

Tsunami mortality in Aceh Province, Indonesia

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Objective Nine tsunami-affected districts in Aceh, Indonesia, were surveyed between February and August 2005 to characterize tsunami mortality.

Methods The surveys employed a two-stage cluster methodology with probability proportional to size sampling, and encompassed 1653 tsunami-displaced households with a pre-tsunami population of 10 063 individuals.

Findings Of the original pre-tsunami population, a total of 1642 people, or 17%, were reported as dead or missing in the tsunami. Crude mortality rates in the four survey areas ranged from a high of 23.6% in Aceh Jaya district on the west coast to 5.3% on the east coast. Age-specific mortality rates followed a similar pattern across the four survey areas, with the highest mortality concentrating in the youngest children (aged 0–9 years) and oldest adults (70+). The risk of mortality was significantly greater among females than males; this difference was most pronounced among individuals between ages 10 and 69 years, and diminished among younger and older age groups.

Conclusion Mortality risk in the 2004 Asian tsunami varied by geographic location, age and sex. The districts of Aceh Jaya, Banda Aceh and Aceh Besar experienced the greatest mortality. Risk of death was highest among females, and among the oldest and youngest population subgroups. While the full human impact of the Asian tsunami in Aceh Province, in terms of lives lost or damaged, may never be fully measured, the resulting female deficit will likely be the tsunami's most deeply felt and prolonged impact.

Bulletin of the World Health Organization 2007;85:273-278.

Une traduction en français de ce résumé figure à la fin de l'article. Al final del artículo se facilita una traducción al español. الترجمة العربية لهذه الخلاصة في نهاية النص الكامل لهذه المقالة.

Introduction

On Sunday morning, 26 December 2004, an earthquake registering 9.0 on the Richter scale struck off the western coast of north Sumatra, triggering massive waves that devastated coastal regions throughout the Indian Ocean rim. Indonesia's Aceh Province suffered the greatest mortality, with widespread destruction extending along more than 1000 km of coastline. Approximately one year after the tsunami, Indonesian government estimates indicated 129 775 deaths, 38 786 missing and 504 518 tsunami-displaced in Aceh Province.¹

Beginning in February 2005, Johns Hopkins Bloomberg School of Public Health, with the local support and cooperation of Mercy Corps, conducted four rounds of household surveys in nine tsunami-affected districts of Aceh Province. The surveys covered essentially the entire coastline from Nagan Raya and Aceh Barat districts on the south-western coast to Aceh Utara on the eastern coast (see Fig. 1). The study aimed to measure

tsunami mortality and injury as well as the needs and current status of the surviving displaced population, and we report our results in this paper.

Methods

Assessments of tsunami-displaced populations aimed to characterize the tsunami's impact as well as the status and needs of surviving internally displaced populations (IDPs). All surveys employed a similar design and survey instrument so that results from the different survey areas could be aggregated. Separate surveys were conducted for logistical purposes and were based on the best available information on displaced populations at the time of implementation, which usually included information from the Humanitarian Information Centre (HIC) and district officials.

The February survey encompassed the districts of Aceh Barat and Nagan Raya, which had reference population of 26 905 IDPs²; four subdistricts within the survey area with an estimated 4428

IDPs were excluded due to inaccessibility and reported insecurity. The March survey of Banda Aceh and Aceh Besar was limited to two districts because of the large reference population of 215 379 IDPs residing in those districts. The July survey encompassed Pidie, Biruen, Aceh Utara and Lhoksumawe, with a total reference population of 152 348 IDPs; the subdistrict of Maura Batu in Aceh Utara was excluded because the survey team could not obtain permission from local authorities to conduct interviews. The final survey, in August 2005, was in the district of Aceh Jaya with a reference population of 40 422 IDPs; the subdistrict of Teunom was excluded because it was difficult to reach by road and NGOs working in the area reported that few IDPs remained there.

Two-stage cluster surveys employing probability-proportional-to-size sampling methodologies were used. Sampling was conducted based on lists of known locations of IDPs using standard cluster sampling methods to identify

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doi:10.2471/BLT.06.033308

(Submitted: 8 June 2006 – Final revised version received: 22 August 2006 – Accepted: 24 August 2006)

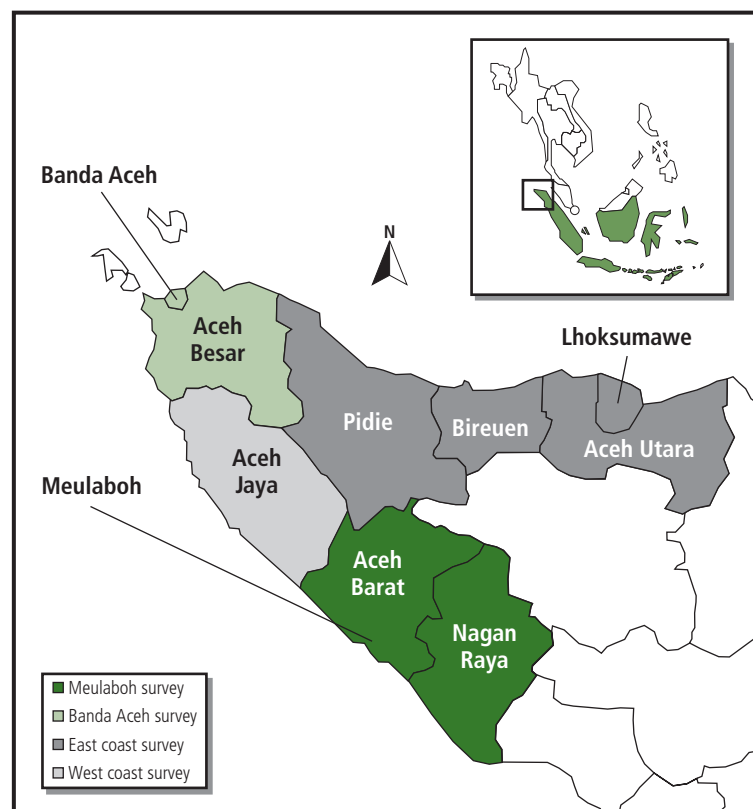
locations where interviews would occur. In the case of the first survey in Aceh Barat/Nagan Raya, the sample was apportioned equally between households living in IDP camps and households living with host families, based on the best available local information at the time of the survey. In later surveys, when displaced populations were reported by settlement type, clusters were identified strictly on the basis of probability sampling from lists of known IDP locations, which included host communities.

In the Banda Aceh/Aceh Besar survey, a 20×24 cluster design was used; in all other surveys, a 20×20 cluster design was used. Upon implementation, it was observed that the actual IDP populations were significantly different from the official estimates. In cases where displaced populations could not be identified in the selected IDP locations, the closest known IDP populations or settlements were sampled; to maintain appropriate geographical distribution, sampling was always conducted in the originally selected subdistrict. IDPs were residing in IDP camps (typically, temporary tent communities), in barracks (semi-permanent wooden structures) or in homes within host communities.

Displaced population information was always reported by settlement type, and interviews were conducted proportionally to subdistrict estimates from local authorities. 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. Self-settled IDP households that were residing in host communities were identified by randomly selecting a direction from a central point within the community (usually the mosque), proceeding to the nearest house, and enquiring if any IDPs were being hosted. Each adjacent house was visited until the requisite number of households was interviewed.

IDP household information was collected using questionnaire-based interviews. Mortality information was collected by asking respondents to list all household members on the day preceding the tsunami and then to provide their age, sex and post-tsunami status. Post-tsunami status was recorded as alive and residing in the household, alive and residing outside of the household, dead or missing. For the mortality analysis,

Fig. 1. Tsunami-affected areas of Aceh and survey regions



these four categories were reduced to a dichotomous variable of alive or presumed dead (dead or missing).

The questionnaire was developed in English and translated into Bahasa. Back-translation and field-testing were carried out with local assistance by Mercy Corps. Most of the interviewers were Acehnese university students. All interviewers received two days of training before the survey and participated in field-testing the questionnaire. Data analysis was performed using STATA Version 8 and SPSS Version 12.0. Cluster-level summary measures³ were used to calculate standard errors that allowed for clustering of observations due to the survey design; 95% confidence intervals (CIs) were developed based on these standard errors for point estimates of mortality.

Permission to conduct the surveys was obtained from local authorities in Aceh province, including both the Ministry of Foreign Affairs and the police department. Informed verbal consent was obtained from each respondent before interviews were conducted. The study was approved by the Johns Hopkins Bloomberg School of Public Health's Committee on Human Research.

Results

The four surveys of tsunami-displaced populations included a total of 1653 households (Meulaboh $n=388$, Banda Aceh $n=478$, east coast $n=400$, west coast $n=387$) with a total pre-tsunami population of 10 063 individuals, of which age and sex were reported for 9451. Of the original pre-tsunami population, 1642 people, 17% of household members, were reported as dead or missing in the tsunami. A total of 597 households, 36.1% of the total, reported one or more persons dead or missing.

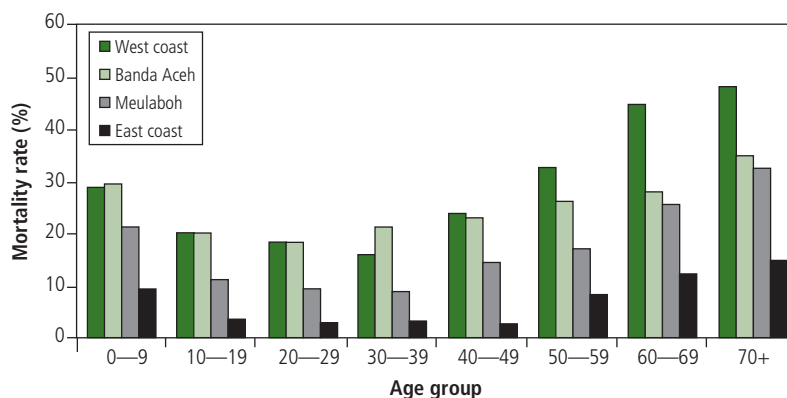
Crude mortality rates in the four survey areas varied significantly. The highest mortality rate (here expressed as a percentage of household members exposed to the tsunami who died or went missing during the tsunami) was 23.6% (95% CI: 17.8–29.4) in Aceh Jaya district on the west coast. In the Banda Aceh/Aceh Besar districts, crude mortality was 22.9% (95% CI: 19.0–26.8), while in the Meulaboh survey, covering Aceh Barat and Nagan Raya districts on the south-western coast, overall mortality was 13.9% (95% CI: 8.4–19.4). The lowest mortality, 5.3% (95% CI: 1.3–8.0), was reported in the east coast

survey, covering Pidie, Biruen and Aceh Utara districts.

Given the different levels of overall mortality, age-specific mortality rates followed a similar pattern across the four survey areas (see Fig. 2) with the highest mortality concentrating in the youngest children (aged 0–9 years) and oldest adults (70+) and lower mortality found among older children (10–19 years) and younger adults (20–39 years). The risk of mortality was greater among females than males in all survey areas. Risk of death for females as compared to males in the four survey areas was as follows: Meulaboh: 2.1; west coast: 1.6; Banda Aceh: 1.2; and east coast: 1.5 ($P < 0.05$ for all comparisons).

Aggregating and weighting data were based on estimates of pre-tsunami population size; weighted calculations were based on population estimates of tsunami-affected communities derived by the Asian Development Bank and applied to the nine districts surveyed. These data from all four surveys enabled us to estimate crude mortality among tsunami-displaced households at 14.1%. The weighted male mortality rate (all ages) was 12.0% and the weighted female mortality rate was 16.4%; the risk of death was 1.4 times higher for females than for males. Comparison of aggregated age-specific mortality rates for males and females (see Fig. 3) indicates that the sex-specific mortality rates differed between the ages of roughly 10 to 69. Among younger children, the sex-specific mortality differences grew less pronounced, especially between the ages of 0–4 years, where tsunami mortality among boys was 25.4% and among girls, 24.1%. Similarly, for adults aged 70 years and over, there appeared to be

Fig. 2. Age-specific tsunami mortality rates by survey area ($n = 1,653$ households with at least one surviving adult member)



little difference in tsunami mortality patterns for males and females.

Discussion

The data presented in this paper are the mortality among sample households and reflect mortality rates among surviving tsunami-displaced households (versus district- or province-level mortality rates).

The present study estimated tsunami mortality among displaced populations in Aceh province at 14.1%. Mortality data available from other sources are limited to counts of dead or missing and rapid assessments (i.e. rates are not presented). When mortality rates from the current surveys were extrapolated to the displaced population in Aceh province, total tsunami mortality was estimated at 131 066. This finding is similar to official figures from the United Nations and Indonesian government of 129 755 dead; however, it is a conservative estimate of actual mortality and is substantially less than the official estimates of 168 561 presumed

dead that includes those classified as missing.¹

Mortality rates

Crude death rates for the four survey areas ranged from a high of 23.6% in Aceh Jaya district on the western coastline close to the earthquake epicentre, to 5.3% in districts along the east coast of Aceh province, where the effects of both the earthquake and the tsunami waves were attenuated by distance and geography. Within days of the tsunami, it was feared that mortality might have been exceptionally high in Aceh Jaya district. A rapid health assessment conducted by the International Rescue Committee (IRC) in the city of Calang in January 2005 reported that local government officials were estimating that 70% of the town's population had perished in the tsunami; the IRC study had found that, of 316 households surveyed, over 65% had reported at least one death of an immediate household member as a result of the tsunami.⁴

The high mortality rates found in Banda Aceh and Aceh Besar districts (22.9%) may be due to several factors. The earthquake and the flooding that ensued not only churned through densely populated urban areas but also churned up millions of tonnes of concrete, brick, wood, glass and metal. In addition, the Banda Aceh/Aceh Besar area is situated on alluvial flood plain and the relatively slow elevation increase resulted in flooding that extended further inland than in other survey areas with greater elevation change. In Aceh Barat and Nagan Raya districts, though overall mortality was high (13.9%), subdistrict mortality rates varied considerably from a low of 1.8% in Bubon, whose western-most

Fig. 3. Age and sex specific mortality rates among tsunami-displaced households

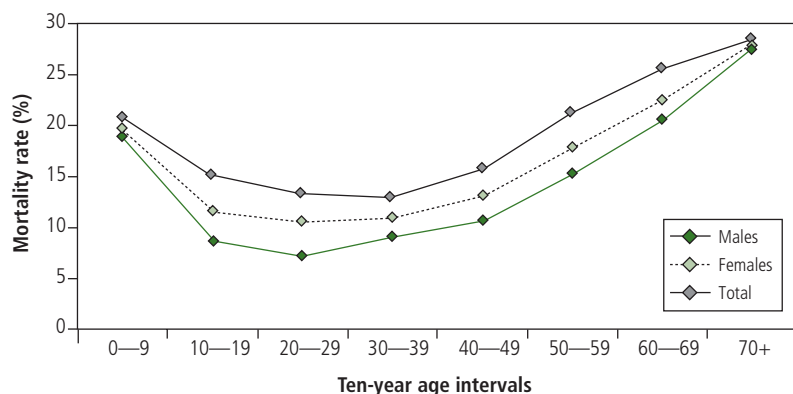


Table 1. Age and sex-specific mortality in the sample population

Age group	Males				Females				Overall			
	Sample population by age	Deaths by age	Unadjusted age specific mortality (%)	Adjusted age specific mortality (%)	Sample population by age	Deaths by age	Unadjusted age specific mortality (%)	Adjusted age specific mortality (%)	Sample population by age	Deaths by age	Unadjusted age specific mortality (%)	Adjusted age specific mortality (%)
0–9	921	193	17.3	19.1	908	212	18.9	20.6	1829	405	18.1	19.8
10–19	1123	118	9.5	8.7	1043	181	14.8	15.0	2166	299	12.1	11.7
20–29	920	85	8.5	7.2	1052	174	14.2	13.3	1972	259	11.6	10.5
30–39	739	84	10.2	9.1	745	114	13.3	12.8	1484	198	11.8	11.0
40–49	475	65	12.0	10.6	458	88	16.1	15.8	933	153	14.1	13.2
50–59	291	52	15.2	15.2	246	63	20.4	21.2	537	115	17.6	17.9
60–69	204	54	20.9	20.6	142	42	22.8	25.5	346	96	21.7	22.6
70+	92	30	24.6	27.8	92	31	25.2	28.4	184	61	24.9	28.1
Total	4765	681	12.5	12.0	4686	905	16.2	16.4	9451	1586	14.4	14.1

boundary lies more than 10 km from the coastline, to a high of 33.1% in Samatiga, a subdistrict with a lengthy coastline.

Although the levels of crude mortality differed by geographical area, all four studies found that age-specific death rates followed a fairly conventional (albeit greatly elevated) J-curve of mortality, with highest mortality among the youngest children and the oldest adults. The data support the view that the tsunami harmed most those who were least able to withstand its force.^{5,6}

Tsunami mortality among males and females also differed significantly, with females accounting for nearly two-thirds of those reported dead or missing. Taking all ages together, females were 1.44 times as likely to die in the tsunami. Anecdotal impressions reported shortly after the tsunami noted a dearth of women and children among the survivors. One nongovernmental organization⁷ offered this explanation, drawn from interviews with survivors:

“In rural coastal areas, many men who were fishing far out at sea survived, as the giant waves passed harmlessly under their small boats. When the waves hit the shore, they flattened coastal communities and killed many of the women and children, most of whom were at home on that Sunday morning. In agricultural areas, men were often working out in the fields or doing errands away from the house, or were taking produce to markets ... The sheer strength needed to stay alive in the torrent was often also decisive in determining who survived.

Many women and young children, unable to stay on their feet, or afloat, in the powerful waves, simply tired and drowned. Women clinging to one or more children would have tired even more quickly.”

Where physiological differences combined with gendered social or behavioural patterns, male and female mortality differed significantly, with the disadvantage always going to the females. However, at the extremes of age, particularly children aged 0–4 years and among adults aged 70 years or over, sex-specific mortality differences seemed to disappear.

Limitations

In assessing the mortality impact of the tsunami in Indonesia, there are several limitations to this study. First, the surveys were conducted at different times over a 7-month period, which could have had an effect on recall error. Second, the study focuses on displaced households only and its conclusions may not apply to the broader tsunami-affected population. It is likely that people who lost their houses to the tsunami would be more likely to have lost household members as well. If this is so, the survey would probably overestimate tsunami mortality rates among a larger population. Conversely, mortality among households that were not displaced is likely to be significant and is not captured in the study. Third, households where no adult member survived had no way of being included in the survey, thereby creating a survivor bias. This bias might be low on the east

coast, where overall mortality was lower, but it might be quite pronounced in areas along the west coast, particularly Aceh Jaya, where government reports indicated that the tsunami might have claimed up to 70% of the population in some areas.

The mortality rates presented here reflect mortality among tsunami-displaced populations only and do not attempt to adjust for mortality among households that were not displaced or those that were excluded as a result of survivor bias. Estimates of survivor bias were developed with regression models that were based on village-level comparisons of household survival ratios to individual survival ratios. Preliminary estimates suggest that adjusting for a survival bias could increase overall mortality by as much as 10%. Combining this figure with our sample-derived crude mortality estimate of over 14% means that the tsunami could have killed up to 25% of the population at risk.

Conclusions

As of December 2005, in the nine districts included in the four surveys, an estimated 163 650 people were reported either killed by the tsunami (129 775) or missing subsequently (38 786). According to both Indonesian government and United Nations estimates, tsunami mortality in these nine districts accounted for 97.5% of all tsunami mortality in Aceh Province.¹ Although our study is limited by its focus on displaced households, and by survivor bias that was undoubtedly significant in high-impact

areas, the data present a plausible picture of tsunami mortality in Aceh Province. Mortality surveys are useful for a variety of reasons in post-disaster contexts; in the case of the tsunami, the survey provided information on differential mortality impact and changes in household structure, which helped to inform nongovernmental organizations' responses. In future post-disaster assessments, it would be ideal to implement one survey (as compared to four) that encompasses the entire disaster-affected population so results are available in a more timely fashion and are easier for nongovernmental organizations and international organizations to interpret.

The differential risks presented by this enormous natural disaster were, first and foremost, geographical. Anyone too close to the shoreline on the western coast of Aceh on the morning 26 December 2005 had poor odds of survival. But age too played an important role, as it does in more mundane life-and-death scenarios. Finally, and perhaps most significantly in terms of longer-term demographic impact, females faced a higher risk in all but the youngest and oldest age groups. The full human impact of the Asian tsunami in Aceh province, in terms of lives lost or damaged, may never be fully measured,

but certainly the female deficit, whether measured in households or in communities, may be the tsunami's most deeply felt and prolonged impact. ■

Acknowledgements

We would like to thank Mercy Corps for providing logistical support required to conduct this research. We would also like to acknowledge all the survey team members, especially the field survey coordinators, who aided in the data-collection process and other field-related aspects of the study.

Conflicts of interest: None declared.

Résumé

Mortalité due au tsunami dans la province de l'Aceh en Indonésie

Objectif Des enquêtes ont été réalisées entre février et août 2005 dans neuf districts touchés par le tsunami afin de déterminer les caractéristiques de la mortalité due à cette catastrophe.

Méthodes Les enquêtes ont fait appel à une méthode d'échantillonnage en grappes à deux degrés avec une probabilité proportionnelle à la taille de l'unité d'échantillonnage et couvraient 1653 foyers déplacés en raison du tsunami, l'ensemble de la population de ces districts avant le tsunami représentant 10 063 individus.

Résultats Parmi la population de départ avant le tsunami, 1642 personnes au total (soit 17 %) ont été signalées comme mortes ou disparues après la catastrophe. Les taux de mortalité bruts dans les quatre zones servant de cadre à l'enquête allaient de 23,6 % dans le district d'Aceh sur la Côte ouest à 5,3 % sur la côte est. Les taux de mortalité spécifiques par âge obéissaient à un schéma de répartition similaire dans les quatre zones d'enquête, les plus forts taux de mortalité concernant les jeunes enfants

(0 à 9 ans) et les personnes âgées (70 +). Le risque de mortalité était significativement plus élevé chez les femmes que chez les hommes, cette différence étant plus prononcée chez les individus entre 10 et 69 ans et plus faible parmi les jeunes et les tranches d'âges plus élevés.

Conclusion Le risque de mortalité comme conséquence du tsunami qui a ravagé l'Asie en 2004 était fonction du lieu géographique, de l'âge et du sexe. Les districts d'Aceh Jaya, de Banda Aceh et d'Aceh Besar ont supporté les plus forts taux de mortalité. Le risque de décès le plus élevé se rencontrait chez les femmes et chez les sous-groupes de population correspondant aux plus jeunes et aux plus âgés. S'il se peut que l'impact total, en termes de vies perdues et des destructions, de ce tsunami dans la province d'Aceh, ne soit jamais être mesuré, le déficit de femmes sera probablement la conséquence la plus intensément ressentie et la plus durable.

Resumen

Mortalidad causada por el maremoto en la provincia de Aceh, Indonesia

Objetivo Entre febrero y agosto de 2005 se estudió la situación de nueve distritos afectados por el maremoto en Aceh, Indonesia, a fin de determinar la mortalidad asociada a esa catástrofe.

Métodos Las encuestas, en las que se empleó una metodología por conglomerados en dos etapas con probabilidad proporcional al tamaño de la muestra, abarcaron en total a 1653 familias desplazadas por el maremoto, que suponían una población de 10 063 personas antes de la catástrofe.

Resultados De la población original, un total de 1642 personas, equivalente al 17%, fueron declaradas muertas o desaparecidas tras el maremoto. Las tasas brutas de mortalidad en las cuatro zonas estudiadas oscilaron entre un máximo de 23,6% en el distrito de Aceh Jaya en la costa oeste y el 5,3% registrado en la costa este. Las tasas de mortalidad por edades mostraron un patrón similar en las cuatro zonas analizadas, concentrándose la mayor mortalidad en los niños pequeños (de 0 a 9 años) y los adultos

viejos (≥ 70 años). El riesgo de mortalidad fue considerablemente mayor entre las mujeres que entre los hombres, y esa diferencia fue más pronunciada entre las personas de 10 a 69 años que en los grupos de edad más joven y más viejo.

Conclusión El riesgo de mortalidad en el maremoto que asoló Asia en 2004 guarda relación con el lugar geográfico, la edad y el sexo. Los distritos de Aceh Jaya, Banda Aceh y Aceh Besar son los que presentaron la mayor mortalidad. El riesgo de defunción fue máximo entre las mujeres y entre los subgrupos de población más viejo y más joven. Aunque es posible que nunca se logre medir de forma fiable el impacto humano del maremoto asiático en la provincia de Aceh en términos de vidas perdidas o personas lesionadas, el déficit resultante de mujeres constituirá probablemente la repercusión más profunda y prolongada de esa catástrofe.

ملخص

وفيات التسونامي في إمارة آسيه في أندونيسيا

مع أعلى معدل للوفيات متركز في أصغر الأطفال عمراً (5-9) سنوات وفي أكبر الأعمار (فوق سن السبعين). وقد كان خطر الموت أكبر وبشكل واضح بين النسوة مما لدى الرجال، وكانت الفروقات أكثر وضوحاً بين الأفراد الذين تتراوح أعمارهم بين 10 و69 سنة، وتتضاءل بين المجموعات الأصغر عمراً أو الأكبر عمراً.

الاستنتاج: اختلفت أخطار الموت في التسونامي الآسيوي عام 2004 باختلاف المواقع الجغرافية والعمر والجنس، وقد عانت مناطق جايا آسيه وباندا آسيه وآسيه بيزار من أكثر معدلات الوفيات. وقد كان خطر الموت الأكثر ارتفاعاً بين الإناث وكبار السن وصغار الأطفال. ورغم أن تأثر الناس بالتسونامي الآسيوي في إمارة آسيه لا يمكن قياسه بشكل كامل من حيث عدد الأموات أو حجم الأضرار فإن النقص الناتج في أعداد الإناث قد يكون أكثر آثار التسونامي التي سوف يعاني منها الناس على المدى الطويل.

الهدف: أجرينا مسحاً لتسع مناطق متضررة بالتسونامي في إمارة آسيه في أندونيسيا، وذلك في الفترة بين شباط/فبراير وآب/أغسطس 2005 لتوصيف وفيات التسونامي.

الطريقة: اتبعنا في المسح منهجية المجموعة العنقودية ذات المرحلتين وذات احتمال متناسب مع حجم العينة، وتضم 1653 من السكان النازحين بسبب التسونامي مع 10 063 من الأفراد قبل التسونامي.

الموجودات: من بين السكان الأصليين الموجودين قبل التسونامي، أبلغ عن 1642 منهم أو ما يعادل 17% منهم أنهم موق أو مفقودون أثناء التسونامي. وكانت المعدلات الخام للوفيات في المناطق الأربعة التي أجري فيها المسح تتراوح بين أعلى قيمة في مقاطعة آسيه جايا في الساحل الغربي (23.6%) و5.3% في الساحل الشرقي. وقد نهجت معدلات الوفيات الخاصة بعمر معين النموذج نفسه في جميع المناطق الأربعة التي أجري فيها المسح،

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