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Perceptions of heat-health impacts and the effects of knowledge and preventive actions by outdoor workers in Hanoi, Vietnam

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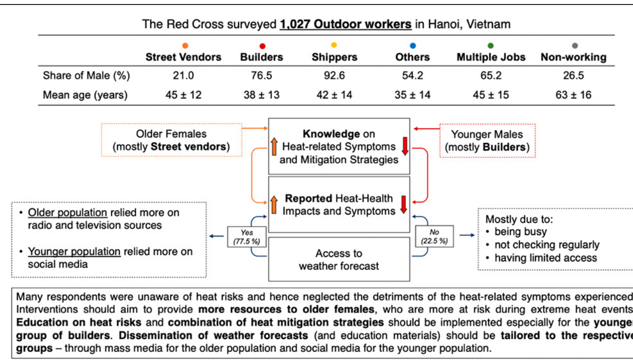
HIGHLIGHTS

- We investigated self-reported heat-health impacts of outdoor workers in Hanoi, Vietnam
- Only small group-wise differences existed, except for construction workers
- Increased drinking did not decrease heat impacts
- Knowledge of heat impacts and actions increased reported heat symptoms
- An air-conditioning device in the bedroom did not reduce heat-health impacts

GRAPHICAL ABSTRACT



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ABSTRACT

Extreme heat is an increasing climate threat, most pronounced in urban areas where poor populations are at particular risk. We analyzed heat impacts and vulnerabilities of 1027 outdoor workers who participated in a KAP survey in Hanoi, Vietnam in 2018, and the influence of their mitigation actions, their knowledge of heat-risks, and access to early warnings.

We grouped respondents by their main income (vendors, builders, shippers, others, multiple jobs, and non-working) and analyzed their reported heat-health impacts, taking into consideration socioeconomics, knowledge of heat impacts and preventive measures, actions taken, access to air-conditioning, drinking amounts and use of weather forecasts. We applied linear and logistic regression analyses using R.

Construction workers were younger and had less knowledge of heat-health impacts, but also reported fewer symptoms. Older females were more likely to report symptoms and visit a doctor. Access to air-conditioning in the bedroom depended on age and house ownership, but did not influence heat impacts as cooling was too expensive. Respondents who knew more heat exhaustion symptoms were more likely to report impacts ($p < 0.01$) or consult a doctor ($p < 0.05$). Similarly, those who checked weather updates were more likely to report heat impacts ($p < 0.01$) and experienced about 0.6 more symptoms ($p < 0.01$). Even though occupation type did not explain heat illness, builders knew considerably less (40%; $p < 0.05$) about heat than other groups but were twice as likely to consult a doctor than street vendors ($p < 0.01$). Knowledge of preventive actions and taking these

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actions both correlated positively with reporting of heat-health symptoms, while drinking water did not reduce these symptoms ($p < 0.01$). Child carers and homeowners experienced income losses in heatwaves ($p < 0.01$). The differences support directed actions, such as dissemination of educational materials and weather forecasts for construction workers. The Red Cross assisted all groups with cooling tents, provision of drinks and health advice.

1. Introduction

Extreme heat is one of the gravest challenges of climate change (Stocker et al., 2013). Exposure to extreme heat increases morbidity and mortality (Costa et al., 2020; Riley et al., 2018; Vargas and Marino, 2016), heat can hamper economic development (Estrada et al., 2017), increase poverty (Hallegatte et al., 2015) and influence migration patterns (Zander et al., 2019). On a global perspective, environmental temperatures are expected to surpass human habitability limits, and heat will increasingly dictate climate adaptation efforts (Sherwood and Huber, 2010; Mora et al., 2017; Xu et al., 2020). In Hanoi, average summer daytime maximum temperatures measure around 34 °C with an average nighttime temperature of 27 °C, but winters are markedly colder with average maximum temperatures around 21 °C.[1] In Vietnam, two or more consecutive days with maximum temperatures above 35 °C are considered a heatwave, and in the whole country of Vietnam, the number of days exceeding 35 °C has steadily increased by 2–3 days per decade over the past 4 decades (T. Trang et al., 2016). The observed temperature increments are attributed to both climate change and urbanization (Nguyen et al., 2019, 2017). Most major cities are located in areas with very high heat sensitivity and vulnerability (Tran et al., 2020). In future, Hanoi's annual mean temperature is projected to increase by 23 °C until 2050 under a medium climate change scenario (RCP4.5), so that Hanoi's 2050 climate would be comparable to the present conditions in Dhaka, Bangladesh (Bastin et al., 2019). It is then expected that the heat threshold for light work determined by the Vietnam Ministry of Health will be continuously surpassed from April to October (Opitz-Stapleton et al., 2016). Health impacts are apparent: heatwaves contributed to an increase in hospital admissions by 3.8% for infectious diseases and 2.5% for all causes (Phung et al., 2017), and to an increase in hospital admissions for mental disorders – a relationship known from wealthier countries (P.M. Trang et al., 2016).

Climate change and an increase in extreme heat are a threat to both occupational health and labor productivity, especially in tropical climates (Kjellstrom et al., 2019a; Watts et al., 2018; Kjellstrom et al., 2019b; Estrada et al., 2017). Factors affecting vulnerability to heat-related illness can be classified into interpersonal-level, community-level and policy-level factors. Interpersonal factors include socioeconomic class, education level, age and preexisting medical conditions such as diabetes, cardiovascular disease, cerebrovascular disease, renal disease, nervous disorders and emphysema (Nutong et al., 2018; Hifumi et al., 2018; Gaudio and Grissom, 2016; Naughton, 2002; Semenza et al., 1996; Semenza, 1999; Stafoggia et al., 2006). On a community level, factors such as living conditions and lack of access to air conditioning increase susceptibility to heat illnesses (Riley et al., 2018; Semenza, 1999; Semenza et al., 1996). Moreover, infants younger than one year (Bytomski and Squire, 2003) and elderly (Kenney et al., 2014) are more susceptible to heat illnesses, possibly due to sub-optimal thermoregulatory mechanisms and behavioral responses (Kenney et al., 2014; Bytomski and Squire, 2003).

Implementing strategies against extreme heat is urgent for urban populations with low adaptive capacities as they are especially at risk (Hallegatte et al., 2015). Poverty is one of the key drivers of heat stress vulnerability as workers prioritize income over health, which often leads them to compromise on protection against extreme heat. Poverty also limits workers' access to social protection and health-care services, further increasing their vulnerability (Hoa et al., 2013). They also tend to work in labor-intensive jobs with prolonged work hours and irregular access to shaded areas or air-conditioning, which increases their heat exposure and hence risk of heat-related illnesses (Red Cross Climate Center, 2019; ILO, 2019; Shah et al., 2015). Occupational heat exposure causes potentially detrimental health outcomes such as heat stroke (Kjellstrom et al., 2019a; Su et al., 2020), and the degree of exertion required in manual outdoor jobs, together with high ambient temperatures, exacerbates the increase in body temperature. Although thermoregulatory mechanisms can regulate body temperature, their efficacy is limited by very high ambient temperature and relative humidity (Hanna and Tait, 2015). Outdoor workers are regularly exposed to higher-than-recommended Wet Bulb Globe Temperatures (WBGT) (Stull, 2011; Venugopal et al., 2015), for example, farm workers in rural Ghana have been found to carry out physically demanding labor under temperatures peaking at 33 °C–38 °C, far exceeding workplace health recommendations (Frimpong, 2017). Heavy workloads, workplace heat stress and high temperatures increase heat illness symptoms by a factor of two to three (Venugopal et al., 2020, 2021).

Awareness of the dangers of extreme heat remains low among the Vietnamese population, despite an increasing number of hot days and associated measurable health impacts. In a study conducted by Hoa et al. (2013), less than 1% of outdoor workers in Da Nang city had sufficient knowledge of heat stress. Construction workers in India were found to be aware of heat-related preventive measures, but few resources were available to actually protect them from exceeding heat stress (Dutta et al., 2015). Mining workers' perception of climate change and occupational heat stress had a negative effect on occupational health (Nunfam et al., 2019) in rural Ghana. In that study, the observed effects varied between small-scale mining and large-scale mining, suggesting that differential occupation situations can result in varying responses to heat exposure. Education related to heat mitigation strategies (Alhadad et al., 2019) can enhance the selection of appropriate strategies to attenuate heat strain when working in extreme heat.

This study targeted Hanoi's most vulnerable population and focused on outdoor workers and populations in informal settlements. Approximately 150,000 persons in Hanoi live in informal settlements and in slum areas with inadequate housing.[2] Often, these houses are poorly designed with low-quality materials, such as metal roofs causing high indoor temperatures. Unsurprisingly, those living in informal settlements are usually among the most socio-economically disadvantaged, and include most outdoor workers. Participants in this study included informal street vendors, construction workers, shippers (riders transporting items or passengers), but also those with multiple jobs, and those who have retired from working. The humanitarian sector aims to prevent humanitarian catastrophes by targeting the most vulnerable and poorest population groups, and is gradually responding to the challenge of extreme heat (Red Cross Climate Centre, 2019). In this context, a *Forecast-based Financing* (FbF) project has been set up by the Vietnam Red Cross Society with technical support from German Red Cross in Hanoi, Vietnam to assist outdoor

[1] Data provided by Vietnam Institute of Meteorology, Hydrology and Climate Change (IMHEN) for *Láng* weather station in central Hanoi.

[2] This estimate is based on a vulnerability assessment carried out by the VNRC in 2019.

workers during heatwaves. FbF is a humanitarian anticipatory approach aiming at reducing the impacts from extreme weather by acting preemptively, with funding automatically released when set thresholds from weather forecasts, hydrological models, and socioeconomic risk analyses are surpassed (Coughlan de Perez et al., 2015). The survey data presented here has been collected as part of the preparatory work which has preceded the implementation of the FbF project in Hanoi.

Our analysis seeks to contribute to the growing body of research to aid the design of early warning early action systems and to evaluate the results of anticipatory humanitarian action (Harriman, 2014; Ghosh et al., 2014; Gros et al., 2019, 2020). Specifically, we addressed whether:

- the different demographics (age, sex and occupation) showed different vulnerabilities to extreme heat exposure, adaptive capacities and access to air-conditioning and hence the heat-health impacts experienced;
- heat mitigation strategies adopted during the heatwave and knowledge of the heat-related symptoms influenced the heat-health impacts experienced;
- receiving weather forecast information and early warnings influenced the heat-health impacts experienced.

2. Methods

We sought to elicit evidence from data collected previously by the Vietnam Red Cross (VNRC) Society in a *Knowledge, Attitudes & Practices* (KAP) survey (Gumucio, 2011) of outdoor workers and inhabitants of informal settlements in Hanoi, Vietnam. The survey was conducted as part of setting up a FbF project by the German Red Cross (GRC) and the VNRC and its goals were two-fold. First, it served to gather baseline data on vulnerable groups in these informal settlements, and second, it had the purpose to determine whether the different demographics of outdoor workers, their knowledge about heat-related injuries, actions taken during extreme heat events and accessibility to weather forecasts led to differing impacts of extreme heat. In addition, in this research we sought to foster an interdisciplinary collaboration of researchers and humanitarian practitioners to produce evidence-based findings for translation to the larger community.

2.1. Methods: data collection

The survey was conducted by VNRC staff with support from 14 public health students from the University of Hanoi, eight men and six women. Participants were surveyed in informal settlements in three Hanoi districts and two wards each: the central Ba Dình district (Vĩnh Phúc and Phúc Xá wards), and the expanded districts Nam Tù Liêm (Xuân Phuong and Me Trì wards) and Hoãng Mai (Thanh Trì and Mai Dông wards). The three districts were randomly selected out of the four central districts and eight expanded districts. The sample size for each target group was determined at 210, and adjusted to each ward using the *Probability Proportionate to Size* method. Practically, within each ward, surveyors were split into groups and walked down predefined paths and within these paths, the study participants were chosen at random. When possible, a door counting methodology with systematic sampling was used to identify eligible respondents. Surveyors used the *KoBo Toolbox* (KoBo, 2020) on their personal smartphones to read the questions, record respondents' answers and to take further notes. It took 15–45 min per participant to complete the survey, mostly depending on an respondent's age. An informed consent was obtained from the participants, as well as an ethics approval from the University of Da Nang, Vietnam. The survey was carried out from October 29th 2018 to November 5th 2018.[3] The then most recent heatwave in July 2018 reached daytime maximum temperatures of 40 °C from July 1st to July 5th.[4] During the survey itself, daytime maximum temperatures were around 28 °C. A qualitative study was carried out to triangulate the key findings of the KAP survey. It consisted of Focus Group Discussions (FGD) and In-Depth Interviews (IDI) which were carried out from March 18th through March 23rd 2019.

The questionnaire was structured into four different sections: **Section A** for respondents' demographics including sex and age, caring for children under 5 years of age, house ownership, access to air conditioning, outdoor working hours and amount of water drunk on "normal days" and on "hot days". The preceding heatwave served as reference period for "hot days". **Section B** surveyed health and economic impacts from past heat events, such as symptoms experienced during the heatwave and whether respondents consulted a doctor. **Section C** surveyed the respondents' use of weather forecast, their perceived clarity, importance and usefulness. **Section D** sampled knowledge about the medical implications and preventative measures against exposure to extreme heat and the actual behavioral responses when exposed to extreme heat. In Tables S15 to S18 we present the full set of questions and descriptive statistics (Pearson's Chi-squared tests and Cramer's V).

2.2. Methods: data analysis

We categorized the respondents into occupation groups based on their main source of income (Q. A13): *informal street vendors*, *builders* (construction site workers), *shippers* (riders transporting items or passengers), *multiple jobs* (respondents holding more than one job), *non-working* (respondents that were unemployed, mainly due to age),[5] and *others*. Respondents in the *others* category responded with income sources that did not fit into any of the main categories and which was extremely diverse. The paper will mainly discuss the three main groups *vendors*, *builders*, and *shippers* as their exposure to environmental and occupational heat can be deduced from their working environment and job scope, respectively. The *non-working* were those who did not report income from work. This group largely comprised retirees and we kept them in the analysis even if they did not follow any formal education, but to keep a sufficient number of age data points above 60 years. We decided against using question A1 ("target group") for determining occupation group, since most people identified both as slum dweller and as one of the other categories. We performed a control run of the statistics using A1 as category group instead of A13, and results remained very similar throughout.

We tested several definitions of "heat impact", which included self-reported heat health impacts and the economic impact from heatwaves. Heat-health impacts were assessed using Questions **B2** ("Did you get any of the following symptoms?") and **B3** ("With above symptom, did you go to see the doctor?"). Economic impact was assessed by income loss, which was directly queried in Questions **B8** ("How much do you earn on a normal day?") and **B9** ("Percentage of your income reduced during the heatwave?").

We used generalized regression models to investigate continuous variables and ordered logistic regressions to investigate ordinal dependent variables. The statistics were carried out with *R* and *RStudio* (R Core Team, 2020; RStudio Team, 2020) and the following variables were used:

- **Dependent variables**: The *total number of symptoms reported* (sum of Q. B2), a binary variable if *any health impacts* were reported at all (Q. B2), if respondents went to see a doctor because of heat-related symptoms. Fainting as an individual symptom was also used. For the economic impact *self-reported income loss* (Q. B9) was used.

[3] The sampling and surveying strategy is described in more detail in the Supporting Information (Section SI 1.1)

[4] Data provided by Vietnam Institute of Meteorology, Hydrology and Climate Change (IMHEN), for *Láng* weather station in central Hanoi.

[5] Note that we keep *non-working* as its own occupation group for the statistical analysis, even if the members of this group are not in an employment as such.

- **Independent variables**: *sex*, *age*, *occupation group*, *house ownership* which was shown to be a proxy for the quality of the house (Q. A10) and the existence of an air conditioning device in the bedroom (Q. A12), *income* (Q. B8), *access to weather forecasts* (Qs. C1, C3, C4), and being a *child carer* (Q. A6). In addition, individual independent variables were used to test their influence, such as access to weather forecast, knowledge of heat symptoms, and remedial actions taken. The category *elderly* comprised all those that are older than 60 years.

3. Results

3.1. Demographics

3.1.1. Age, sex and occupation group

A total of 1027 respondents participated in the survey, out of which 51% were males and 49% were females (Table S15). The majority of the construction workers were young men (38 ± 13 years, 81% males), *informal street vendors* tended to be older and female (45 ± 12 years, 82% females), *shippers* were of all age groups and nearly all-male (41 ± 14 years, 96% males). Those who were categorized as *non-working* did so mostly because of their age, and were predominantly females (63 ± 16 years, 74% females). The workers who did not fit into any of the previous groups – *others* – were rather young and of mixed sexes (35 ± 14 years, 50% females), similarly to those who fell into the *multiple jobs* category (45 ± 16 years, 61% females).

3.1.2. Heat-health symptoms

We grouped the self-reported symptoms (Q. B2) into three categories of increasing severity: heat cramps, heat exhaustion and heat stroke (see Table 1). Heat cramps were experienced by 58%–70% of respondents, depending on occupation group. Symptoms of heat exhaustion were reported in 65% of the *informal street vendors*, and in 40% of the *builders* and *shippers*. A majority of the respondents reported to have suffered from tiredness (78%), sweating (73%), and thirst (67%). Around half the respondents said that they suffered from feeling hot (58%) headache (57%), dizziness (54%). A minority reported coughing (23%), muscle cramps (23%), cold, pale and clammy skin (18%), and nausea or vomiting (13%). 4% reported to have fainted, and thus quite clearly have suffered from heat stroke. *Builders* reported a smaller number of symptoms. Out of those that reported fainting, 88% were female.

3.1.3. Access to air conditioning

Access to air conditioning (AC) in the bedroom (Q. A12) increased with age ($p < 0.01$) and varied across occupation groups, but seemed to be an non-discriminating factor for heat-health impacts (Table S6). While 33% of the street vendors and 42% of the shippers indicated AC devices in their bedrooms, only 13% of the builders did so. Another observation is that builders predominantly lived in rented housing. Respondents that owned a house, as compared to living in a rented house, were 50% more likely to have AC in the bedroom ($p < 0.01$). Child carers were 16% more likely to have AC in the bedroom ($p < 0.01$). Although AC ownership was independent of income, focus group discussions revealed that regular use of AC was beyond the financial capacities of the respondents (Fig. S1).

3.1.4. Influence of demographics on heat-health impacts

Table 2 shows the influence of demographics on self-reported heat-health impacts, measured by (1) if any health impact was reported at all, (2) the number of reported symptoms, and (3) whether a doctor was consulted. With each year of age, the reported number of symptoms increased by 0.016 symptoms ($p < 0.05$) and the likelihood of doctor visit by 2.8% ($p < 0.01$). Women were more likely to report health impacts by 50% ($p < 0.05$). *Builders* and the *others* group reported 45% and 55% fewer symptoms as compared to *informal street vendors* ($p < 0.05$). Moreover, with everything kept constant, *builders* were twice as likely ($p < 0.01$) and people with *multiple jobs* were four times as likely ($p < 0.01$) to consult a doctor. Neither AC nor house ownership had any effect on heat-health impacts (Table S6).

3.2. Knowledge of heat mitigation strategies and taking actions

3.2.1. Influence of knowledge of heat-related symptoms on heat-health impacts

Knowledge of symptoms for both heat exhaustion (*Knows HE symptoms*; Q. D1) and heat stroke increased the likelihood of also reporting heat symptoms and doctor visits. Those who know more heat exhaustion symptoms were nearly three times as likely to report any heat health impacts ($p < 0.01$) and also nearly twice as likely to consult a doctor ($p < 0.05$) (Table 3). Similarly, those who knew heat stroke symptoms had 45% higher odds to consult a doctor than those who did not know heat stroke symptoms, but no influence was observed on whether any symptoms were reported (Table S8). Those who had fainted in the previous heatwave showed double the odds ($p < 0.01$) of knowing about preventive measures against heat exhaustion (*Knows HE prevention*; Q. D3) (Table 3). In general, 17.8% of participants could not name any heat exhaustion symptoms, and 66% could not name any heat stroke symptoms (Figs. S10; S11). Similarly to

Table 1
Reported symptoms (Q. B2), category (heat cramps, heat exhaustion or heat stroke) and share of symptoms reported by all respondents, share of these symptoms among builders, and values reported in a study on construction site workers in Ahmedabad, India (Dutta et al., 2015). The list of symptoms included in the survey was non-exhaustive, the heat injuries mentioned are not mutually exclusive and do not necessarily occur independently of each other.

Symptom	Classification	Total	Builders	Dutta et al. (2015)
Heavy sweating	Cramps	746 (73%)	74%	74%
Thirsty	Cramps	685 (67%)	64%	79%
Cough	Cramps	234 (23%)	18%	–
Muscle cramps	Cramps	233 (23%)	17%	18%
Tiredness or weakness	Exhaustion	796 (78%)	73%	–
Headache	Exhaustion	582 (57%)	47%	38%
Dizziness	Exhaustion	558 (54%)	46%	34%
Cold, clammy skin	Exhaustion	184 (18%)	18%	–
Nausea or vomiting	Exhaustion	134 (13%)	12%	22%
Feeling hot	Stroke	591 (58%)	49%	–
Fainting	Stroke	42 (4.1%)	2.5%	20%

Table 2
Influence of socioeconomic characteristics on self-reported heat-health impacts. Dependent variables are (1) if any impacts have been reported (log), (2) total number of symptoms reported (linear), (3) consulting a doctor because of heat-related symptoms (log). Values in brackets denote the standard error.

	Dependent variable		
	Any health impact *logistic*	No. symptoms *normal*	Visited doctor *logistic*
	(1)	(2)	(3)
Age	−0.005 (0.009)	0.016** (0.007)	0.028*** (0.008)
Sex (*male*)	−0.695** (0.299)	−0.435* (0.222)	−0.267 (0.253)
Income (1000 VND)	−0.001 (0.001)	−0.001** (0.001)	−0.0003 (0.001)
Child carer	0.422 (0.267)	0.122 (0.176)	0.209 (0.198)
Homeowner	−0.056 (0.285)	−0.372* (0.195)	0.119 (0.219)
Occ. (*builders*)	−0.142 (0.343)	−0.611** (0.256)	0.829*** (0.291)
Occ. (*shippers*)	0.661* (0.393)	−0.187 (0.270)	0.440 (0.319)
Occ. (*others*)	−0.583 (0.386)	−0.776** (0.312)	0.565 (0.361)
Occ. (*mult. jobs*)	−0.533 (0.471)	0.111 (0.414)	1.460*** (0.416)
Constant	2.783*** (0.487)	5.610*** (0.354)	−2.797*** (0.420)
Observations	836	742	741
Log likelih.	−282.475	−1,627.668	−370.872
Ak. Inf. Crit.	584.949	3,275.337	761.744

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 3
Logistic regression on the effect of knowledge on several heat exhaustion symptoms. Values in brackets denote the standard error.

	Dependent variable		
	Any health impact	Visited doctor	Fainting
	(1)	(2)	(3)
Age	−0.004 (0.009)	0.026*** (0.008)	−0.005 (0.009)
Sex (*male*)	−0.408* (0.245)	0.131 (0.188)	−0.497** (0.244)
Income	−0.001 (0.001)	−0.0002 (0.001)	−0.001 (0.001)
Child carer	0.385 (0.267)	0.200 (0.196)	0.355 (0.266)
Homeowner	0.147 (0.275)	0.079 (0.208)	0.100 (0.273)
Knows HE symptoms	1.046*** (0.242)	0.601** (0.289)	
Knows HE prevention			0.888*** (0.264)
Constant	1.776*** (0.497)	−3.032*** (0.480)	1.953*** (0.495)
Observations	836	741	836
Log likelihood	−279.872	−376.622	−283.321
Akaike Inf. Crit.	573.745	767.243	580.641

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 4
Linear regression with total number of symptoms as dependent variable, testing for the influence of preventive actions around drinking. (1) Increasing water intake (reporting different drinking amounts for “normal” and “hot” days), (2) responding to act upon heat by “drinking plenty” and by (3) following weather updates. Values in brackets denote the standard error.

	Dependent variable		
	Number of symptoms		
	(1)	(2)	(3)
Age	0.018*** (0.007)	0.019*** (0.007)	0.018*** (0.007)
Sex (*male*)	−0.652*** (0.168)	−0.577*** (0.167)	−0.603*** (0.166)
Income	−0.001*** (0.001)	−0.001*** (0.001)	−0.001*** (0.001)
Child carer	0.088 (0.176)	0.053 (0.176)	0.053 (0.176)
Homeowner	−0.261 (0.189)	−0.282 (0.189)	−0.318* (0.189)
Increased water intake	0.464*** (0.162)		
Drinking plenty (Q. D8/2)		0.831*** (0.267)	
Weather updates (Q. D8/10)			0.608*** (0.173)
Constant	5.132*** (0.349)	4.571*** (0.421)	4.964*** (0.357)
Observations	742	742	742
Log Likelihood	−1,629.128	−1,628.368	−1,627.042
Akaike Inf. Crit.	3,272.255	3,270.736	3,268.085

* $p < 0.1$.
*** $p < 0.01$.

respondents' knowledge about heat symptoms, 14% could not name any actions against heat exhaustion, and 41% none against heat stroke. “Move to a cool place” was the only remedial action that was known by the majority of respondents (Figs. S10; S11). *Builders* knew less about symptoms of heat-illness and prevention measures, 92% of the *builders* could name less than three preventive measures against heat stress, and 14% of *builders* claimed to be completely unaware of heat mitigation strategies.

3.2.2. Influence of preventive actions taken on heat-related symptoms reported

Respondents were asked about which measures they had taken to cope with very hot weather (Q. D8). “Staying in the shade” was the only measure that was named by a majority of the study participants (Fig. S9).

Whether respondents have taken any action at all (as a binary variable) did not yield any predictive power on any of the heat-health indicators used (Table S9). However, differences emerged when testing for specific measures taken: Reporting to drink more as a remedial action showed to increase the number of reported heat symptoms, and this was consistent across three different questions in the survey that all addressed water intake (Table 4). Respondents who rescheduled outdoor activities, took longer lunch breaks and changed their working schedules in response to hot weather reported experiencing more symptoms ($p < 0.05$) (Table S10). Other heat mitigation actions (Q. D8) showed no effect on heat-related symptoms reported (not shown).

3.2.3. Preventive actions taken: water intake

In general, respondents drank more water on hot days than on normal days based on their response of how much they consumed both on “normal” and “hot” days (Q. B10). We focused on the self-reported differences between normal days and hot days, since we expect that the reported amounts were subject to report bias and recall bias, and were thus unlikely to accurately represent individuals' total fluid intake. On average, respondents reported to drink 1.95 L on normal days, and 2.55 L on hot days (Fig. 1). Generally, we observed that men, *builders* and those with *multiple jobs* drank more water than other groups. A linear regression analysis showed that age had a small positive effect on drinking amounts on normal days, with an increase of 0.04 L per 10 years of age ($p < 0.01$; Table S11), however, no such effect was observed for hot days and the effect also did not seem to be present for populations older than 55 years of age.

3.3. Weather forecasts and early warnings

3.3.1. Knowledge on weather forecasts

Those who knew about weather forecasts also reported more heat-related symptoms (Table 5). In total, 78% of the respondents received weather forecast information and heatwave warnings although 88% felt that it is important. Out of which, 71% relied on television for weather forecasts, probably because 51% and 44% felt that television was the most reliable and accessible source, respectively. Of those respondents who did not receive weather forecast information, 38% were “too busy” and 17% lacked access to sources. It is noteworthy that, of those that received weather forecast information, only 82% found the information useful Fig. 2.

3.3.2. Influence of knowledge on weather forecasts on reported heat-health impacts

As compared to those who did not receive the forecast, respondents who received heatwave weather forecasts (Q. C1) had nearly twice the odds of reporting heat-health impacts ($p < 0.01$). Those who found weather forecasts “definitely useful” (Q. C6) were more than triple as likely to report heat-health impacts ($p < 0.01$) (Table 5). However, accessing weather forecasts or finding weather forecasts useful did not influence the total number of symptoms reported, number of doctor visits, or the likelihood of fainting (not shown).

4. Discussion

We investigated the relationship between self-reported symptoms of heat-illness and possible explaining factors for different groups of outdoor workers and slum dwellers in Hanoi, Vietnam. Explaining factors were age, sex, occupation, house ownership, night-time access to air-conditioning, income, use of weather forecasts and being a child carer.

The different occupation groups (builders, street vendors, shippers, multiple jobs and non-working) showed marked differences in their mean age, sexes and socioeconomic properties. The *informal street vendors* were the oldest group with the greatest share of elderly (mean age: 45 ± 12 years; share elderly: 9.9%). On the other hand, *builders* were the youngest group (mean age: 38 ± 13 years; share elderly: 3.1%) (Fig. S2 and Table S7). Age was a strong predictor for living in higher quality

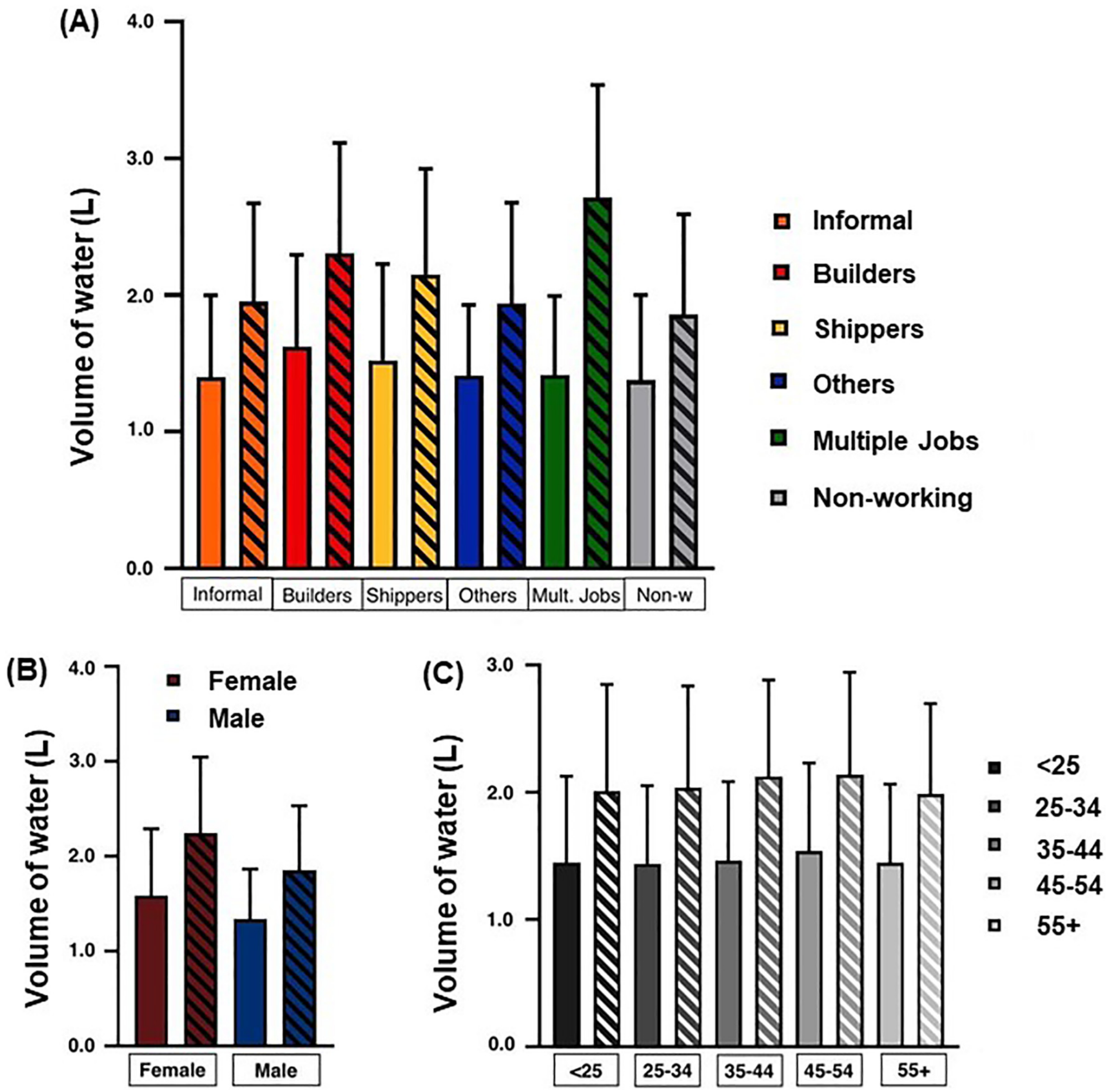

Fig. 1. Self-reported water intake on "normal days" (solid bars) and "hot days" (dashed bars) grouped by (a) occupation, (b) gender and (c) age.

Table 5
Logistic regression models for investigating whether respondents reported any health impact from heat and which role weather forecasts played. Model (1) included "Received Forecast" (Q. C1) as additional independent variable, model (2) included the perceived usefulness of forecasts as additional independent variable (Q. C6). Values in brackets denote the standard error.

	Dependent variable	
	Any health impact	
	(1)	(2)
Age	−0.004 (0.009)	−0.004 (0.009)
Sex (*male*)	-0.565^{**} (0.245)	-0.516^{**} (0.246)
Income	−0.001 (0.001)	-0.001^{*} (0.001)
Child carer	0.350 (0.266)	0.301 (0.274)
Homeowner	0.040 (0.272)	0.052 (0.278)
Received forecast	0.662^{***} (0.239)	
Forecast useful		1.176^{***} (0.247)
Constant	2.227^{***} (0.480)	1.840^{***} (0.492)
Observations	834	833
Log likelihood	−284.641	−275.335
Ak. Inf. Crit.	583.282	564.670

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

housing and thus night-time access to air-conditioning. In general, older females were more likely to experience heat-related symptoms and to consult a doctor.

In all metrics, construction workers reported being less impacted by heat than the other groups, even though they may be exposed to additional heat exposure and conduct physically challenging work. This

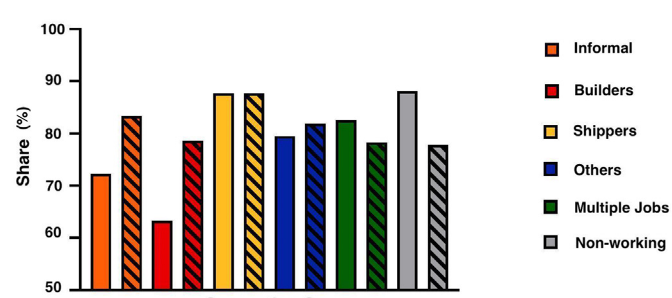

Fig. 2. Share of respondents that received weather forecast information of the previous heatwave (solid), and share of those who received a forecast and found it useful (dashed), grouped by occupation.

could be attributable to intrinsic factors such as their lower age (Foster et al., 2020; Kenny et al., 2010) and possibly higher aerobic fitness (Notley et al., 2020; Foster et al., 2020; Périard et al., 2012; McLellan, 2001) which was not assessed in our survey, though. They might also have been more motivated, supported by ground evidence that young builders claimed to be "unaffected" and "used to" the heat. This might have contributed to their altered perception of the severity of heat-related symptoms and injuries (Guérin and Fortier, 2012; Coquart et al., 2012; Kircher, 1984). The other occupation groups were more comparable to each other in the number of symptoms reported. This stands in contrast to other findings which stated that workers with heavier workloads also showed more heat-related symptoms (Venugopal et al., 2015, 2020). The participants in our study were exposed to direct sunlight and urban heat canyons. A recent study (Venugopal et al., 2020, 2021) on workers that included foundry and salt pan workers, who were exposed to more intense heat, determined that it increased the odds of adverse heat-health outcomes by a factor of 2.3, and heavy workloads tripled the odds. In the sample of workers analyzed here, construction site workers were among those who reported the fewest health impacts. This sheds a light on the importance of work conditions for health impacts, and highlights where the participants of our study can be placed in the wider context. Other literature has shown no difference between heat impacts on organized and unorganized labor (Venugopal et al., 2015), even though other findings showed drastic differences in heat vulnerability between large-scale and small-scale miners (Nunfam et al., 2019). The respondents from this current survey all worked in comparable locations and hence did not show drastic differences in heat vulnerabilities.

The symptoms reported by participants in this study and survey data for construction workers in Ahmedabad, India (Dutta et al., 2015) were largely comparable (Table 1). The reported prevalence of heat cramp symptoms (sweating, thirst and cramps) were nearly identical, while more symptoms of heat exhaustion (headache, dizziness) have been reported here than in the Ahmedabad study. Nausea and fainting have been reported significantly less in our study: Fainting in particular was only reported by 2.5% of construction workers in this study, but by 20% of those interviewed in Ahmedabad. Further, the construction site workers in our study reported consistently fewer symptoms than the other work groups, except for sweating and muscle cramps, where the numbers were nearly identical (both 74% for sweating and 17% respectively, 18% for cramps). Under-reporting was indicated by the focus group discussions that followed the survey, where builders reported that "they are used to the heat". While our data were not sufficient to draw final conclusions and more work would be needed to refine the comparison, this may confirm our hypothesis of under-reporting of symptoms by construction workers. Knowing the symptoms and risks of heat-related injuries can be the first step towards prevention. Hence, the builders may be putting themselves at risk by ignoring and being unaware of signs of heat illnesses (Leyk, 2019). As a consequence, heat-health education programs may be targeted to the builder group.

We observed no relationship between nighttime access to air-conditioning and heat-health impacts, even though access to AC is considered an important heat mitigation strategy (Semenza et al., 1996; Bouchama et al., 2007). The focus group discussions (see SI 1.4.6) revealed that AC, even if it existed, was sparsely used by the study participants because their income was too low: The estimated monthly income of a worker was about ~185 USD – ~280 USD. Comparably, a representative household study in India found a threshold for ownership of air-conditioning at a daily household income greater than ~12 USD, equivalent to ~360 USD/month (Ramakrishnan et al., 2020). At an average device purchase price ~500 USD and additional electricity costs, the large majority thus could either not afford and operating AC device. An exception were families who cared for children under 5 years of age, who adjusted other expenditures in order to provide cooling for their infants. Alternative cooling with ingestion of cold fluid or ice slurry has been shown to substantially reduce body core temperature (Yeo et al., 2012; Siegel et al., 2010, 2012) which can potentially confer protective effects against heat injuries (Costa et al., 2020; Snipe et al., 2017), and as such could be a more practical approach to be adopted during extreme heat events.

Water ingestion is a known heat mitigation strategy with the majority of respondents reportedly increasing their water intake to combat the heat. However, the self-reported drinking amounts were likely an underestimate of actual drinking volumes, as field studies conducted by Delgado Cortez (2009) and Brake and Bates (2003) measured that workers under heat stress ingest about 6.61 L and 6.48 L of water per shift, respectively, considerably more than the drinking amounts reported here. Surprisingly, increased water intake was a positive predictor for the number of heat symptoms experienced. This finding was consistent across several metrics to address drinking response to heat. This could be due to factors such as the number of outdoor working hours, and occupational heat exposure could have exacerbated the heat symptoms experienced. Contrary to popular belief, water ingestion is the least effective among the other physiological heat mitigation strategies as presented in a meta-analysis by Alhadad et al. (2019). Apart from behavioral adaptations, other physiological heat mitigation strategies presented includes improving aerobic fitness, heat acclimatization and pre-cooling (Alhadad et al., 2019). However, for tropical natives, such as those surveyed in Vietnam, the benefits of heat acclimatization are minimal due to having achieved partial acclimatization from living in a tropical country (Lee et al., 2012). It may be preferable to couple increasing water intake with other heat mitigation strategies such as improving aerobic fitness, cooling with ice slurry before work and taking regular breaks during extreme heat exposure.

The respondents were able to access and understand weather forecasts from radio, television, and social media. This is relevant because weather forecasts have been shown to be useful for humanitarian action if early warnings, opportunity for action and an organizational mandate for action are available (Coughlan de Perez et al., 2015, 2016), and they have been proven useful in occupational settings (Varghese, 2019; McInnes et al., 2017). Our analyses revealed that receiving weather forecasts also increased the likelihood for reporting heat-related symptoms, or in other words, those who were less aware about forecasts recalled fewer heat symptoms. Focus groups gave the additional insight that elderly tended to lean towards television and radio as information sources, whereas younger people were more reliant on social media and phone applications. As such, it is important to address the specific audiences via their channels and tailor the information to reach the target populations more effectively. While a majority of the respondents received weather forecasts, such measures could improve the preparedness of those 22% who did not receive them.

The average daily maximum temperatures in Hanoi summers around 35 °C are already higher than what is allowed by health rules in Vietnam: The Vietnamese Ministry of Health has issued a regulation to protect workers from extreme heat, describing maximum ambient temperatures for light, medium and heavy work at 34 °C, 32 °C and 30 °C, respectively and RH below 80% with a maximum permitted temperature difference between outdoor and area of work of 5 K (MOH, 2002). However, these regulations are rarely enforced in the informal economy, where the majority of outdoor workers operate. Climate change means that outdoor workers need to adapt to even higher temperatures in future summer months. Our data also did not include occupation-specific heat load, but field insights indicated that construction workers were more likely to work in the sun, while vendors would seek shaded places where possible and motorbike riders would also take pauses in the shade. Beyond the actions already reported in the survey, focus group discussions revealed that workers would go asleep in wet sheets to cool down in hot nights, and where possible, some residents watered their roofs in the evening.

In our analysis, knowing about heat-health effects, weather forecasts and taking actions all correlated with a higher likelihood to report detrimental impacts from heat. It is a possibility that those respondents who suffered more from heat also had a higher awareness of heat-related symptoms, appropriate remedial actions and weather forecasts, and thus reported more. This highlights the importance of increasing heat-health knowledge and awareness about heat-related symptoms, illnesses and weather forecasts.

4.1. Limitations and future direction

Our study has several limitations that may inhibit correct interpretation of the results. First, our study suffered from a relatively long delay of four months between survey and heatwave. It is thus expected that answers were influenced by recall bias. Future surveys should be carried out during or immediately after a heatwave. Similarly, the heat related symptoms have been subjective and self-reported, we have no account of objective symptom measurement. Reported doctor visits, which could be used as a proxy for this, have shown no significant explanatory power. Third, the temperatures that workers were exposed to were not measured, also not including possible exposure to additional heat from machinery or direct sunshine. As the participant's individual heat load remained unknown, we could only generalize assumptions about the severity of heat exposure. Heat exposure – either from industrial applications or direct sunlight – has shown to strongly increased heat symptoms (Venugopal et al., 2021, 2020). Further, study participants were not provided with any direct support as a consequence of taking part in the survey, but we cannot rule out that some of them were under the opposite expectation and thus exaggerated their conditions.

5. Conclusion

Adapting to extreme heat is a major challenge for vulnerable population groups. Those who work in the outdoors are particularly affected, and effective adaptation efforts are necessary. This study helps to better understand heat-health impacts and the effectiveness of mitigation efforts of such populations.

Older people and females reported more heat-related symptoms. In contrast, the group of young construction workers claimed to be largely unaffected by extreme heat. Even though occupation group itself was not a strong predictor of the degree of heat-health impacts, the age structure of the various occupation groups was an indicator of their heat vulnerability.

The study participants were largely unable to afford air-conditioning, and existence of an air-conditioning device in the bedroom did not reduce heat symptoms. This is the small-scale manifestation of the global cooling gap, a discussion which points at an inability of large population numbers worldwide to access cooling (Mastrucci et al., 2019). Implementing AC for all households is unattainable, and would also increase energy consumption. Some participants also reported to take individual actions against nighttime heat such as sleeping in damp sheets.

Drinking more liquids did not help our study participants deal with the heat. Instead, reporting to increase water intake increased the statistical likelihood to report more heat-health symptoms, so that other strategies on top of drinking need to be found. Indeed, some insights from the focus group discussion revealed that female workers often refrained from drinking much liquids due to a lack of safe bathroom facilities, a circumstance which points at one possible assistance strategy.

Knowledge of heat mitigation strategies, mitigation actions taken during heatwaves, as well as being informed through weather forecasts and early warnings all had a reinforcing effect on heat-health symptoms. This seems counterintuitive and we believe that this lies in the nature of self-reported symptoms. A KAP-survey by definition captures opinions and subjective experiences, leading to differences between "what is said and what is done" (Gumucio, 2011). Therefore, respondents who were more attuned to heat mitigation strategies may also have been more sensitive to remembering symptoms.

The survey data investigated here was collected as part of a much larger Forecast-based Financing project by the Vietnam Red Cross Society and the German Red Cross. As part of this project, several early actions were selected. These included the opening of community cooling centres to outdoor workers during their working day, providing water, cold tea and fresh towels, alongside information on heat-health measures. The community cooling centres allowed outdoor workers and other vulnerable populations to recover from long exposure to high ambient temperatures and they were supposed to be complemented by cooling buses which traveled the main streets and directed the vulnerable population to the centres. These actions aimed at encouraging the adoption of appropriate behavior to mitigate heat-health impacts.

Our findings can be extended to places of similar context and we encourage more of such profiling to be done in other cities. In cities, the urban heat island effect increases temperatures well beyond rural background temperatures, making cities hot spots of heatwaves (Oleson et al., 2015), and poverty is a heat risk factor (Tran et al., 2013). Thus, climate adaptation for heatwaves in cities needs to be addressed on several scales. Our study is concerned with the local and immediate scale, investigating how the most vulnerable can be helped most effectively. In the bigger picture, a reduction of carbon emissions is urgently needed, and in cities architectural strategies could reduce the urban heat island effect. Examples are urban greening and an optimized street morphology for convective cooling.

Credit authorship contribution statement

JF designed the initial survey and the sampling strategy. SL, JF and JL designed this article and analysis. CG, SL and MC performed the statistical analyses described in the paper. SL and MC wrote the first draft and designed the figures. The final version was reviewed and discussed with all authors.

Data availability

The codes used to produce the statistical outcomes can be shared upon request in a GitHub repository. The survey data is available from the authors and can be shared in anonymized form upon reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2021.148260.

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