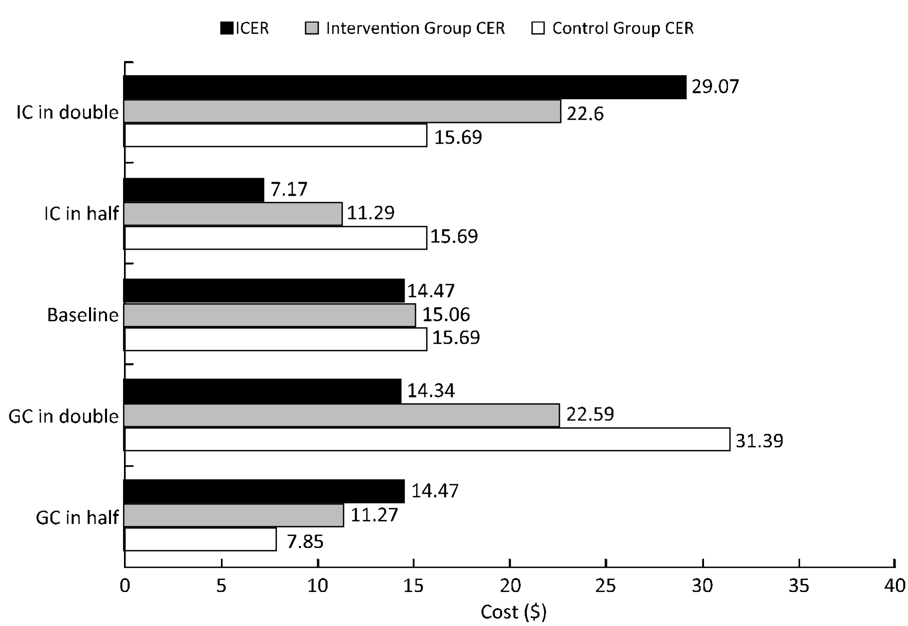

Figure 3. Sensitivity analysis of the cost effectiveness analysis.

UHI, further support is needed from the government, such as increasing the area of vegetation[14,34-35], albedo enhancement (reflecting sunlight to reduce direct radiation energy)[34-37] and building dwellings that are specially designed to absorb less radiation[36,38-39].

In addition, our study also shows that women, participants with a junior middle school education level and those with a monthly income of $322-483 had a higher net D-value in the intervention group. This indicates that the interventions play a vital role to protect these subgroups. In support of this, Derick[40] has suggested that participants who have post-secondary education or a university diploma and who earn a relatively high gross annual household income may have a high perceived benefit and have good adaptive behaviors during heat waves. Therefore, interventions should target those with low education and low monthly income.

Indicators are needed to assess adaptation and intervention effects, considering not only physiological adaptation, but also socioeconomic and economic indicators[41]. As much quasi-experiment-related research examines only the effectiveness of interventions, but fails to demonstrate collective cost-effectiveness[22,42-43]. This study sought to also determine economic assessments of the costs and benefits of the intervention program; according to Campbell[24], these are believed to be crucially important. The total mean intervention cost was $1.53 per participant. This cost is rather low, considering the physical health benefits observed in this 4-month intervention program. More importantly, the CER in the intervention group was lower than that in the control group, which indicated that the cost of reducing one patient with heat-related illness was lower in the intervention group. Therefore, the intervention program can be viewed as cost effective. In a review of the cost-effectiveness of physical activity interventions targeted at general populations, many interventions were found to be cost effective[44]. To provide further evidence, the ICER was also calculated, as it requires less effort to interpret than do full economic evaluations[20]. The ICER ranged from $7.17 to $29.77 in the sensitivity analysis; these values were much lower than the gross domestic product per capita ($12,076) suggesting that the increased cost was acceptable[45]. This also implies that the HWIP costs was quite small to gain the same benefits.

There are also several possible limitations in our study. First, this study evaluated the entire set of activities related to the demography, behaviors, knowledge, and other aspects of the participants rather than focusing on a single component. Therefore, further efforts are needed to validate the findings for each aspect. Second, as in any observational study, recall errors by individuals who were interviewed could affect the accuracy of our estimates. However, we believe such errors would similarly affect both the intervention and control groups. Third, relationships with local authorities were of great importance in the evaluation. Fortunately, all district officers were very helpful at providing practical and financial support for the study. In addition, the health literacy of heat-related illness might be different between urban and rural areas. So before the survey, all interviewers received systematic training for several days. And try the best for the interviewers to ensure the consistence of understanding.

CONCLUSION

An intervention program helped reduce the heat-related illness during heat waves in rural areas, but not in urban areas. Maybe, different heat intervention strategies should be used for rural and urban areas. Therefore, refined interventions should be targeted towards urban areas. Moreover, the intervention costs were lower compared with non-intervention costs during the same period, thus the intervention may be considered as a worthwhile investment for areas where are more likely to experience heat waves. Efforts to address health risks within HWIP should be expanded even further, and future research should examine whether the intervention strategies could be spread to other domestic or international regions.

AUTHOR CONTRIBUTIONS

LI Jing, XU Xin, LIU Zhi Dong, and LIU Qi Yong conceived and designed the study; WANG Jun, ZHAO Yun, SONG Xiu Ping, CAO Li Na, and JIANG Bao Fa organized the field works; LI Jing and LIU Zhi Dong analyzed the data; LI Jing wrote the paper.

CONFLICTS OF INTERESTS

The authors declare that they have no competing interests.

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