



Carers' perceptions of harm and the protective measures taken to safeguard children's health against inhalation of volcanic ash: A comparative study across Indonesia, Japan and Mexico

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ABSTRACT

Volcanic ash contains potentially toxic elements which could affect human health. There is a paucity of research focusing on the impact of airborne volcanic emissions on the health of children, and on their exposure reduction. Children's carers (parents/guardians) are critical to their protection, so documenting their perceptions of the health risk and their knowledge of how to reduce their children's exposure is an important first step to increase our understanding of how risks are acted upon. This article reports the findings of a survey of 411 residents with caring responsibilities for children aged 12 and under in communities near the active volcanoes of Sakurajima in Japan, Merapi in Indonesia, and Popocatepetl in Mexico. Informed by the Protective Action Decision Model (PADM) and Protection Motivation Theory (PMT), we investigated their perceptions of the health effects and harmful consequences of the ash on their children, how important they thought it was to protect them, and the protective actions taken. The Indonesian carers were the most concerned and motivated to protect their children, although, in all three countries, the large majority of carers had adopted protective measures that they perceived to be most effective, such as keeping windows and doors closed. Path analysis illustrated how the connection between perceptions of harm/worry and importance of protection could partially account for higher motivation levels to protect children, in the Indonesian carers. We discuss the key messages conveyed through the findings that are of relevance for policy, practice and training in all three countries.

1. Introduction

In 2015 it was estimated that around 1 billion people (14% of the world's population) lived within 100 km of a potentially active volcano [1]. Volcanoes emit a mixture of gases, aerosols, and particulate matter including ash, which contains a variety of potentially toxic elements [2–4]. The potential health impacts of inhaling volcanic ash relate to particle size, mineralogy, and the physicochemical properties of its surface [3,5]. Although volcanic ash is known to exacerbate acute

respiratory conditions such as asthma and bronchitis [6], little is known about the chronic impact of such airborne emissions on human health [5] and very few studies have been conducted on the impacts of ash on children's health [7–10].

The health effects identified, to date, as well as general evidence that particulate matter can cause ill health in children, indicate that it may be important to reduce children's exposure to ash [11]. This may, depending on the age of the child, require parents and carers to take protective actions on their behalf. International advice (e.g., from the

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World Health Organization: www.paho.org/disasters/index.php?Itemid=1171&lang=en) is primarily that adults and children should seek shelter from ashfall by going indoors and closing/sealing openings to the outdoor environment. However, as eruptions may be prolonged, people need to venture outdoors for work, school and other activities. For this, many agencies recommend the use of facemasks (see <http://www.ivhhn.org/information/global-ash-advice> for a database of advice offered globally), although it is rarely specified if this advice applies to children.

The actions that need to be encouraged or promoted rest not only on identifying the most appropriate and effective measures but also on understanding what carers have done or are currently motivated to do to protect their children from inhaling ash. The Health Interventions in Volcanic Eruptions Project (HIVE) has contributed to filling this gap in the literature through research documenting the protective measures undertaken by communities to reduce exposure to volcanic ash near the active volcanoes of Sakurajima in Japan, Merapi in Indonesia, and Popocatepetl in Mexico (<http://community.dur.ac.uk/hive.consortium/>). One of these studies was a questionnaire survey in which 2003 residents aged 13 and over were asked about how concerned and worried they were about the harmful effects of the ash on their health and the actions they had taken (including using a facemask) to protect themselves from inhaling volcanic ash [12]. In this paper, we report further findings from this survey, on questions that were only asked to the 411 respondents who had caring responsibilities for children aged 12 or under.

The carers were asked how they thought the ash was affecting their children's health and the measures they had taken to protect them and thought would be effective at mitigating the risk of their children inhaling ash. To our knowledge, the HIVE study is the first to investigate the risk perceptions and protective actions of carers of children in response to volcanic ash and the work highlights the importance of considering those who care for children as partners in protecting children. There is, however, a small but growing body of research that has explored carers' roles in protecting their children from other types of health risks and we position this paper within this wider literature, before outlining our methodology, and presenting our findings, discussion and conclusions.

Previous research in this area includes exploration of the commonly held beliefs which guide parents' decisions to adopt sun-protective measures for their children [13] or take actions to reduce their exposure to environmental hazards [14,15]. For example, Crighton et al. (2013) [14] conducted a qualitative study in Ontario, Canada to investigate new mothers' perceptions of how environmental health risks were affecting their children. Risks that originate outside the home, such as outdoor air pollution and heat, were viewed as less controllable and more threatening by some mothers. The level of concern varied from mother to mother, however, and some mothers like Brenda were "resigned to the risk, acknowledging that the outdoors was out of her control and something to which her kids would have to adjust" (see p305 in [14]). Building on these findings, a telephone survey of new mothers in Ontario conducted by Laferriere et al. (2016) [15] found raised levels of concern about the effects of environmental hazards on their baby's health in nearly half of the sample (49%). Concerns were more likely to be raised in mothers who perceived environmental hazards as less controllable. However, risk awareness did not always convert into protective actions. Mothers rarely mentioned doing anything to protect their babies from outdoor risks like air pollution.

These studies highlight how concerns about hazards may not necessarily translate into protective actions. As proposed by theoretical models such as the Protective Action Decision Model (PADM) [16] and Protection Motivation Theory (PMT) [17,18], protective action or inaction depends not only upon a threat appraisal (i.e., consideration of vulnerability to the hazard and its severity) but also upon the perceived efficacy of protective measures (i.e., consideration of one's ability to take effective action and whether taking action will reduce the risk). People, therefore, need to believe that the actions they take will be

effective and studies by Beirens et al. (2008), Norman et al. (2003) and Wortel et al. (1995) have confirmed the importance of response efficacy in the prediction of parental safety behavior [19–21].

Our survey design was also informed by these theoretical constructs. In terms of threat appraisal, we asked carers (usually parents and guardians) how they thought the volcanic ash was affecting their children's health and the symptoms they thought had been brought on or made worse by their children's exposure to volcanic ash. We also examined how concerned carers were about their children being exposed to the ash – both in terms of how much harm they perceived the ash might be doing to their children's health and how worried they were about the effects of the ash. We were particularly interested here in whether carers were more concerned about their children's exposure to the ash than they were about their own exposure and whether, as predicted by PMT, carers' levels of concern about the effects of the ash on their children's health could predict their motivation to protect their children. In terms of perceived efficacy, we examined carers' beliefs about whether the specific actions that they might have taken in the past to protect their children from ash inhalation are actually effective at avoiding the threat.

Across these issues, we explored how the patterns of results and effect sizes varied across the geographic regions and socio-demographic characteristics of the residents including their age and education level. This enabled us to ask questions about, for example, which types of symptoms were most commonly reported in each country and whether carers were equally concerned about and motivated to protect their children in different volcanic and cultural locations. This type of comparative analysis aligns with the approach adopted in Covey et al. (2019) [12] which demonstrated important between-country differences in the predictive ability of the threat and coping appraisal factors in motivating people to use respiratory protection for *themselves* against volcanic ashfall. For example, in the Japanese sample perceptions of harm or worry about ash inhalation was a stronger predictor of facemask use than it was in either the Indonesian and Mexican samples. This paper therefore extends this comparative analysis by examining carers' motivations to protect *their children*. Knowledge such as this will increase our understanding of how risks are perceived and acted upon, which is important for the development of effective risk reduction and communication strategies.

2. Materials and methods

2.1. Sampling and sampling procedure

Conducted as part of the HIVE project, a key objective of this survey, was to understand the actions that adults would take to protect their children when volcanic ash is in the air. The survey was conducted between May and September 2016 on 411 residents from three communities near the active volcanoes of Sakurajima in Japan, Merapi in Indonesia and Popocatepetl in Mexico who had caring responsibilities for children aged 12 or under. The respondents living near Merapi volcano, Central Java, had also recently (February 2014) experienced a major ashfall from another volcano, Kelud, in East Java. In Mexico, although ashfall was frequent, they also experienced heavier ashfall than usual in April 2016.

For detailed explanations of these three survey locations, how the survey was designed, piloted and administered, and how the participants were recruited using a non-probability quota sampling method, please refer to Covey et al. (2019) [12]. In that paper we outline the practical considerations that underpinned our decision to use a non-probability quota sampling method over a probability random sampling method and the approaches we used at both the sampling and estimation stages to deal with the challenge of making inferences to the population. These approaches included designing a quota sample that aimed to produce a sample with a mix of residents that was comparable to the population of each country and region with respect to three

covariates for which census data were available - age, gender and educational level. And at the estimation stage we demonstrated that the application of weighting adjustments based on those covariates did not affect any conclusions based on the unweighted data that is reported in this paper.

Demographic information about the carers and their children is shown in Table 1. Two thirds (66.7%) of the 411 carers who completed the survey were women. Japan had the highest percentage of female carers in the cohort (76.3%), and Mexico the lowest (61.5%). The large majority of the carers were aged 59 and under (Indonesia, 98.4%; Mexico 98.2%, Japan, 97.3%). Most were aged 13–39 years (overall 60.3%). Mexico had slightly more carers in this 13–39 year age-range (69.5%) than Indonesia (54.5%) and Japan (52.6%). Just over 60% of the carers were educated to at least high school level (29.7% high school, 32.1% college/graduate). However, there are large differences among the countries, with 96.5% of carers from Japan educated to high school level compared to 69.9% in Indonesia and 33.3% in Mexico. As noted in Covey et al. (2019) [12] these differences in our respondents broadly reflect the demographics of the local populations.

The 411 carers had 657 children among them (average 1.6 children under 12 years old per carer) of which 346 were female (52.7%). Across all three countries, just over half of the carers had one child aged 12 years or less (54.5%) with only a minority having 3 or more (11.5%). The carers in Indonesia were more likely to have only one child aged 12 years or less (64.3%). Carers in Mexico were more likely to have three or more children aged 12 years or less (17.2%). The mean age of all children was 6 years, 11 months; 21.7% of all carers had an infant/toddler (child aged 3 or less). Mexican carers were more likely to have infants/toddlers (29.9% compared to 18.4% in Japan and 13.0% in Indonesia), and their children were slightly younger on average (6 years, 6 months).

The health status of carers and children is also covered in Table 1. Respiratory health problems (especially allergic rhinitis and asthma) were reported by 17.5% of the carers. The incidence was higher in Japan (35.1%) compared to Indonesia (13.0%) and Mexico (9.2%). 19.7% of the carers reported that one or more of their children had a respiratory

health problem. Like the data for the carers, allergic rhinitis and asthma were again the most common respiratory health problems and the incidence of respiratory health problems in the children was higher in Japan (40.4%) compared to Indonesia (11.4%) and Mexico (12.1%). The raised reporting in Japan may be due to the common allergy to cedar pollen discussed in Covey et al. (2020) [22].

2.2. Survey design

The survey questions relevant to the analyses reported in this paper are outlined below. As noted previously, the full survey also included questions only about adults which are reported in Covey et al. (2019) [12] and are referred to in this paper where relevant. In this carers' survey, parents were first asked to give details of their children's age and gender and when each child was last exposed to volcanic ash. Carers then listed health issues that their children may have, taken from a list of 12 respiratory and cardiovascular diseases (plus an open 'other' option). Carers were then asked what health symptoms their children had experienced which the carers perceived were caused or made worse by ash exposures. Carers selected from a list of 19 symptoms (see Table 2) and were also provided with the opportunity to select 'other' and provide details of any symptoms not provided on the list. Related to threat appraisal, carers were then asked to rate (using a 4-point Likert scale with a 'can't say' additional option) if they thought inhaling ash might harm their own and their children's health (0 = not at all harmful, 3 = very harmful) and whether they were worried about themselves and their children inhaling ash (0 = not at all worried, 3 = very worried). Carers then rated how important it was to them to protect themselves and their children from inhaling ash (0 = not at all important, 3 = very important). In the next part of the survey, carers were provided with a list of 13 actions (plus an 'other' option) and asked if they had ever taken any of the actions to protect their children from inhaling ash. The list provided is shown in Table 4 and included actions such as limiting outdoor time, closing windows/doors, and encouraging their children to use a facemask. In the final question, related to coping appraisal

Table 1
Demographic characteristics of the carers and their children.

	All	Japan	Mexico	Indonesia
Total number of carers	411	114	174	123
Age-group of carers				
13–39 years	248 (60.3%)	60 (52.6%)	121 (69.5%)	67 (54.5%)
40–59 years	155 (37.7%)	51 (44.7%)	50 (28.7%)	54 (43.9%)
60+ years	8 (1.9%)	3 (2.6%)	3 (1.7%)	2 (1.6%)
Gender of carers				
Male	137 (33.3%)	27 (23.7%)	67 (38.5%)	43 (35.0%)
Female	274 (66.7%)	87 (76.3%)	107 (61.5%)	80 (65.0%)
Education level of carers				
No formal education	31 (7.5%)	1 (0.9%)	29 (16.7%)	1 (0.8%)
Primary/Junior high	124 (30.3%)	1 (0.9%)	87 (50.0%)	36 (29.3%)
High school	122 (29.7%)	36 (31.6%)	24 (13.8%)	62 (50.4%)
College/graduate	132 (32.1%)	74 (64.9%)	34 (19.5%)	24 (19.5%)
Missing	2 (0.5%)	2 (1.8%)	0	0
Carers with a respiratory problem ^a	72 (17.5%)	40 (35.1%)	16 (9.2%)	16 (13.0%)
Total number of children ^b	657	185	301	171
Male children	311 (47.3%)	89 (48.1%)	150 (49.8%)	72 (42.2%)
Female children	346 (52.7%)	96 (51.9%)	151 (50.2%)	99 (57.9%)
Carers with 1 child	225 (54.5%)	56 (49.1%)	90 (51.7%)	79 (64.3%)
Carers with 2 children	138 (33.6%)	44 (38.6%)	54 (31.0%)	40 (32.5%)
Carers with 3 children	36 (8.8%)	11 (9.6%)	21 (12.1%)	4 (3.3%)
Carers with 4 or more children	11 (2.7%)	2 (1.8%)	9 (5.2%)	0
Age of children				
Mean age (all children)	6y11 m	7y1m	6y6m	7y7m
Mean age (youngest child)	5y11 m	6y2m	5y3m	6y9m
Mean age (oldest child)	8y0m	8y1m	7y8m	8y4m
Carers with one or more children aged 0–3 years (infant/toddler)	89 (21.7%)	21 (18.4%)	52 (29.9%)	16 (13.0%)
Carers with one or more children who has a respiratory problem ^a	81 (19.7%)	46 (40.4%)	21 (12.1%)	14 (11.4%)

Notes.

^a The most commonly reported respiratory problems in both carers and children were allergic rhinitis and asthma.

^b One carer in Japan did not provide any information about how many children they had.

Table 2
Carers' reporting of symptoms caused or made worse by their children's exposure to volcanic ash.

	Country contrasts ^a				Significant predictors ^b (OR)
	All	Japan	Mexico	Indonesia	
One of more symptoms	68.4%	39.5% ¹	68.4% ²	95.1% ³	Respiratory child (10.6)
Eye irritation	47.9%	25.4% ¹	45.4% ²	72.4% ³	Respiratory child (3.34)
Cough	46.5%	14.0% ¹	44.3% ²	79.7% ³	Respiratory child (3.74)
Sore throat	24.3%	8.8% ¹	27.0% ²	35.0% ²	Respiratory child (3.55)
Shortness of breath	22.9%	1.8% ¹	6.3% ¹	65.9% ²	Respiratory child (6.81)
Low mood	18.7%	0.9% ¹	5.7% ¹	53.7% ²	None
Flu-like symptoms	18.0%	1.8% ¹	21.8% ²	27.6% ²	Respiratory child (2.87)
Skin irritation	16.8%	2.6% ¹	16.7% ²	30.1% ³	Respiratory child (3.68)
Runny nose	15.8%	14.0% ¹	23.6% ²	6.5% ¹	Respiratory child (6.94)
Phlegm	13.4%	6.1% ¹	13.8% ²	19.5% ²	Age-group carer (0.33)
Stuffy nose	12.9%	11.4% ¹	16.1% ²	9.8%	Respiratory child (4.23)
Trouble sleeping ^c	11.7%	0	5.7%	30.9%	Respiratory child (4.25)
Loss of appetite ^c	10.9%	0	4.6%	30.1%	–
Headache ^c	9.5%	0	15.5%	9.8%	–
Chest pain ^c	9.0%	0	5.7%	22.0%	–
Wheeziness ^c	7.8%	5.3%	2.9%	17.1%	–
Stress ^c	6.1%	2.6%	2.3%	14.6%	–
Fatigue ^c	4.9%	0	8.0%	4.9%	–
Muscle pain ^c	1.9%	0	4.0%	0.8%	–
Other ^c (e.g., stomach pain/constipation)	0.7%	0	1.1%	0.8%	–

Notes.

^a For countries with a different superscript number, the odds of reporting the symptoms are significantly different ($p < .05$).

^b Socio-demographic predictors tested alongside country dummies: age-group of carer (1 = 13–39 years, 2 = 40–59 years, 3 = 60+ years), gender of carer (0 = female, 1 = male), education level of carer (0 = no formal education, 1 = elementary/junior high, 2 = high school, 3 = college/graduate), infant (0 = carer does not have an infant/toddler aged 0–3 years, 1 = carer has one or more infant/toddler aged 0–3 years), respiratory-child (0 = none of the carer's children have a respiratory problem, 1 = one or more of the carer's children have a respiratory problem).

^c Logistic regression not appropriate due to small number of carers (less than 50) who did not report this symptom.

(response efficacy), carers were asked to rate how effective they thought each of the 13 actions was at reducing ash exposure regardless of whether they took those actions or not (0 = not at all effective, 3 = very effective).

2.3. Data analysis

The statistical software IBM SPSS Statistics 24 with AMOS Graphics was used to analyse the data.

For each of the symptoms we computed the percentage of respondents who reported the symptom was brought on or made worse by the ash. To explore whether carers from some countries were more likely to report symptoms affecting their children than others, logistic regressions were conducted with country dummies and socio-demographic variables entered as predictors.

Mean ratings of harm, worry and importance of protection that carers gave for their children were computed. We explored how these ratings varied across the countries using ordinal regressions with

country dummies and socio-demographic variables entered as predictors. The ratings they gave for themselves were also subtracted from the ratings they gave for their children. If carers are on average more concerned about their children than they are about themselves then we would expect the mean of these differences to be positive and one-sample Kolmogorov-Smirnov tests were conducted to test whether the differences in each country were greater than zero.

Path analysis was used to test whether geographic or socio-demographic variants in people's ratings of the importance of protecting their children were mediated by perceptions of harm and worry. Path coefficients were estimated in AMOS Graphics using Markov chain Monte Carlo (MCMC) maximum likelihood estimation. This Bayesian approach provides a solution when the dependent (endogenous) variable like ours is not continuous or normally distributed [23].

For each of the 13 protective actions we computed the percentage of respondents from each country who reported taking each action. We also explored how uptake of each action varied across the countries using logistic regressions with country dummies and socio-demographic variables entered as predictors.

Spearman's rank-order correlations (r_s) were used to test whether mean ratings of effectiveness across the 13 actions correlated with the percentage of respondents reporting that they had undertaken each action.

The assumptions for conducting binary or logistic regressions were checked and in the reporting of our results we highlight cases where any assumptions did not hold (see <https://statistics.laerd.com/spss-tutorials/binomial-logistic-regression-using-spss-statistics.php>; <https://statistics.laerd.com/spss-tutorials/ordinal-regression-using-spss-statistics.php>). Variance inflation factors (VIFs) were computed to check for multicollinearity between predictor variables (none of the VIFs were greater than 2); the Box-Tidwell procedure was used to check that the relationship between ordinal independent variables treated as continuous (i.e., age-group and education level) and the dependent variables were linear; tests of parallel lines were conducted on the ordinal regressions to check that the assumption of proportional odds were met and when the tests were significant, we checked whether the coefficients were significant at each cumulative split.

3. Results

3.1. Symptoms perceived to be made worse by ash exposures

Table 2 shows the symptoms in their children which carers perceived were triggered or made worse by exposure to ash. Overall, 68.4% of carers thought that their children had experienced one or more of the symptoms. Symptom reporting was, however, much more likely in the Indonesian carers with 95.1% reporting at least one symptom brought on or made worse by the ash, which the logistic regression confirmed was significantly higher than the reporting rates of 68.4% in the Mexican carers and 39.5% in the Japanese carers.

The most frequently reported symptoms were eye irritation (47.9%) and cough (46.5%). Sore throat was the next most frequently reported at 24.3% and all other symptoms were reported by less than 20% of carers. The logistic regressions did, however, identify that carers who had one or more children with a respiratory problem were more likely to report all but one of the symptoms in their children, where differences were tested ($ORs \geq 2.87$).

The only symptom where respiratory problems in the child were not significant was low mood. Carers who had a child with a respiratory problem were no more likely to report that the ash brought about a low mood in their child. Socio-demographic variables, such as level of education of the carer, did not influence the reporting of symptoms. The logistic regressions also identified that the frequency of symptom reporting varied among the three countries. For example, the Indonesian carers tended to have the highest number of people reporting most of the respiratory symptoms apart from runny nose and stuffy nose, which

were more likely to be reported by the Mexican carers. The Japanese carers, on the other hand, tended to have the lowest numbers reporting most of the symptoms covered. As carers in Japan reported a higher incidence of respiratory problems in their children, we would have anticipated these carers - and not those in Indonesia - would choose a higher number of respiratory symptoms as applying to the children, but they did not. The reasons for this finding are unclear and merit further research.

Table 3
Carer's concerns about the effects of the ash on themselves and their children.

	Country contrasts ^a				Significant predictors ^b (OR)
	All	Japan	Mexico	Indonesia	
Harm to children					
No harm (0)	1.8%	3.8%	1.8%	0%	
A little harmful (1)	15.0%	42.3%	8.4%	0.8%	
Quite harmful (2)	17.8%	28.8%	16.3%	10.6%	
Very harmful (3)	65.4%	25.0%	73.5%	88.6%	
Mean	2.47	1.75 ¹	2.61 ²	2.88 ³	Respiratory child (2.18)
Harm difference (children-themselves) ^c	0.25***	0.23***	0.32***	0.19***	None
Worry about children					
Not at all worried (0)	2.7%	6.6%	2.3%	0%	
A little worried (1)	17.5%	44.3%	12.2%	1.6%	
Quite worried (2)	19.5%	22.6%	22.7%	12.2%	
Very worried (3)	60.3%	26.4%	62.8%	86.2%	
Mean	2.37	1.69 ¹	2.46 ²	2.85 ³	Respiratory child (1.62)
Worry difference (children-themselves) ^c	0.39***	0.32*** ¹	0.53*** ²	0.24*** ¹	Respiratory child (1.72)
Importance of protecting children					
Not at all (0)	1.3%	2.8%	1.2%	0%	
A little important (1)	11.8%	39.6%	2.3%	0.8%	
Quite important (2)	12.8%	30.2%	8.8%	3.3%	
Very important (3)	74.3%	27.4%	87.7%	95.9%	
Mean	2.60	1.82 ¹	2.83 ²	2.95 ³	None
Importance difference (children-themselves) ^c	0.22***	0.17***	0.31***	0.13***	None

Notes.

*p < .05, **p < .01, ***p < .001.

^a For countries with a different superscript number the odds of giving a one point higher rating on the scale is significantly different (p < .05).

^b Socio-demographic predictors tested alongside country dummies: age-group of carer (1 = 13–39 years, 2 = 40–59 years, 3 = 60+ years), gender of carer (0 = female, 1 = male), education level of carer (0 = no formal education, 1 = elementary/junior high, 2 = high school, 3 = college/graduate), respiratory carer (0 = carer does not have a respiratory illness, 1 = carer has a respiratory illness), infant (0 = carer does not have an infant/toddler aged 0–3 years, 1 = carer has one or more infant/toddler aged 0–3 years), respiratory child (0 = none of the carer's children have a respiratory problem, 1 = one or more of the carer's children have a respiratory problem).

^c A positive mean difference indicates that respondents were on average more concerned about the effects of the ash on their children than they were about themselves. Kolmogorov-Smirnov tests were conducted to test whether the differences for the sample as a whole, and in each country, were greater than zero.

Table 4
Actions carers take to protect their children from inhaling volcanic ash and mean ratings of effectiveness (in brackets).

	Country contrasts ^a				Significant predictors ^b (OR)
	All	Japan	Mexico	Indonesia	
One or more action	97.8%	93.0%	99.4%	100%	n/a
Keep windows and doors closed	95.9% (2.53)	90.4% (2.22)	96.6% (2.60)	100% (2.73)	None
Limit time outdoors	88.8% (2.51)	78.1% (2.06)	87.9% (2.62)	100% (2.76)	None
Encourage to wear a facemask	71.5% (2.29)	63.2% ¹ (1.89)	60.3% ¹ (2.24)	95.1% ² (2.72)	Infant (0.25)
Encourage to wear a hat	65.9% (1.55)	70.2% ¹ (1.37)	53.4% ² (1.60)	79.7% ¹ (1.63)	Respiratory child (2.34)
Hold handkerchief over mouth/nose	46.5% (1.76)	50.0% (1.64)	48.9% (1.95)	39.8% (1.60)	Education level (0.76)
Use an infant/baby mask	42.6% (2.02)	28.9% ¹ (1.69)	29.9% ¹ (2.08)	73.2% ² (2.24)	Respiratory child (2.15)
Encourage to use an umbrella/parasol	36.3% (1.30)	44.7% ¹ (1.24)	20.1% ² (1.12)	51.2% ¹ (1.58)	Gender (0.57)
Hold hand over mouth or nose	33.6% (1.13)	37.7% ² (1.35)	41.4% ² (1.27)	18.7% ¹ (0.74)	Education level (0.78)
Tie scarf or bandana over mouth/nose	33.6% (1.70)	12.3% ¹ (1.44)	42.0% ² (1.83)	41.5% ² (1.72)	Respiratory child (1.81)
Encourage to wear a shawl over their face	20.0% (1.49)	10.5% ¹ (1.30)	14.4% ¹ (1.32)	36.6% ² (1.83)	Age-group (0.57)
Drape cloth over cot/buggy	15.6% (1.39)	17.5% ¹ (1.04)	21.3% ¹ (1.76)	5.7% ² (1.41)	Respiratory child (2.44)
Use a fixed cot/buggy cover	14.6% (1.66)	13.2% ¹ (1.50)	21.8% ² (2.04)	5.7% ¹ (1.50)	None
Use umbrella/parasol over cot/buggy	13.9% (1.39)	13.2% (1.08)	19.5% ¹ (1.73)	6.5% ² (1.38)	Respiratory child (2.44)
Other action (e.g., wear goggles)	1.0%	0%	1.1%	1.6%	None
Correlation between % taking action and mean effectiveness rating	0.713**	0.605*	0.676**	0.848***	None

Notes.

^a For countries with a different superscript number the odds of taking the action is significantly different (p < .05).

^b Socio-demographic predictors tested alongside country dummies: age-group of carer (1 = 13–39 years, 2 = 40–59 years, 3 = 60+ years), gender of carer (0 = female, 1 = male), education level of carer (0 = no formal education, 1 = elementary/junior high, 2 = high school, 3 = college/graduate), respiratory carer (0 = carer does not have a respiratory illness, 1 = carer has a respiratory illness), infant (0 = carer does not have an infant/toddler aged 0–3 years, 1 = carer has one or more infant/toddler aged 0–3 years), respiratory child (0 = none of the carer's children have a respiratory problem, 1 = one or more of the carer's children have a respiratory problem).

3.2. Carers' concerns about the effects of the ash on their children

In relation to perceived harmfulness of ash to their children's health, the four-point Likert scale from 'no harm' to 'very harmful' was coded 0 to 3 and means calculated (see Table 3). Overall, the carers perceived

the ash to be quite harmful to their children’s health ($M = 2.47$) and the ordinal regression showed that ratings of harm were highest in the Indonesian sample ($M = 2.88$) compared to the Mexican ($M = 2.61$) and Japanese ($M = 1.75$). Across all three countries respondents who had a child with a respiratory illness perceived the ash to be more harmful to their child’s health ($OR = 2.18, p < .05$). In all three countries respondents rated the harm to their children as significantly higher than to themselves. The logistic regression showed that this raised concern about the harmful effects on their children, compared to themselves, was significantly greater in respondents across all three countries who had one or more child who was an infant (i.e., aged 0–3 years).

In terms of worry about inhaling ash, using the same conversion of the Likert scale to a numerical mean, again, the pooled cohort were quite worried about their children’s health ($M = 2.37$) and, as found for the harm ratings, ratings of worry were highest in the Indonesian sample ($M = 2.85$) compared to the Mexican ($M = 2.46$) and Japanese samples ($M = 1.69$). Across all three countries, respondents who had a child with a respiratory illness were more worried about the effects of the ash on their child’s health ($OR = 1.62, p < .05$). Respondents in all three countries were also significantly more worried about the effects of the ash on their children than they were about the effects on themselves ($Ms = 2.85, 2.46, 1.69$) and the logistic regression showed that this raised worry for their children, compared to themselves, was significantly higher not only in respondents from all three countries with infant-aged children ($OR = 1.72, p < .05$) but also especially in the Mexican sample where the mean difference was 0.58 compared to 0.32 in the Japanese sample and 0.24 in the Indonesian sample.

When asked about the importance of protecting their children from inhaling ash, the patterns of results are similar to the ratings of harm and worry in that the Indonesian carers gave the highest ratings of importance and the Japanese the lowest ratings, and, in all three countries, respondents thought it was more important to protect their children from the ash than to protect themselves. The logistic regressions confirmed that ratings of the importance of protecting their children were highest in the Indonesian sample, compared to the Mexican and Japanese samples, but no significant between-country differences or socio-demographic variants were identified in the degree to which children were given higher importance ratings.

Path analysis was used to test whether the geographic or socio-demographic variants in people’s ratings of the importance of protecting their children were mediated by perceptions of harm and worry. Path coefficients for the model were estimated in AMOS Graphics using Markov chain Monte Carlo (MCMC) estimation. In this analysis we adopt the same approach used to model the data in Covey et al. (2019) [12] in which the highly correlated harm and worry variables (i.e., $r_s = .762$) are represented by a latent variable (harm/worry). All the country dummies and socio-demographic predictors were included in the model whether they had been found to be significant or not in the ordinal regression shown in Table 3. This is because indirect effects can be significant even when a total effect is non significant [24,25].

Fig. 1 shows only the significant paths. All three country contrasts had significant indirect effects on ratings of importance via the harm/worry latent variable. This suggests that carers in Indonesia thought it was more important to protect their children than carers in either Mexico or Japan, and carers in Mexico thought it was more important to protect their children than carers in Japan, partly because they perceived the ash to be more harmful and were more worried about the effects of the ash on their children. The effects were, however, only partial mediation effects because the direct effects between the country contrasts and importance ratings are also significant. It is also worth noting that there was also a significant indirect effect of having a child with respiratory illness (‘respiratory child’) on importance ratings via harm/worry. This suggests that carers who had one or more children with a respiratory illness perceived the ash to be more harmful and were more worried about the ash which raised the importance they placed on protecting their children. However, the total effect of ‘respiratory child’ on ratings of importance was not significant (i.e., ‘respiratory child’ was not significant in the ordinal regression reported in Table 3), which could suggest other factors not included in our analysis were having a negative mediating effect. So, although increased perceptions of harm/worry are raising the importance that carers of children with a respiratory illness place on protecting them, another unmeasured mediator could be reducing the importance.

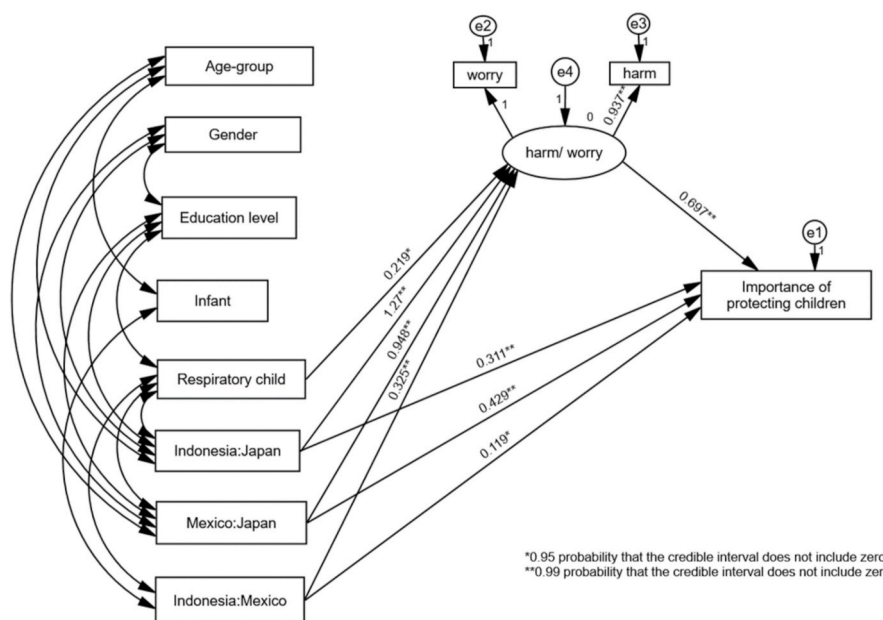


Fig. 1. Path analysis exploring the relationship between geographic and socio-demographic variables on perceptions of harm/worry and the importance of protecting children from ashfall. The effects of geographic variables are presented as pairwise country contrasts. Only significant paths and covariances are shown and the model had a very good fit (RMSEA = 0.024; CFI = 0.998; $X^2 = 34.3, p = .19$).

3.3. Actions carers take to protect their children from inhaling ash and their perceptions of effectiveness

Carers were asked to indicate which measures they have taken to protect their children from inhaling ash. Carers could choose more than one measure from a given list and the percentage of carers in each country who had adopted each action is shown in Table 4. The large majority (97.8%) reported adopting at least one of the actions on the list to protect their children from inhaling ash. Also it is notable that the very small number who provided 'other' responses (4 out of 411 in the overall sample) listed actions such as wearing goggles that would not protect their children from inhaling ash. The most frequently taken actions were keeping windows and doors closed ($\geq 90.4\%$) and limiting time outdoors ($\geq 78.1\%$). In Indonesia, 100% of respondents chose these options. Encouraging children to wear facemasks was also a popular action ($\geq 63.2\%$), particularly in Indonesia (95.1%). There were however some actions more specific to each country and the logistic regression confirmed that Indonesian carers were least likely to use a fixed cot/buggy cover or umbrella/parasol over the cot, Japanese carers were least likely to tie a scarf or bandana over their children's mouth/nose, and Mexican carers were least likely to encourage their children to wear a hat or use an umbrella/parasol. The logistic regression also showed that carers who had one or more children aged between 0 and 3 years (infant/toddler) were more likely to take actions such as using a fixed cot/buggy cover, or putting an umbrella/parasol or drape cloth over the cot or buggy. Carers who had one or more child with a respiratory illness were more likely to use an infant/baby mask or encourage their children to use a facemask. Carers with lower levels of education were more likely to encourage their children to wear a hat, or a shawl over the face, or to hold a handkerchief over the mouth/nose, all of which are actions which are likely to have a low efficacy in relation to preventing ash inhalation [26].

The mean ratings of the effectiveness across the 13 actions that carers could choose from were calculated from the 4-point Likert scale (0 = not at all effective, 1 = a little effective, 2 = quite effective, 3 = very effective) and are shown in brackets in Table 4 alongside the percentage of carers who had undertaken each action. In all three countries, the actions rated as most effective were limiting time outdoors ($M = 2.51$), keeping windows and doors closed ($M = 2.53$), encouraging their children to wear a facemask ($M = 2.29$), and using an infant/baby mask ($M = 2.02$). A rating of 2 equates to 'quite effective' and it is notable that all of the remaining actions were rated on average lower than this (i.e., not at all effective/a little effective). The least effective actions were perceived to be holding a hand over the children's nose/mouth ($M = 1.13$) and using an umbrella/parasol or draping a cloth over their cot/buggy ($M_s = 1.39$).

Spearman's correlations with the percentage of those reporting to have undertaken each action are also shown to allow examination of whether effectiveness ratings are predictive of whether or not someone actually takes that action. The correlations shown in Table 4 are moderate to strong ($r_s = .713$ in the full sample) in each country which suggests that the carers were significantly more likely to have undertaken the actions they perceived to be the most effective. The correlation was slightly stronger in the Indonesian sample ($r_s = .848$), although Fisher's Z tests confirmed that it was not significantly different from the correlations in Japan ($r_s = .605$) or Mexico ($r_s = .676$).

4. Discussion

The findings of this survey give specific insights into how carers from communities living near active volcanoes in Japan, Indonesia and Mexico, perceive the risks that their children face by being exposed to volcanic ash and the protective actions taken to mitigate those risks. By studying three countries with very different socio-demographic and geographic contexts, our findings are not bound to a single culture and, where similarities are found in our results, a more universal perspective

in understanding human behavior is provided.

We investigated how carers from the different communities thought the ash was affecting their children's health. They reported symptoms they thought were brought on or made worse by their children's exposure to ashfall. Across all three countries eye irritation and cough were the most frequently reported symptoms, although the reporting of both was particularly high in the Indonesian sample compared to the Mexican and Japanese samples. The Indonesian sample was also much more likely to report low mood in their children as a consequence of the ashfall – although they were less likely to report them having a runny nose. Although there are some commonalities in the perceived experiences of ashfall on children's health, there are also notable discrepancies that deserve explanation. Possible explanations, especially for the high number of perceived health impacts in the Indonesian sample, include differences in the frequency and quantity of ash deposited, differences in the physicochemical composition or particle size of the ash, and socio-demographic differences among the affected populations.

It is notable, for example, that both the volcanoes affecting the Mexican and Japanese communities had a history of repeated eruptions with small to medium quantities of ashfall being deposited on a daily or weekly basis. In contrast, although the Indonesian community had not experienced ashfall on such a regular basis, the eruption of Kelud, in 2014, had deposited a very large quantity of ash, up to 5 cm depth, in Yogyakarta city in a matter of hours [27]. The quantity of the ashfall experienced might, therefore, go some way to explaining why symptom reporting was more common in the Indonesian carers, compared to Japan and Mexico where light ashfall was sometimes part of everyday life. The Kelud ashfall was also an unexpected event in the Indonesian community (the volcano was 260 km away) so the carers may have been more likely to notice the effects it was having on their children's health. In contrast, regular ashfall and the symptoms that may go with that, were part of everyday life in the communities in Japan and Mexico. However, this cannot be the whole story because it does not explain why certain symptoms such as runny noses and stuffy noses were less prevalent in the Indonesian sample. This might relate to the physicochemical composition and particle size of the ash, but there is insufficient knowledge of which ash characteristics might trigger these respiratory symptoms [5,28].

Socio-demographic differences in the affected populations could also have influenced their children's sensitivity to certain symptoms. There were notable differences among the countries in relation to some of the measured socio-demographic factors such as the age of the carers (slightly younger in Mexico), education levels (more highly educated in Japan), and the incidences of respiratory health problems in the children (higher in Japan). However, despite finding these differences, all symptoms (apart from low mood) were more frequently reported in carers whose children had a respiratory health problem. Our analysis controlled for this and the differences found among the countries could not be fully accounted for by this effect. Of course, our analysis only controlled for a limited number of socio-demographic factors that might differentiate the populations, and we did not take into account factors known to be associated with health inequalities such as income, ethnicity and religion [29,30]. Although our findings are limited by not collecting this type of data from our survey respondents, we chose not to include intrusive questions such as this in our survey. We wanted to avoid respondents believing they were being judged about their financial status or being identified as a member of a minority ethnic or religious group. Ethnicity is a particularly sensitive issue in Japan, for example, where people not of Japanese ancestry may be considered 'foreigners' and minority groups may feel marginalised [31].

Additionally, the amount of information that local communities have received (which may or may not be accurate [32]) about the health effects of ash may have had some impact on their responses, especially if they had been previously informed that the ash can cause harm. This could also lead to demand effects where respondents give answers which they think are the 'correct' answers, rather than those that accurately

reflect their experience [33].

As well as asking carers to report symptoms that were being exacerbated by the ashfall, we investigated their worries about the harmful effects of the ash and their motivation to protect themselves and their children. On average, carers across all three countries thought the ash was more harmful to children than themselves, and worried more about the effects of the ash on their children's health than their own. This raised concern for their children over themselves was particularly prominent in carers who had one or more child who was an infant or toddler (i.e., aged 0–3 years); a finding which is consistent with the idea that younger children are likely to be considered more vulnerable and reliant on their carers than older children [34]. The Mexican carers were also particularly worried about their children, irrespective of how old their children were. This could be associated with cultural patterns since maternal care and protection are highly valued socially in the country [35].

In line with predictions derived from Protection Motivation Theory (PMT) [17,18], carers in all three communities thought it was more important to protect their children from inhaling ash if they were concerned and worried about the harmful effects of the ash on their children's health. Moreover, path analysis illustrated how this connection between perceptions of harm/worry and importance of protection could partially account for higher motivation levels in Indonesia compared to Mexico and Japan, as well as well as differences in the motivation levels of carers who had children with existing respiratory problems.

Although, on the face of it, the Indonesian carers were the most highly motivated to protect their children from the ash, the large majority of carers in all three communities did something to try to mitigate the risk to their children. Over 90% said that they kept their windows and doors closed when there was ashfall. Other frequently adopted actions included limiting their children's time outdoors ($\geq 78.1\%$) and encouraging them to wear a facemask ($\geq 63.2\%$). Although few studies have been conducted to prove the ability of these actions to reduce respiratory exposure to volcanic ash in different cultures [26,36], they are recommended by major humanitarian and government agencies (<http://www.ivhnh.org/information/global-ash-advice>). They were also rated as the most effective methods of protection by the carers, confirming the importance of response efficacy beliefs (an element of PMT's coping appraisal construct) in the prediction of protective behavior.

There were, however, some notable differences in the types of actions that were most commonly used for protection. For example, Japanese carers were more likely to encourage their children to use a parasol or umbrella, Mexican carers were more likely to use a cover on their children's cots or buggies, and Indonesian carers were more likely to use facemasks on their children including infant/baby masks. These preferences might partly reflect socio-demographic differences among the countries. In our sample, the Mexican carers were more likely to have children aged under three, where placing babies and toddlers in prams and cots might form part of their daily routine. There might also be cultural differences in the use of umbrellas which, in Japan, are part of everyday culture (https://japan-magazine.jnto.go.jp/en/1607_mask.html). And the high incidence of mask use in Indonesia was probably influenced by government advice and large scale mask distribution by agencies following the 2014 Kelud eruption and the 2010 Merapi eruption [27].

These findings reveal the importance of promoting nuanced responses regarding the use of protective measures. More specifically, the advice offered by humanitarian aid and disaster relief practitioners can accommodate what we now know about the mitigation measures carers in the different communities have and have not adopted in the past and perceive to be effective. Therefore, responses in each country can be tailored to be contextually-specific and culturally-relevant. Carers, government and practitioners should consider carefully the protective measures for children. Adults have an obligation to ensure that children have adequate and appropriate protection, especially in relation to the UN Convention on the Rights of the Child (CRC; <https://www.ohchr.org>

</en/professionalinterest/pages/crc.aspx>), which is ratified by the three countries studied here. Failure to protect children against volcanic ash could be against the "best interests of the child" principle, one of the guiding principles of the CRC.

Building upon research conducted in disaster contexts, future research should also ask children about their views on protective measures as part of the CRC's other guiding principle regarding a "Child's rights to express his or her views freely in all matters affecting the child" (child participation). The importance of hearing children's voices in disaster contexts is highlighted by Peek et al. (2017) [37] who have categorised research on children and disasters into six waves including assessment of their psychological and behavioural reactions (wave 1); and considering their voices, perspective and actions (wave 6). The argument follows that, if protective measures are supplied in line with the children's needs and aspirations, they will be more likely to use them whilst, at the same time, the fulfilment of their rights are ensured.

5. Conclusions

This study is the first to evaluate carers' perceptions of the impact of volcanic ash on the health of their children, the actions that they may take to protect them, their perceptions of the efficacy of these measures, and the factors that they will assess and take into account in reaching their decision. The comparative nature of the study has allowed us to see how these vary among the diverse cultures of Mexico, Indonesia and Japan.

Our findings identify important variations among the three countries that highlight the significance of culture and location. Additionally, there are significant key messages conveyed through the findings that are relevant for policy, practice and training in all three countries, and potentially globally, given the numbers of people living with active volcanoes on their doorstep. These are:

- 1) Carers consider the impact of ash on children's health as being more harmful than on their own health.
- 2) Carers take a range of protective measures in safeguarding children's health which need to be investigated for their efficacy, which can then inform service provision and delivery, and policy formulation.
- 3) Carers' views on the effectiveness of the protective measures they might undertake determine those measures that they will actually carry out.
- 4) Country specific differences are important in ensuring that messages from those in authority or those training practitioners are contextually-specific and culturally-relevant.
- 5) Generalisations from the findings of this survey should be conducted with caution given the diverse social contexts, cultures and legislation pertaining in other countries.
- 6) Finally, and of crucial importance, future research should focus on accessing children's own voices in discussing their health experiences of inhaling ash.

Data availability

Datasets related to this article can be found at <https://data.mendeley.com/datasets/ryzz2p65v7/draft?a=2b2dc7b7-b9e5-426c-ad01-36a4c70c2c21>, an open-source online data repository hosted at Mendeley Data.

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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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