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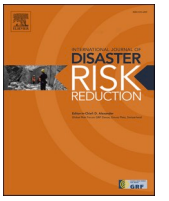

Perceptions of tsunami susceptibility and self-efficacy among adolescents in Indonesia: The influence of gender, religion, location, age, hazard information source, and past experience

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ABSTRACT

Perceptions of tsunami susceptibility and self-efficacy among adolescents in Indonesia: The influence of gender, religion, location, age, hazard information source, and past experience.

The densely populated Indonesian archipelago is highly vulnerable to earthquakes and tsunamis. Behavioral theory suggests perceived susceptibility and perceived self-efficacy are positively correlated with preventive behaviors. We surveyed adolescents (N = 2386) in tsunami-vulnerable coastal areas of Java, Bali, Lombok, and Sumba Indonesia. We conducted a stepwise logistic regression analysis of perceived tsunami susceptibility and self-efficacy. Explanatory variables included sex, age, religion, island of residence, hazard information source, previous participation in tsunami evacuation drills, and personal tsunami experience. The majority (60.6%) of participants believed that they were susceptible to an earthquake. About half of participants believed they were susceptible to a tsunami (49.8%) and that they would be able to save themselves if a tsunami occurred (48.5%). Individuals residing in Java, females, Muslims, older participants, and those who received tsunami information from the Internet and Indonesia's regional governmental disaster management agency (BPBD) were significantly more likely to feel susceptible to a tsunami. Catholics, Protestants, individuals living in Java, those who participated in past tsunami evacuation drills, and those with personal tsunami experience had significantly higher perceived self-efficacy. Females and participants who received hazard-related information from the Internet and BPBD had significantly lower perceived self-efficacy. Our study highlights the importance of providing culturally competent information about local tsunami risk to vulnerable locations through a variety of communication channels. Identifying cultural, economic, and religious barriers is important when developing educational interventions. Efficacy perceptions should be improved through education about immediate self-evacuation after observation of tsunami natural warning signs, construction of vertical evacuation structures in coastal areas, and encouraging participation in tsunami evacuation drills.

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1. Introduction

1.1. Earthquake and tsunami hazards in Indonesia

The densely populated archipelago of Indonesia has more persons exposed to geophysical hazards such as earthquakes and tsunamis than any other country [1]. There have been 18 major earthquakes from 2000 to 2021, including four magnitude >8.0 events and one magnitude >9.0 event. The 2004 Indian Ocean earthquake and tsunami killed over 227,000 people including over 165,000 in Indonesia, making it the deadliest socio-natural disaster to occur in the 21st century [2]. Even though this event had been forecast by geoscientists [3], information about the hazard had not been disseminated to the general public and many did not know how to protect themselves [4].

Tsunami preparedness considerations include developing and maintaining early warning systems, structural measures such as Temporary Evacuation Shelters (TES), coastal forests and vegetative barriers, community education efforts, and evacuation planning and simulation [5–7]. The Indonesian Tsunami Early Warning Systems (InaTEWS) face challenges including lack of communication infrastructure and non-functioning tsunami monitors and sirens that has resulted in loss of life [8,9]. Recognition of tsunami natural warning signs (e.g. earthquake, sudden receding ocean shoreline, wall of water or a roaring sound) and immediate self-evacuation is important to prevent loss of life [10]. Considerations in evacuation success include evacuation time, distance to the evacuation zone, and method of transportation with evacuation by foot generally preferred to avoid congestion from traffic jams [11].

1.2. Theoretical background and gaps

Perceived threat and efficacy are important theoretical constructs in the Extended Parallel Process Model (EPPM) [12]. The EPPM incorporates perceptions of perceived threat (perceived severity and perceived susceptibility), fear, and perceived efficacy (perceived self-efficacy and perceived response efficacy) as predictors of behavior change. According to the EPPM, if little to no threat is perceived, the individual will not feel fear and will not change their behavior regardless of perceived efficacy. If an individual perceives a threat, they will feel fear and engage in one of two possible processes depending on efficacy. If an individual has a high perceived threat but low perceived efficacy, the individual will engage in the fear control process and will not adopt preventive behavior. If an individual has a high perceived threat and high perceived efficacy, they will engage in the danger control process and adopt preventive behavior. Two meta-analyses found that high-threat/high-efficacy messages result in the greatest behavior change, while high-threat/low-efficacy messages produced defensive responses [13,14]. Studies have used the EPPM [15,16] in the context of natural hazards and disaster preparedness.

A growing number of studies [17–20] suggest that natural hazard preparedness increases with the populations' perceived risk of possible harm. A study in Hitachi Japan found that risk perception was the only significant predictor of tsunami evacuation [21]. Dash and Gladwin suggest that low risk perception is likely to decrease response evacuation speeds in the event of a tsunami [22]. Recent studies found that threat and self-efficacy perceptions had a positive significant influence on disaster preparedness or intended tsunami evacuation behavior [23–25].

A systematic review assessing the application of behavioral theories around the world found that most of the disaster-related studies were from Western countries [26]. The authors called into question how well these studies pertain to regions - particularly in Asia and the Middle East - where cultural values and traditions differ from where the theories were first developed and tested. There is a further gap in the literature in the assessment of adolescent populations. Children and adolescents are potentially most subject to disaster response training in their school systems and are important sources of natural hazard information for families and communities. Our study seeks to directly address these gaps.

1.3. Factors Related to Perceptions of Hazard Risk and Efficacy

While social and psychological conditions have been studied for the case of tsunamis, there is a lack of strong consensus in the literature as to which factors are the primary drivers of risk and efficacy perceptions. Perceived tsunami susceptibility may include actual risk related to demographic factors such as sex, age, and disability. Cultural considerations such as gender norms and religion may influence tsunami evacuation. Personal experiences with prior hazards and preparedness initiatives may influence risk and efficacy perceptions.

Some suggest that biological factors such as walking speed [27], evacuation response speed [11], or the ability to stand within a marginally significant tsunami flow (stronger tsunami flows are indiscriminate) [28] vary by gender. Gender roles and dependency vary in developing versus developed countries and relate to human hazard exposure, mobility, and evacuation speed [29]. For example, women may be more likely to be caregivers and thus delay their own evacuation due to helping children or elderly parents. Conversely, a study on volcanic risk perceptions performed in a Javanese community found that women said they would evacuate more quickly because men would stay behind longer to protect assets like their home or livestock even though women were found to have lower hazard knowledge [30]. However, Müller, Reiter, and Weiland [31] suggest that prior knowledge and experience with hazards are more important predictors than traditional factors such as sex. Many studies suggest that adult females have higher risk perceptions than adult males for hazards such as floods [32–34], severe storm events [35,36], landslides [37], volcanoes [38], and earthquakes [39–42]. A study of high school students in Pakistan found that female students had higher fear of earthquakes, floods, and landslides than male students [43].

Age has been found to influence tsunami risk with older adults (60+ years) and children (9 years and under) being most vulnerable [29]. Mortality rates were highest among older adults during the Aceh tsunami [44]. A study in Japan found older adults needed longer evacuation time, were less prepared, and had difficulty receiving warning alerts [45]. The influence of age on risk perception is inconsistent. A study on tsunami risk perceptions in Italy found that participants aged fifty years and older had slightly higher risk

perceptions than younger adults [46] while a study in Dhaka found that younger people have higher awareness levels for earthquakes [47]. Studies in Pakistan [48] and a South African Community in New Zealand [49] found no correlation between age and risk perception. These studies did not include participants under eighteen years of age.

Religion interacts with social, economic, and political issues to influence disaster vulnerability [50]. Religious interpretations of the 2004 tsunami in Indonesia included the notion that the disaster was preordained from God [51]. Religion significantly shaped how the 2006 earthquakes in Indonesia were viewed [52]. Studies in Muslim communities in Morocco and Bangladesh found that questions about earthquake or tsunami risk resulted in the responses *God is wisest* or *it depends on Allah's wish* [53,54]. Research in Java found that a quarter of survey participants believed that tsunamis could be caused by the *will of God/Allah;* this was the most common response after *earthquakes* [10]. These studies did not compare risk or efficacy perceptions among various religions.

The impact of past hazard experience on risk perceptions and preparedness are mixed. Results vary by geographic region and how strongly the person was impacted. One study found that past experience impacted perceived susceptibility but not preparedness behaviors [25]. Other studies found that experience with past hazards increased evacuation intentions [55–57]. Buylova et al. [24] found past experience with extreme events was associated with lower likelihood of immediate tsunami evacuation intentions, noting that past experience that did not result in severe damage may cause a person to overestimate their ability to survive. Becker et al. [58] found that personal experience with smaller earthquakes or other disasters helped individuals develop preparedness. Tsunami evacuation drills are important as educational and assessment tools [59]. Few studies investigate the influence of prior participation in tsunami evacuation drills on self-efficacy. Two studies from Japan suggest participation in tsunami evacuation drills improved self-efficacy [45] and increased evacuation behavior [60] for adults.

Tsunami information sources may influence tsunami awareness and evacuation behavior. A study in Samoa found that during the 2009 earthquake and tsunami, the most common sources of initial awareness were earth shaking and broadcast media while radio, face-to-face contacts, and phone calls were other important sources [61]. A study in Indonesia found that the tsunami sirens failed to provide a warning and most residents obtained hazard information through neighbors, family members, and natural warning signs such as feeling the earthquake and observation of the sea [62].

Our study aims were (1) to identify earthquake and tsunami susceptibility and efficacy perceptions among schoolchildren in tsunami-vulnerable locations in Indonesia, (2) to evaluate how sex, age, religion, island of residence, hazard information source, personal experience with hazards, and participation in evacuation drills influence levels of perceived earthquake and tsunami susceptibility and efficacy, and (3) to use results to make recommendations for future educational campaigns. We hypothesized that combinations of several factors such as sex, religion, participation in tsunami evacuation drills, and personal hazard experience would contribute to perceived earthquake and tsunami susceptibility and efficacy, and therefore used a modeling approach to analyze the strength of their associations.

2. Materials and methods

2.1. Survey development

Our study focused on constructs found to influence behaviors in the Health Belief Model and EPPM. Our survey instrument contained questions regarding perceptions of tsunami susceptibility ('it is possible that a tsunami could occur in the environment around me') and self-efficacy ('I believe that I would be able to take action to save myself if a tsunami occurred in the environment around me'). Since earthquakes are the most common triggers of tsunamis in Indonesia, we additionally assessed perceived earthquake susceptibility. Perceptions of threat and efficacy were assessed on a 1–5 Likert scale from *strongly disagree* to *strongly agree*.

Multiple-choice questions assessed demographic factors of sex (male or female), age (SMP/junior high or SMA/high school), religion (Muslim, Hindu, Catholic, Protestant, Buddhist, or other), and island of residence (Java, Bali, Lombok, or Sumba). Personal history was assessed with questions about tsunami information sources, prior hazard experience, and participation in tsunami evacuation drills. The evacuation simulation question provided options of: (1) yes, I have participated in a tsunami evacuation drill, (2) no,

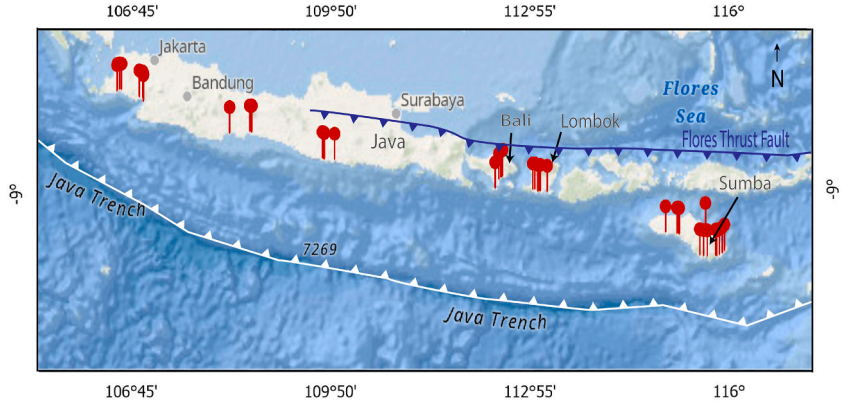

Fig. 1. Research locations.

I have never participated and I do not know of my community or school ever hosting a tsunami evacuation drill, and (3) no, I have never participated but my community or school has hosted a tsunami evacuation drill. Information sources included Internet, school, social media, family, friends, neighbors, TV, radio, and Indonesia's regional governmental disaster management agency 'Badan Penanggulangan Bancana Daerah' (BPBD). Survey questions were validated in previous research [10]. Surveys were conducted in Indonesian.

2.2. Site selection and survey administration

Coastal schools (N = 50) with high earthquake and tsunami hazard risk on four islands were identified and selected for participation by BPBD officials. We created inundation maps to assess tsunami inundation risk in each area [63]. We conducted surveys in coastal regions around Java (Pelabuhan Ratu, Pangandaran, Pacitan), Bali (Denpasar and surrounding coastal areas), Lombok (Kuta, Mataram) and Sumba (Waingapu and surrounding coastal areas) (see Fig. 1). The researchers administered pencil/paper surveys which were individually completed by students aged 12–18 during school. Following survey completion, the researchers and BPBD officials delivered an hour-long educational session and conducted a tsunami evacuation drill with the students. The researchers additionally conducted informal interviews with government officials, school leadership, teachers, community members, and students regarding risk and efficacy perceptions and personal and community evacuation plans.

2.3. Statistical analysis

Participants that failed to respond to three or more survey questions were excluded from the study. We used Pearson's Chi-square to compare sampling distributions for sex, age, religion, prior tsunami experience, tsunami information sources, and participation in a prior tsunami evacuation drill. We used cross-tabulation by island of residence for multiple-choice questions regarding demographic factors and personal history.

We conducted a regression analysis using three ordinal dependent variables measured on a 5-step Likert scale from "strongly disagree" to "strongly agree", coded as the numbers one to five. These variables were (1) perceived susceptibility to earthquake, (2) perceived susceptibility to tsunami, and (3) perceived self-efficacy during a tsunami. To determine the best analytical methods, we tested the proportional odds assumption for four explanatory variables that we intended to include in each model (sex, age, religion, and island of residence) and the dependent variables. The proportional odds assumption was not met for any of the four variables (Brant, nominal and scale tests were all significant), which is a scenario frequently found with survey data.

We therefore aggregated the ordinal data to two categories. If participants responded with "strongly disagree", "disagree" or "neutral", they were assigned as being in a "low" susceptibility or personal efficacy category. If they responded with an "agree" or "strongly agree" they were grouped as high susceptibility or personal efficacy. These groupings gave roughly even numbers of participants in each category. We proceeded with a stepwise logistic regression analysis, using the glm function in R (v. 4.0.0), with model selection based on minimizing the Akaike's information criterion (AIC, stepAIC command in R). We defined the reference groups as

Table 1
Participant demographics and personal experience by island of residence.

	Java (N = 649)	Bali (N = 388)	Lombok (N = 432)	Sumba (N = 917)	Total (N = 2386)
Gender, N: %					
Male	283: 43.6%	162: 41.8%	163: 37.7%	337: 36.8%	945: 39.6%
Female	350: 53.9%	214: 55.2%	245: 56.7%	524: 57.1%	1333: 55.9%
Age*, N: %					
SMP (Junior High)	328: 50.5%	192: 49.5%	216: 50.0%	595: 64.9%	1331: 55.8%
SMA (High School)	321: 49.5%	185: 47.7%	196: 45.3%	289: 31.5%	991: 41.5%
Religion*, N: %					
Muslim	617: 95.1%	72: 18.6%	342: 79.2%	297: 32.4%	1328: 55.7%
Protestant	1: 0.2%	5: 1.3%	6: 1.4%	414: 45.1%	426: 17.9%
Hindu	3: 0.5%	289: 74.5%	53: 12.3%	6: 0.65%	351: 14.7%
Catholic	3: 0.5%	8: 2.1%	5: 1.2%	142: 15.5%	158: 6.6%
Other	7: 1.1%	3: 0.8%	6: 1.4%	6: 0.7%	22: 0.9%
Prior tsunami experience*, N: %	100: 15.4%	12: 3.1%	22: 5.1%	43: 4.7%	177: 7.4%
Information sources*, N: %					
School	484: 74.6%	258: 66.5%	290: 67.1%	604: 65.9%	1636: 68.6%
Internet	302: 46.5%	210: 54.1%	238: 55.1%	355: 38.7%	1105: 46.3%
Social media	254: 39.1%	192: 49.5%	217: 50.2%	335: 36.5%	998: 41.8%
BPBD	145: 22.3%	98: 25.3%	70: 16.2%	148: 16.1%	461: 19.3%
Neighbors	52: 8.0%	16: 4.1%	19: 4.4%	50: 5.5%	137: 5.7%
Family	248: 38.2%	135: 34.8%	172: 39.8%	242: 26.4%	797: 33.4%
Friends	99: 15.3%	62: 16.0%	81: 18.8%	89: 9.7%	331: 13.9%
TV/Radio	339: 52.2%	175: 45.1%	236: 54.6%	481: 45.6%	1231: 51.6%
Other	45: 6.9%	6: 1.5%	27: 6.3%	35: 3.8%	113: 4.7%
Tsunami evacuation drill participation*, N: %					
Yes, participated	296: 45.6%	127: 32.7%	93: 21.5%	154: 16.8%	670: 28.1%
Never participated; not aware of drills	251: 38.7%	182: 46.9%	256: 59.3%	593: 64.7%	1291: 54.1%
Never participated; community/school has held drill	84: 12.9%	70: 18.0%	68: 15.7%	124: 13.5%	346: 14.5%

Total percentages may not add up to 100% in all categories due to missing responses. Information source totals may add up to more than 100% since participants could select multiple sources. *Indicates significant differences between islands at $p < 0.05$.

being male, Muslim, SMA education level (high school), and residing on the island of Sumba. Due to only 10 respondents identifying as Buddhist, these participants were grouped in the category with those who identified as "other religion." We proceeded to analyze the data using a stepwise logistic regression model as described for the three dependent variables: perceived susceptibility to earthquake, perceived susceptibility to tsunami, and efficacy during a tsunami.

The full list of explanatory variables that could potentially be included by the stepwise algorithm were sex, age, religion, island of residence, hazard information sources, participant experience with tsunami evacuation drills, and participant personal experience with a tsunami or earthquake. Non-significant variables that improved model fit remained in the model. We calculated the odds ratios and p-values for each of the explanatory variables included in the final models. We further calculated the Hosmer-Lemeshow goodness of fit test for each model and reported these along with the standard deviance and AIC.

3. Results

3.1. Participant demographics and sampling distribution

Survey participants were students aged 12–18 at 50 schools in Indonesia (N = 2386). Respondents resided in Java (N = 649), Bali (N = 388), Lombok (N = 432), and Sumba (N = 917). There were no significant differences in sampling distribution among the islands with regard to sex ($p > 0.15$). There were significant differences with regard to religion ($p < 0.001$), prior tsunami experience ($p < 0.001$), all tsunami information sources ($p < 0.05$), age ($p < 0.001$), and previous participation in tsunami evacuation drills ($p < 0.001$). Differences in religion were expected since religious demographics vary substantially among islands. Respondents were primarily Muslim in Java and Lombok, Hindu in Bali, and Protestant and Muslim in Sumba. Differences with prior tsunami experience were expected due to the 2006 tsunami in Pangandaran Java. Table 1 provides a breakdown of reported personal experience and tsunami information sources of participants by island and total.

3.2. Descriptive statistics

A majority (60.6%) of respondents believed that they were susceptible to an earthquake. Approximately half (49.8%) believed they were susceptible to a tsunami and that they would be able to save themselves if a tsunami occurred (48.5%). The percentages of respondents who *agreed* or *strongly agreed* they would be able to save themselves in the event of a tsunami were: Java (57.2%), Sumba (52.9%), Bali (36.9%) and Lombok (36.4%). Many participants *disagreed* or *strongly disagreed* that they would be able to save themselves: Java (21.3%), Bali (21.4%), Lombok (31.9%), and Sumba (33.9%) (see Fig. 2). The most common tsunami information sources were school, TV or radio, Internet, and Social Media. A minority of participants reported prior tsunami experience (7.4%) and participation in a tsunami evacuation simulation (28.1%) (see Table 1).

3.3. Regression results

Our first dependent variable was perceived susceptibility to earthquakes. Regression results showed that individuals residing on the

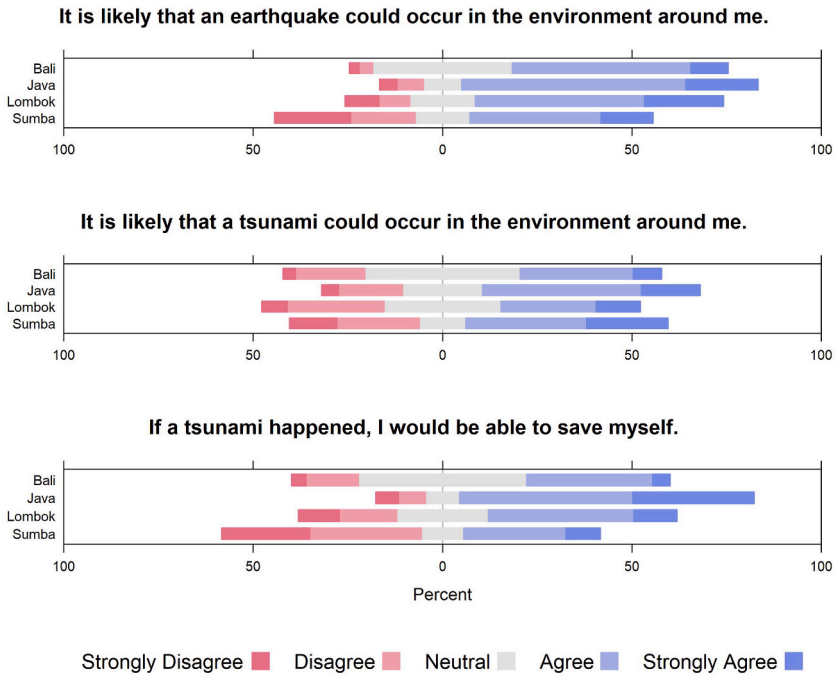

Fig. 2. Diverging stacked bar charts showing responses to primary response variables of interest: susceptibility and self-efficacy in the event of an earthquake or tsunami. Results shown by island as percentages. Missing data not shown (⩽10 persons per category).

island of Java (OR = 2.21, $p < 0.001$) and females (OR = 1.42, $p < 0.001$) were more likely to believe they were susceptible to an earthquake, as were those who received information from the Internet (OR = 1.76, $p < 0.001$), BPBD (OR = 1.34, $p = 0.02$), and school (OR = 1.24, $p = 0.04$). Younger students in SMP (junior high) were less likely (OR = 0.72, $p < 0.001$) to believe they were susceptible to experiencing an earthquake compared to older students in SMA (high school). Catholics (OR = 0.44, $p < 0.001$), Hindus (OR = 0.51, $p = 0.001$), and Protestants (OR = 0.41, $p < 0.001$) were less likely than Muslims to believe they were susceptible to experiencing an earthquake.

Our second dependent variable was perceived susceptibility to a tsunami. Regression results showed that residing on the island of Java (OR = 3.63, $p < 0.001$) and being female (OR = 1.37, $p = 0.001$) were associated with being more likely to feel susceptible to a tsunami. Those who reported receiving hazard-related information from the Internet (OR = 1.72, $p < 0.001$) and BPBD (OR = 1.40, $p = 0.01$) were more likely to report feeling susceptible to a tsunami. SMP (junior high) students were less likely to believe they were susceptible to a tsunami (OR = 0.79, $p = 0.02$). Catholics (OR = 0.35, $p < 0.001$), Hindus (OR = 0.48, $p < 0.001$), and Protestants (OR = 0.45, $p < 0.001$) were less likely than Muslims to believe they were susceptible to a tsunami.

Our third dependent variable was perceived self-efficacy in the event of a tsunami. Our regression results demonstrated that

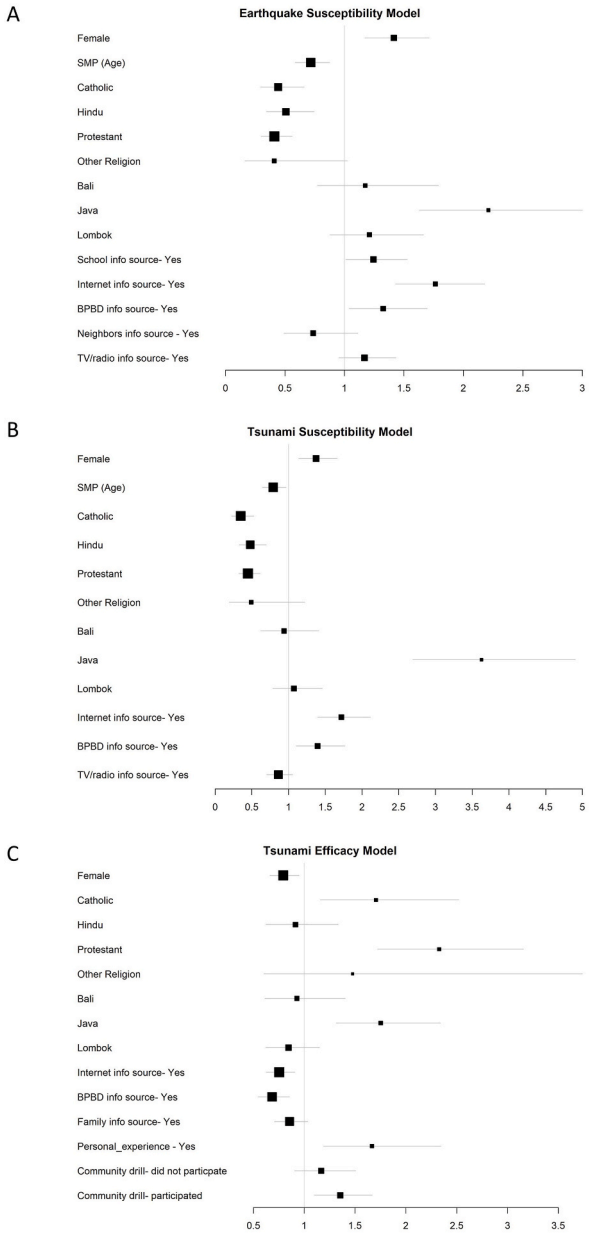

Fig. 3. (a–c). Forest plot showing odds ratios and confidence intervals for tsunami susceptibility, earthquake susceptibility and tsunami efficacy regression models. Note: scale and listed variables differ between plots.

residing on the island of Java was associated with higher perceived self-efficacy (OR = 1.75, $p < 0.001$). Catholics (OR = 1.71, $p = 0.01$) and Protestants (OR = 2.33, $p < 0.00$) had higher perceived self-efficacy compared to Muslims. Those who reported personal history of participation in a tsunami evacuation drill had higher self-efficacy (OR = 1.35, $p < 0.001$) while there was no significant difference for those who reported that their community held such drills but they did not participate. Those who reported personal experience with a tsunami had higher perceptions of efficacy (OR = 1.67, $p < 0.001$). However, females reported lower self-efficacy (OR = 0.79, $p = 0.01$) than males. Those who reported receiving hazard-related information from the Internet (OR = 0.75, $p < 0.001$) and the BPBD (OR = 0.68, $p < 0.001$) had lower self-efficacy. Fig. 3(a-c) shows the forest plots for perceived earthquake susceptibility, perceived tsunami susceptibility, and perceived tsunami efficacy.

4. Discussion

4.1. Perceived threat

Slightly fewer than half of participants in tsunami-vulnerable areas we surveyed felt that they were susceptible to a tsunami. Only about three out of five felt that they were susceptible to an earthquake. This indicates a need for educational efforts to increase perceptions of seismic and tsunami susceptibility. To increase threat perceptions, interventions should define a populations' hazard risk level, communicate susceptibility consistent with the population's actual risk, and personalize risk [64]. Our study found that sex, age, hazard information source, religion, and island of residence were associated with risk perceptions.

Females in our study were more likely to believe that they are susceptible to an earthquake or tsunami compared to males. This is in line with several other studies relating to sex and natural hazards in adult [32–38,40,41], young adult [39,42] and high school [43] populations throughout the world. Our study found the same pattern was observed among junior high and high school students for earthquakes and tsunamis in Indonesia. This is in contrast to a recent study in Cascadia that found that age and gender were not significantly associated with earthquake and tsunami risk perception [65].

Our study found that students in lower grade levels were less likely to feel susceptible to both earthquakes and tsunamis. Recent studies among youth in the Netherlands and Italy demonstrate varying levels of risk perception and efficacy related to floods [66] and volcanoes [67] but did not compare risk perceptions for various ages. A study on high school students in Dhaka found that higher-grade students had more earthquake awareness than lower-grade students, although higher-grade students had lower levels of earthquake preparedness [47]. Reasons for differences in earthquake and tsunami risk perceptions between younger and older schoolchildren merits further research. Those who reported receiving hazard information from the Internet, BPBD, and school were more likely to believe they were susceptible to an earthquake, and those who reported receiving information from the Internet and BPBD were significantly more likely to feel susceptible to a tsunami, indicating these are important hazard information sources for our adolescent population.

Our study addresses a gap in the literature by providing an analysis of the direct influence of religion on hazard risk perceptions. We found that Muslim participants were associated with higher earthquake and tsunami risk perceptions compared to Catholic, Protestant, Hindu, and other religious participants. A study in Banda Aceh found that Islamic teachings are used to explain the relationship between religion and natural hazards in textbooks and teaching processes in school, and from religious leaders, mass media, and public signage in the community [68]. This includes stories of natural disasters in the Quran and accepting natural disasters as God's will. The authors concluded that risk-based communication interventions in Muslim communities should use Islamic teachings to educate people to be prepared for the next geophysical event in context of the Quran. Adiyoso and Kanegae [69] found that leaflets containing Islamic messages increased knowledge and behavior with regard to tsunami preparedness for residents of Yogyakarta. This suggests an opportunity to culturally tailor tsunami risk messages for Muslim communities in Indonesia by incorporating Islamic teachings.

Residing on the island of Java was strongly associated with higher perceptions of susceptibility to earthquakes and tsunamis. We explore possible contributing factors: socioeconomic status, population size and density, and proximity to recent earthquakes or tsunamis. On a Human Development Index (HDI) ranking of 34 regions in Indonesia, Bali ranked 5, West Java, 10; Central Java, 11; East Java, 15; and West Nusa Tenggara (comprising Lombok and Sumba), 29 [70]. Bali's high ranking is bolstered by its strong tourist economy and is in stark contrast to the HDI of neighboring Lombok and Sumba. Risk perception related to income level in prior studies are mixed, with lower or higher income groups having different levels of perceived risk for various hazards in different countries which may relate to factors such as loss of investments, housing insecurity, and income inequality [71,72]; [48]; [49]. Our study found higher earthquake and tsunami susceptibility perceptions for participants in Java compared to lower-HDI Sumba and Lombok and higher-HDI Bali, suggesting Java's higher susceptibility perceptions may more closely relate to another unaccounted for variable in the model. For example, Java is the largest and most populous of the islands (about 147 million inhabitants). Bali and Lombok's populations are 4.4 million and 3.8 million, respectively. Sumba's population is about 779,000. Jakarta's national agencies and research centers on Java may facilitate access to information about earthquakes and tsunamis while the high population density may increase transfer of information.

Major earthquakes are more likely to occur along plate boundaries with prolonged seismic quiescence [73]. Studies indicate perceptions of risk may be lower for people who are temporarily removed from recent disasters or for people who have not yet experienced hazards [17–19,74–76]. Java is just southeast of Sumatra where the majority of the 2004 tsunami deaths occurred. Java experienced several recent geophysical hazards including an earthquake in May 2006 that killed more than 5000 people [77] and the Pangandaran tsunami in July 2006 that killed approximately 668 people [78]. Bali, Lombok, and Sumba, which had lower tsunami risk perceptions, are further east from Sumatra and Java. This may have been a factor in differing risk perceptions among the islands.

Emerging themes relating to perceived risk from our informal interviews highlighted several important considerations. Many Hindu participants in Bali said that they did not believe they were at risk of a tsunami because their daily religious offerings would

protect them. However, no religious reasons were expressed in connection with low tsunami susceptibility for Protestant and Catholic individuals. The most common reasons given for low tsunami susceptibility in Sumba were references to the island's far distance from Sumatra. Interventions in areas with diminished threat perceptions due to proximity from recent disasters require different communication approaches than areas where risk perceptions are influenced by religious factors, reinforcing the importance of local needs assessments and culturally tailored messages.

4.2. Perceived efficacy

High self-efficacy perception is an important predictor of engaging in preventive behavior. Our study found that perceptions of efficacy were lacking in our survey respondents; fewer than half believed they would be able to save themselves in the event of a tsunami. This study agrees with another from New Zealand suggesting a need for interventions increasing perceptions of self-efficacy [79]. This may require measures to increase actual efficacy depending on the cause of low self-efficacy perceptions. Our study found that females and individuals who reported receiving hazard information from the Internet and BPBD were associated with lower self-efficacy perceptions. Those living on the island of Java, Catholics, Protestants, individuals with reported personal tsunami experience, and individuals who had previously participated in tsunami evacuation drills were associated with higher efficacy perceptions.

Our study found that although females were more likely to report believing they were susceptible to a tsunami, they were less likely to feel that they could save themselves if a tsunami occurred. This is in line with lower levels of self-efficacy reported for females for earthquakes [40] and floods [80]. Education for females should consider focusing on increasing their confidence through successfully practicing self-evacuation routes.

Participants who received hazard-related information from the Internet and BPBD were more likely to believe they were susceptible to a tsunami but less likely to believe they could save themselves in the event of a tsunami. When media messages show tsunami devastation that generates fear with no efficacy component, audiences are exposed to a high-threat, low-efficacy message which is postulated to result in denial [13]. Tsunami reporting in popular media outlets often shows individuals, vehicles, and homes being helplessly swept up in a fast-moving flood of water. A study in Mexico found that when tsunamis are perceived as catastrophic in a one-directional risk communication from experts to non-experts, the non-experts are prone to a feeling of futility resulting in inaction [81]. This stresses the importance of following theory in creating effective high-threat, high-efficacy educational messages through education sources such as the Internet and BPBD. To reach older adults, it is important to include other communication channels such as TV and radio [82]. Media messages should include information on how to recognize natural tsunami warning signs and simple actions to prevent injury or death (e.g. immediate self-evacuation to high ground).

Location can impact self-efficacy in many ways. A study of small islands around Sumatra found that some areas were in critical tsunami preparedness conditions due to limited space for tsunami evacuation and short tsunami estimated time of arrival [83]. Availability of adequate evacuation terrain such as natural hills or presence of TES or other sturdy tall buildings, and wide roads for evacuation, are important structural factors related to efficacy. Our research locations in Java had numerous hills that could be used for quick evacuation which is one possible explanation for higher self-efficacy perceptions in Java. Educational campaigns to increase perceived efficacy will do little to save lives in the event of a tsunami if there is nowhere safe to evacuate within the timeframe between a tsunamigenic earthquake and the first tsunami wave. Construction of a TES in these areas has the potential to increase actual efficacy, and in turn, perceived efficacy. Several of our research locations in southern Bali had relatively flat terrain and few options for safe evacuation. We recommend construction of additional TES in Bali.

Prior personal hazard experience was correlated with higher perceived efficacy in our study. This is in line with existing research that suggests prior knowledge and experience with hazards influence awareness, beliefs, or behavioral intentions [31,55–58]. Our study also found that Protestant and Catholic participants had higher perceived efficacy than Hindu and Muslim participants, which merits further research.

We found that reported participation in community evacuation drills was positively correlated with higher self-efficacy perceptions for adolescents. This is in line with results from adult populations in Japan [45,60]. Furthermore, another study asserts that even movie clips showing school evacuation drills and tsunami inundation simulations help change non-experts perception's of futility to the ability to engage in risk preparedness activities [81]. However, only 28.1% of our respondents indicated they had ever participated in a tsunami evacuation simulation and 54.1% said they do not know of simulations being offered in their community or school. This suggests an opportunity for school, government, community, and nonprofit organizations to identify local evacuation routes and conduct tsunami evacuation drills in coastal areas of Indonesia. Previous research identified that evacuation speed is associated with factors such as slope, terrain surface, walking at night, and distance to destination [59]. Effective evacuation drills should generally define safe gathering spaces out of the projected tsunami inundation zones within a 10–20 min or less walk from schools and homes [10]. Evacuation zones with emergency facilities, at higher elevations, far from the coastline, and with evacuation routes and emergency infrastructure may be psychologically preferred and influence evacuation [84]. Personal ability to evacuate is influenced by disability, illness, injury, age, and other factors that may prevent an individual from running or climbing to a safe place in time, and therefore should be taken into consideration. A study found that school evacuation plans sometimes conflicted with family plans (e.g. students assigned by parents to pick up younger siblings at other schools before evacuating) [85]. A survey in Chile found that a primary reason for the decision to evacuate by car was influenced by the presence of the elderly or children needing to be evacuated and that many families said they would pick up their children from school before evacuating [11]. It is important to discuss parallel family evacuation plans with students and to make parents aware of school evacuation plans, the importance of immediate evacuation, and potentially involve parents in evacuation drills and incorporating school plans into the family plan.

Themes related to efficacy that may require different local intervention strategies emerged from our informal interviews. First,

leaders in southern Bali expressed concerns about community resistance to TES construction since the structure would be taller than the Hindu temples. Second, community members in a particular area of Java expressed beliefs that water from a tsunami wave would not go past a coastal road and that they would thus not need to leave their homes to climb a nearby hill. This was not consistent with our tsunami modeling for the area which showed water would likely reach the residential area past the road. Third, leaders in an area of Lombok expressed hesitancy to direct community members up a hill knowing that it was land privately owned by a resort. Fourth, in areas of Sumba and Lombok, tsunami evacuation signs pointed away from hills and toward low-lying gathering areas that would be inundated in the event of a tsunami. One community's evacuation plan was to gather community members in the low-lying area to be accounted for while they waited for a government vehicle to pick them up and drive them up the hill. In the event of a major earthquake triggering a tsunami, communication would likely be compromised and roads blocked. Time spent gathering would result in potentially deadly evacuation delays. The clash between collectivistic culture versus an individualistic approach that encourages immediate self-evacuation, religious resistance to building TES, and other cultural factors must be handled in a culturally competent manner.

5. Conclusions and recommendations

Slightly fewer than half of our study participants in tsunami-prone coastal areas of Indonesia believed they were susceptible to a tsunami and that they could save themselves in the event of a tsunami, suggesting a need for educational interventions and communication campaigns to increase threat and efficacy perceptions. Individuals residing in Java, females, Muslims, older participants, and those who received tsunami information from the Internet and Indonesia's regional governmental disaster management agency (BPBD) were significantly more likely to feel susceptible to a tsunami. Catholics, Protestants, individuals living in Java, those who participated in past tsunami evacuation drills, and those with personal tsunami experience had significantly higher perceived self-efficacy while females and participants who received hazard-related information from the Internet and BPBD had significantly lower perceived self-efficacy. Our informal interviews found several location-specific factors that merit further research including distance from a previous major tsunami, culture, religion, proximity to the coast, and land ownership for evacuation drill practice.

Risk-reduction efforts should address preservation of natural tsunami barriers (e.g. coastal reefs and mangrove forests), construction of TES where there is inadequate opportunity for evacuation, and community education. Research has found confusion about tsunami warning sources, tsunami arrival time, recommended mode of evacuation, misconceptions about an earthquake needing to feel strong to generate a tsunami, an overreliance on alert from authorities before evacuation, and under-reliance on tsunami natural warning signs [10,86]. We recommend a broad initiative targeting coastal tsunami-vulnerable areas around the globe in addition to culturally-tailored local initiatives.

A worldwide initiative targeting coastal communities should be disseminated through various communication channels. The initiative should strive to increase perceptions of earthquake and tsunami risk and efficacy and address misconceptions. Key messages should include recognition of tsunami natural warning signs and the importance of immediate self-evacuation to a safe height in the hills or a nearby sturdy building. The 20-20-20 guideline may be used as a simple framework for communication and adjusted to local initiatives to account for local tsunami modeling. The 20-20-20 principle states that if the ground shakes for more than 20 seconds (whether the shaking feels strong or weak), one should evacuate immediately (by foot or motorcycle) within 20 min, to a height of at least 20 m [10]. Educational campaigns that show dramatic earthquakes prior to a tsunami should be avoided as they may reinforce existing misconceptions and discourage people from evacuating if the earthquake feels weak.

Local initiatives incorporating geophysical, cultural, religious, and economic considerations should accompany a broader initiative. Geophysical considerations include tsunami inundation modeling, identification of walkable evacuation zones that can be reached within the evacuation window, and identification of areas where construction of vertical tsunami evacuation structures are needed when terrain is a challenge to successful evacuation. Campaigns should work with local government and community leaders to develop sound community evacuation plans matching placement of tsunami evacuation signs. Needs assessments should determine unique local cultural, religious, and economic barriers and inform the creation of culturally competent messaging. Conducting evacuation drills in schools and communities are important to increasing self-efficacy.

Including hazard information in school curriculum has been found to improve natural hazard knowledge and lead to increased risk perception [87]. Local school educational initiatives should include key concepts of natural tsunami warning signs, the importance of immediate self-evacuation after observation of natural warning signs even if a siren does not sound, time to evacuate, identification of safe evacuation zones near the school, and the importance of remaining on high ground to avoid being hit by a subsequent wave [10]. Empowering children to take charge of their evacuation by not waiting for an official warning is important to avoid situations such as Okinawa primary school [57]. Safe zones for school evacuations should include recognizable landmarks or objects; for example the school's flag [85]. Sutton et al. [88] found that short messages about tsunamis may not deliver enough content to inform about threat and protective actions while longer messages with more specific information lead to better outcomes. We therefore recommend longer tsunami lessons and evacuation drills be implemented into school curriculum in tsunami-vulnerable areas.

Geohazards preparedness interventions are prone to paternalism because they involve telling people what to do and how to behave in an effort to prevent harm from coming to them [89]. Additionally, educational campaigns will only be effective if there are available safe spaces for evacuation. If communities are aware of the danger but lack resources related to efficacy, educational efforts to increase perceptions of threat and efficacy will fail to save lives. In these areas, efforts should first focus on the creation of safe evacuation locations through structural measures such as constructing TES. Educational campaigns should work with local leaders and key influencers to ensure cultural competency and increase community buy-in.

Our study had several limitations. The many differences between islands resulted in inconclusive evidence on which factors related

to the island of residence most influenced risk and efficacy perceptions, such as population size and density, economic considerations, or proximity to recent disaster. There is an opportunity for more formal qualitative research to bolster our quantitative findings to explore reasons for observed differences in threat and efficacy perceptions in terms of religion and age.

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.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijdrr.2022.103151.

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