

Tsunami-related injury in Aceh Province, Indonesia

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(Received 16 October 2006; final version received 22 January 2008)

The Asian tsunami, of December 2004, caused widespread loss of life. A series of surveys were conducted to assess tsunami-related mortality and injury, risk factors, care seeking and injury outcomes.

Three surveys of tsunami-affected populations, in seven districts of Aceh province, were conducted between March and August 2005. Surveys employed a two-stage cluster design and probability proportional to size sampling methods.

Overall, 17.7% (95% confidence interval (CI) = 16.8–18.6) of the population was reported as dead/missing¹ and 8.5% (95% CI = 7.9–9.2) had been injured. Odds of mortality were 1.41% (95% CI = 1.27–1.58) times greater in females than in males; risk of injury was opposite, with an odds of injury of 0.81 (95% CI = 0.61–0.96) for females in comparison to males. Mortality was greatest among the oldest and young population sub-groups, and injuries were most prevalent among middle-aged populations (20–49). An estimated 25,572 people were injured and 3682 (1.2%) suffered lasting disabilities.

While mortality was particularly elevated among females and among the youngest and oldest age groups, injury rates were the greatest among males and the working-age population, suggesting that those are more likely to survive the tsunami were also more likely to be injured.

Keywords: tsunami; injury; disasters; Indonesia

Introduction

The 2004 Asian tsunami resulted in over 175,000 deaths, nearly 50,000 missing, and over 1.7 million people displaced in the Indian Ocean region (USAID 2005). Indonesia's Aceh Province, closest to the epicentre of the quake, was exceptionally hard hit, with an estimated 129,775 deaths, 38,786 missing and 504,518 persons displaced (UNIMS/BRR 2005). Although, data on death is routinely collected, little information is available on injuries from natural disasters, which is an important area for research on the health effects of the disasters (Noji 1997, Guha-Sapir *et al.* 2004).

Because tsunamis are less frequent than other types of natural disasters, little documentation is available on tsunami injury patterns. What injury data exists from the 2004 Asian tsunami comes from health facilities, and suggests that most frequent injuries were lacerations, fractures, and near drownings (Maegele *et al.* 2005, Johnson and Travis 2006). The Aitape tsunami had mortality and injury rates of 24 and 6%, respectively (International Tsunami Survey Team 1998). More than

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one-fourth of the injured were children, and the most frequent injuries were fractures and wounds from the debris in the water surge (Taylor *et al.* 1998).

Methods

Johns Hopkins Bloomberg School of Public Health conducted surveys in tsunami-affected areas of Aceh Province to characterise the tsunami-affected population and quantify the mortality and injury impact of the tsunami in 2005 (see Figure 1). Injury data were collected in seven districts, with a tsunami-displaced population of more than one quarter of a million people (Humanitarian Information Center (HIC) 2005). The two districts, where injury data were not collected, were the first two of the nine tsunami-affected districts to be surveyed, and on the basis of findings in that survey, an injury module was added in the seven remaining districts.

The three surveys employed a similar design and survey instrument, but were conducted separately for logistical reasons. Displaced population estimates used for sampling were the best available to date, and relied heavily on information drawn from the UN Office for the Coordinator of Humanitarian Affairs (OCHA), HIC, and local government sources.² The March survey focused on the districts of Banda Aceh and Aceh Besar, with a population of 215,379 displaced persons. The July survey encompassed the East Coast districts of Pidie, Bireuen, Aceh Utara, and Lhoksumawe, with population of 152,348 displaced persons. The final survey was conducted in August in the district of Aceh Jaya, with a reference population of 40,422 displaced persons. In several cases, sub-districts were excluded because they were difficult to reach and reportedly had few internally displaced person (IDP) (one of six sub-districts in Aceh Jaya), or because permission from the local authorities could not be obtained (two of 40 eligible sub-districts in the East Coast survey area).



Figure 1. Tsunami-affected districts in Aceh, Indonesia.

Sampling was conducted from the lists of known locations of displaced persons using two-stage cluster sampling methods to identify persons for the interview. The sample size was based on the findings of a prior similar survey of the districts of Nagan Raya and Aceh Barat that was conducted in February 2005 (Rofi *et al.* 2006). In that study, a sample size of 400 households was determined to be adequate for estimation of tsunami mortality rates, and subsequent surveys were conducted with the same sample size to allow for pooling of survey findings from other regions with similar power and precision in mortality estimates. In the Banda Aceh/Aceh Besar survey, a 20 cluster, 24 household design was used; in the following two surveys, a 20 cluster, 20 household design was used because 400 households was a sufficient sample size, and a cluster of 20 households was logistically easier to complete in one day. The total number of individuals included in each survey is shown in Table 1.

At selected sites, where affected populations were indicated by official reports, but where none could be found, the closest known displaced populations or settlements were sampled within the selected sub-district. Displaced population information was reported by settlement type (IDP camp, barrack, or host community), and interviews were conducted proportionally to sub-district estimates. For households residing in IDP camps or barracks, within-cluster sampling was conducted by estimating the total number of households in an IDP site and then selecting every n th household. IDP households that were residing in host

Table 1. Age and sex specific Tsunami injury rates (per 1000) by survey region in Aceh, Indonesia.

Age group		Aceh Jaya	Banda Aceh	East coast	All areas	Odds
		(west coast)	and Aceh		combined	
		($n = 1993$)	Besar	($n = 2103$)	(95% CI)	(95% CI)
0–4	Overall	6	24	36	24 (14–37)	
	Males	0	23	55	29 (14–51)	0.65
	Females	11	24	17	16 (8–38)	(0.21–1.85)
5–14	Overall	40	63	46	51 (41–63)	
	Males	44	87	50	64 (48–83)	0.55
	Females	33	34	43	37 (24–53)	(0.33–0.91)
15–44	Overall	97	114	93	105 (96–115)	
	Males	121	125	82	113 (99–128)	0.86
	Females	78	104	107	98 (85–112)	(0.69–1.06)
45–59	Overall	59	166	149	132 (108–159)	
	Males	53	183	124	133 (100–172)	0.98
	Females	68	145	182	131 (96–172)	(0.62–1.56)
60+	Overall	42	116	73	78 (54–110)	
	Males	62	182	51	101 (65–149)	0.48
	Females	18	43	100	51 (24–95)	(0.19–1.12)
All ages (95% CI)	Overall	70 (59–82)	100 (90–111)	80 (69–92)	86 (80–93)	
	Males	84 (67–103)	115 (100–131)	73 (58–91)	95 (85–105)	0.81
	Females	58 (44–74)	84 (70–99)	89 (72–107)	78 (69–87)	(0.69–0.96)
	Odds	0.68	0.71	1.23		
	ratio	(0.47–0.97)	(0.55–0.89)	(0.89–1.71)		

communities were identified by randomly selecting a direction from a central point (usually the mosque), proceeding to the nearest house, and inquiring if any IDPs were being hosted. Each adjacent house was visited until the requisite number of households were interviewed.

Household information was collected using questionnaires, which queried pre- and post-tsunami household composition, including deaths and injuries. The injury and mortality component of the questionnaire was identical in the three surveys, and included: (1) a listing of all pre-tsunami household members, their age, sex, and status post-tsunami; (2) a pictorial diagram used to indicate the location and type of injury for all individuals reported as injured; and (3) a brief series of questions on care seeking and injury outcome that were asked for each injured household member. In the initial stages of the survey, attempts were made to collect more detailed information on the date and cause of death or injuries. However, because many tsunami victims were buried, unidentifiable, or missing, this information was unknown for a large proportion of casualties and extensive probing was not considered appropriate by the investigators. Interviewers were either university students or other locally hired Indonesians. All interviewers received two days of training prior to the survey, and participated in field testing the questionnaire.

Data analysis was performed using STATA Version 8 (Stata Corp, College Station, TX) and SPSS Version 13.0 (SPSS Inc., Chicago, IL). Data analysis included chi-square tests for comparison of proportions between groups, and odds ratios and corresponding CI were calculated based on binomial proportions. Permission to conduct the survey was received from the local authorities in Aceh, including both the Ministry of Foreign Affairs and the police. Informed verbal consent was obtained from each respondent before the interviews were conducted. The study was approved by the Johns Hopkins Bloomberg School of Public Health, Committee on Human Research.

Results

Demographic characteristics

The three surveys encompassed a total of 1265 households, with a total pre-tsunami population of 7935 individuals. Age and sex were recorded for 7392 (92%) household members. Aggregating and weighting data³ from all three surveys enabled us to estimate that among tsunami-displaced households, the mortality and injury rates were 14.1 and 8.8%, respectively. Overall, 17.7% (95% confidence interval (CI) = 16.8–18.6) of the survey population were reported as dead or missing, and 8.5% (95% CI = 7.9–9.2) were injured (unweighted proportions).⁴

Injury and death by region

Mortality and injury rates varied significantly by region, sex and age. Injury and mortality rates were significantly lower along the East Coast than the West Coast and Banda Aceh/Aceh Besar areas. The highest mortality rate was 23.6% (95% CI = 17.8–29.4) in Aceh Jaya. In the Banda Aceh/Aceh Besar districts, the mortality rate was 22.9% (95% CI = 19.0–26.8). The lowest mortality, at 5.3% (95% CI = 1.3–8.0), was in the East Coast districts of Pidie, Biruen, and Aceh Utara. In general, injury

rates did not correlate with death rates. Injury rates among the three survey areas were Aceh Jaya, 6.9% (95% CI = 5.9–8.1); Banda Aceh/Aceh Besar, 10.0% (95% CI = 9.0–11.0); and East Coast, 8.0% (95% CI = 6.9–9.2).

Injury and death by sex

Overall, the odds of dying were 1.41% (95% CI = 1.27–1.58) times greater for females when compared to males. However, the risk of injury was opposite, with an odds of injury of 0.81% (95% CI = 0.69–0.96) for females compared to males. Risk of death was significantly greater for females than males in all survey areas: West Coast, 1.6; Banda Aceh, 1.2; and East Coast, 1.5 ($p < 0.05$ for all comparisons). Age and sex specific injury rates by survey region are shown in Table 1. Among survivors in all survey areas, injury rates for males were 11.5% (CI = 10.4–12.6), and 9.7% for females (CI = 8.9–10.8).

Injury and death by age

When assessed by age intervals, mortality and injury rates had an inverse relationship. The age groups with the highest mortality had the lowest injury rates. Injury was least commonly reported, and mortality greatest, among children 0–9 years and adults over 60. Conversely, the highest injury rates and lowest mortality rates were observed among persons aged 20–29 and 30–39 (see Figure 2). Sex-specific injury rates were lower among females than males. However, differences were statistically significant in only two of five age groups.

Injury types, care seeking, and outcomes

Of the 707 persons that reported injuries, 661 (93%) reported details, such as the type of injury, care sought, and treatment outcomes (see Table 2). The most frequent injuries were lacerations, fractures, and aspiration/near drowning. Near drowning was not separately asked in the first survey, but was specifically asked in the later surveys, on the East Coast and in Aceh Jaya. In these two surveys, the frequency of aspiration/near drowning was 8.3% (CI = 5.5–11.8). For injuries, the majority of individuals sought treatment at clinics (63%), while 14% were hospitalised, and 21%

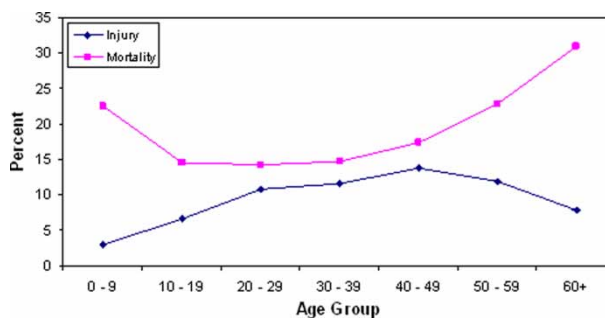


Figure 2. Tsunami injury and mortality rates by age group in Aceh province, Indonesia ($n = 7392$).

Table 2. Tsunami injury types and related care seeking and injury outcomes in Aceh, Indonesia.

Injury type (<i>n</i> = 623)	<i>N</i>	Percent (CI)	Care seeking (<i>n</i> = 611)**		Outcome (<i>n</i> = 604)		Percent (CI)	
			<i>N</i>	Percent (CI)	<i>N</i>	Percent (CI)		
Laceration	529	74.8 (71.5–78.0)	No treatment	127	20.8 (17.6–24.2)	Recovered	489	81.0 (77.6–84.0)
Not infected	374	52.9 (49.1–56.6)	1 clinic visit	57	9.3 (7.1–11.9)	Some loss	83	13.7 (11.1–16.7)
Infected	155	21.9 (18.9–25.2)	2–4 clinic visits	174	28.5 (24.5–32.2)	Full loss	4	0.7 (0.2–1.7)
Fracture	59	8.3 (6.4–10.6)	5+ clinic visits	169	27.7 (21.1–31.4)	Death	28	4.6 (0.3–6.6)
Other*	119	16.8 (14.2–19.8)	Hospitalisation	84	13.7 (11.1–16.7)			
Total by type	707	100.0						

*Note: Aspiration/lung injury is included in other injuries; a total of 28 aspiration/lung injuries were reported in the East coast and West coast surveys; information on aspiration/lung injury was not captured in the Banda Aceh survey.

**Reported by the most care or highest level of care sought for any reported injury.

reported not seeking care from the formal health system. It is not clear whether this represented a conscious decision not to seek care, or whether there were no functioning facilities available. Of the 14% of injured that were hospitalised, the mean length of stay was 18 days (median 7; range = 0–240), and 19.8% (*n* = 18) reported one or more surgical procedures. A total of 28 deaths as a result of injury were reported, with a 4.5% (CI = 3.0–6.5) case fatality rate among the injured. Mortality rates among the injured were similar across survey regions, but varied significantly by age ($p < 0.001$). The case fatality rate from injuries was 25% (CI = 9–51) among those aged 0–5 years; 9% (CI = 4–18) among those aged 5–14; 2% (CI = 0–8) among 45–59 year olds; and 9% (CI = 2–24) for those 60 and above.

Discussion

Injury data is rarely collected after disasters, often because the formal health sector has collapsed and services are not readily available. Emergency services, established by international NGOs and foreign military deployments, might not be integrated into a host country's information system, or might not participate fully in the emergency information system (assuming that one is established). Even when the host health system remains partially or fully functional, the information system may suffer in a time of crisis. Facility-based data, given limited access or underutilisation by the affected population, are likely to under-report injuries, and may lead to a lack of preparedness for the care of injuries in future emergencies, particularly those of a mild to moderate nature. The relationship of tsunami mortality and injury rates was affected by a variety of factors. The risk factors of most importance included geographic location, age and sex, which concur with other assessments of injury and mortality risk in the Asian tsunami (Guha-Sapir *et al.* 2006).

Injury and mortality by region

Crude mortality rates, in the Aceh Jaya and Banda Aceh/Aceh Besar survey areas, were around 23%, and much higher than the 5% observed in the East Coast survey region, where the effects of the tsunami waves were attenuated by distance and geography. However, injury rates were relatively similar in the three survey area, and ranged from 7 to 10%. Extrapolating sample injury rates to displaced populations in each region, we estimated the number of injured in each survey areas as follows: Aceh Jaya, 1300; Banda Aceh/Aceh Besar, 11,092; and East Coast, 9705.

In Aceh Jaya, the proportion of the population lost was much greater than in other areas of Aceh; in addition, the district had heavy infrastructure devastation, including destruction of the main coastal road (Brennan and Rimba 2005). This may have resulted in a disproportionately high number of severe injuries and extreme limitations in access to medical care, and, consequently, an under-reporting of injuries in the hardest hit areas. In comparison, mortality rates among the tsunami-affected population in Banda Aceh/Aceh Besar were similar to Aceh Jaya, but a larger proportion of the total population survived in Banda Aceh/Aceh Besar. Higher injury rates in this region could be attributed to lower overall mortality, which resulted in a larger surviving proportion of the population that could have been injured. In addition, Banda Aceh was the focal point of the first international relief efforts, which included several field hospitals, and had the most extensive health infrastructure in the region, which likely resulted in better access to care. In the East Coast survey area, where tsunami impact produced relatively less mortality and infrastructure destruction, the injury rates were intermediate. This may be a reflection of the lower overall mortality rates with the lesser magnitude of the tsunami, resulting in milder injuries. In the East Coast area, major roads and health facilities were not severely affected, and access to care may have made it possible for more severely injured people to have survived.

Injury and death by sex

Among those exposed to the tsunami, injury rates were significantly greater among males than females. Among survivors, the frequency of injury was statistically similar by sex, at 11.5 and 9.7% among males and females, respectively. When interpreting overall injury rates, differential mortality between the sexes must be considered: nearly two-thirds of those reported dead or missing were female, and females were 1.41 times more likely than males to die in the tsunami. Because females were less likely to survive the tsunami, they were also less likely to be categorised as injured when the rates describe the exposed (versus surviving) population. When assessed by survey region, the risk of injury was lower among females than males in the highest impact areas (Banda Aceh/Aceh Besar and Aceh Jaya), and in the lesser affected East Coast region, the opposite was observed where females faced increased injury risk.

Injury by age

The highest injury rates were concentrated in the middle age groups, which also had the greatest survival rates, while the lowest prevalence of injury was observed among

those at the beginning and end of the lifespan, who also experienced the most significant mortality. Age-specific death rates followed a fairly normal shaped (albeit greatly elevated) J-curve, with the highest mortality among the youngest children and the oldest adults; injury rates mirrored death rates as an inverted J-curve, where injury was most prevalent among those in the middle of the lifespan (see Figure 2). These findings are not unanticipated, where overall injury rates would be expected to be the greatest among populations with higher survival rates.

Injury types, care seeking, and outcomes

The most frequent types of injuries were lacerations and fractures, which corresponds with injury patterns reported in Thailand and Sri Lanka (Guha-Sapir *et al.* 2006, Johnson and Travis 2006). Near drowning/aspiration was reported separately in the East Coast and West Coast surveys, and accounted for 8.3% of injury in those areas; lung injury is not unexpected in this context, and was documented in the 2004 Asian tsunami (Allworth 2005). The majority of the injured (63%) received outpatient care, which, in most cases, included multiple visits to health clinics. A significant proportion (14%) reported hospitalisation, with 20% reporting one or more surgical procedures. Inaccessibility of secondary or tertiary care was likely a contributing factor to increased injury-related mortality in areas without functioning hospitals.

Extrapolating sample percentages, to the total number of injured (22,097), resulted in an estimated 3094 hospitalisations and 613 surgical cases. While this is likely an under-estimate of tsunami injury (see limitations), it represents a significant burden to a health system that was devastated by the tsunami, both in terms of damage to physical infrastructure and loss of health workers. Of those reporting injuries, 13.7 and 0.7% reported some or complete loss of function, respectively. Combining these figures, it can be estimated that 14.4% of the injured, and 1.2% of the pre-tsunami population at risk, may suffer from disability or reduced function as a result of the tsunami. Applying these rates to the total tsunami-exposed population, an estimated 3181 individuals may have been disabled due to tsunami-related injuries. This could have important implications for the recovery effort, as those with physical disabilities, as well as those with psychosocial trauma, will be less able to contribute to reconstruction, and will place more demands on the weakened health system.

Limitations

There are several limitations to this study. First, the study focuses on displaced households, and may not be generalisable to the broader tsunami-affected population. Second, households where no adult member survived had no way of being included in the survey, thereby creating a survivor bias. This bias is likely to be relatively low on the East Coast, but quite pronounced in areas along the West Coast, particularly Aceh Jaya, where reports indicate that the tsunami may have killed up to 70% of the population (Doocy *et al.* 2007a). Consequently, injury rates may be over-estimated because populations that suffered the greatest injury and mortality were also the most likely to be displaced, while the total number of injured

is likely to be underestimated because non-displaced households were excluded from the reference population.

The surveys were conducted at different times over a seven-month period, which could have had an effect on recall error. It is also possible that households that remained displaced after the passage of more than six months might have had different injury and mortality experiences than those that returned earlier to their villages. However, because construction of permanent housing was not complete at the time of the surveys, the vast majority of households initially classified as displaced would have that same classification, even if they had returned to their original villages of residence but resided in temporary structures, thus, it is likely that the tsunami-displaced population is relatively similar to the tsunami-affected population.

Respondents were asked to report injuries of household members, but the severity of the injuries was not reported, so differential reporting of minor injuries may have influenced findings. It is possible, but unlikely, that injuries were a result of the earthquake that preceded the tsunami; both the types of injuries reported, key informants, and general perceptions from the area, indicate that nearly all injury and mortality were attributable to the tsunami. Lastly, the survey was not able to capture cause of death, or the proportion of individuals who died within several days of the tsunami as a consequence of injury, because this information was unknown to many respondents (identification of bodies was not systematically conducted, many individuals were reported as missing, and often family members did not view corpses).

Conclusions

The differential risks presented by the tsunami in Sumatra were, first and foremost, geographical, and, while mortality rates varied greatly, prevalence of injury was relatively similar among the survey areas and was estimated at 8.5%. Because males had greater odds of survival, they may have been more likely to survive their injuries than females. Injury rates were also highest among younger to middle age adults, and lower in the oldest and youngest age groups; this is also a reflection of mortality risk, where the population in the middle of the life span were most likely to survive. Finally, and perhaps most significant in terms of longer-term impact on the population, is the disability burden that resulted from the tsunami.

Acknowledgements

We would like to acknowledge Mercy Corps for providing the logistical support required to conduct this research. We would also like to acknowledge the survey team members, including Eric Spring, Scott Bradley, Anita Shankar, and Bahie Rassekh, as well as the Indonesian interviewer teams and translators who aided in the data collection process and other aspects of the study. Lastly, we would express our appreciation to Dr. Adnan Hyder for his comments and recommendations.

Notes

1. See Doocy *et al.* (2007a, 2007b) for a complete discussion of tsunami mortality.
2. Tsunami displaced populations were identified during the response and included individuals who lost their homes or were displaced within their own communities, in

host communities, or in barracks or camps; see Doocy *et al.* (2007b) for a more detailed description of sampling methods.

3. Weighted calculations were based on population estimates of tsunami-affected communities derived by the Asian Development Bank and applied to the nine districts surveyed.
4. Rates reflect immediate tsunami mortality and injury; see Doocy *et al.* (2007b) for a complete discussion of tsunami mortality.

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