Fact-Finding about the Evacuation from the Unexpectedly Large Tsunami of March 11, 2011 in East Japan

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SUMMARY:
Almost twenty thousand people died in a region where the disaster preparedness level was thought to be relatively high. The truth about why so many people had to die was surveyed to extract lessons for the community, municipalities and the next generation. About 1,350 evacuees in two typical areas were interviewed or subjected to a questionnaire. One of the areas was Yamada-machi which had a sawtooth coastline. The other was the coastal area of west of Ishinomaki-shi which comprised flat land along Sendai bay. The major findings are: 1) The age distribution of the dead was concentrated in the 60's-80's. 2) Young families of these old persons went back home to rescue their parent, and some of them were washed away. 3) Experience of past tsunami disaster was not always helpful. Well prepared disaster education has to cover the deficit. 4) Car evacuation cannot be inhibited at all.

Keywords: Great East Japan Earthquake, tsunami, evacuation, interview, questionnaire

1. INTRODUCTION

Almost twenty thousand people died due to the giant tsunami caused by the Great East Japan Earthquake, even though the earthquake occurred in daytime, the tsunami took at least half an hour to arrive at coast line and people in the region should have been at a relatively high disaster preparedness level. The purposes of this survey were to find the truth about why so many people had to die and to extract lessons for the community, municipalities and the next generation.
At the beginning of the survey, a group was established consisting of researchers and engineers who were interested in determining the facts about the people's evacuation from the giant tsunami. The group was chaired by Professor Imamura of Tohoku University. It was separated into several task teams, which were assigned to different areas to avoid further traumaizing evacuees by overlap of the survey.

Our task team was assigned to Yamada-machi and Ishinomaki-shi. The member of the task team is listed below. All of them are co-authors of this paper.

Table 1.1 The task team for Yamada-machi and Ishinomaki-shi (Alphabetical order)

Ikuo Abe	Fuji-Tokoha Univ.	Tetsuo Morita	Gunma National College of Tech.
Junya Fukuoka	Eight-Japan Engineering Consultant	Hitomi Murakami	Yamaguchi Univ.
Yozo Goto	ERI, Univ. of Tokyo	Itsuki Nakabayashi	Meiji Univ.
Shoji Hasegawa	JICA	Shigeki Nakamura	Nihon Univ.
Taro Ichiko	Tokyo Metropolitan Univ.	Yujiro Ogawa	ITRI, Univ. of Tokyo
Hirotaka Ikeda	Fuji-Tokoha Univ.	Seiichi Sato	Nippon Koei Co., LTD.
Chikako Isouti	Mikuniya Corporation	Hikari Suzuki	IFDP
Kazuyo Kamita	Landbrains Corporation.	Tsutomu Tanaka	Eight-Japan Engineering Consultant
Masaru Kitaura	Kanazawa Univ.	Madoka Ujita	Landbrains Corporation
Taku Mikami	Gunma National College of Tech.	Kazutosi Yamamoto	Pacific Consultants
Hiroyuki Morita	Chiken Sogo Consultant	Sumio Yanagihara	Okumura Corporation

1.1. Yamada-machi of Iwate Prefecture (hereafter Yamada)

Yamada has a sawtooth coastline, and had a population of 19,270 and 7,182 households as of March, 2011 (statistic data of Yamada town office). The main business was culture fishery. Yamada had suffered destructive tsunami three times in the past 115 years. They were the Meiji Sanriku Tsunami (1896), the Showa Sanriku Tsunami (1933) and the Chile Earthquake Tsunami (1960). The main area of the town was protected by sea walls 5-8 meters high. The JMA Intensity of the shaking of the Great East Japan Earthquake was 5-lower (MMI 7-8). The maximum tsunami height was estimated to be 11-12 meters and it arrived about 35 minutes after the earthquake. The dead and the missing due to the giant tsunami numbered 771 (web page of Yamada of April 2, 2012), which was 3.9% of the population, and 6.8% of the people where the land was inundated (Ministry of Internal Affairs and Communications). 2,762 houses collapsed or were washed away, which was about 38% in Yamada.

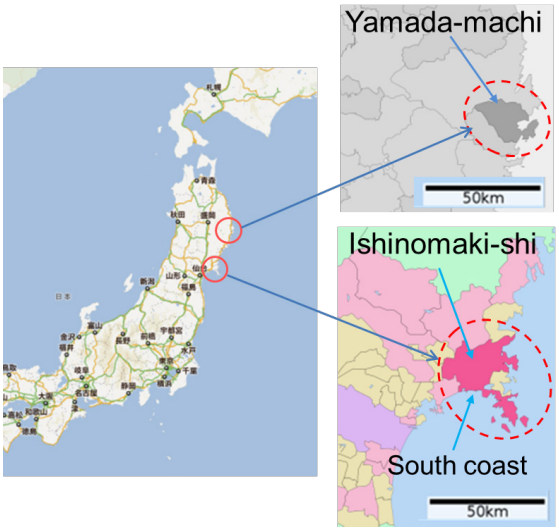


Figure 1.1. Location of two areas

1.2. Ishinomaki-shi of Miyagi Prefecture (hereafter Ishinomaki)

Ishinomaki has flat land in its southwest part along Sendai Bay. The population was 160,826 and there were 57,871 households as of 2010, October (census data). The main industries were fishery, fish processing, commerce, and paper manufacture. The JMA Intensity of the shaking was 6-lower (MMI 9-10). The giant tsunami arrived about 45 minutes after the earthquake, and its maximum height was 4-5 meters along the coast of Sendai Bay. The tsunami inundated the flat and low area of the city, where the major population and industries had been concentrated. The dead and the missing due to the giant tsunami numbered 3,819 (Web page of Ishinomaki of March 11, 2012), which was 2.6% of the population, and 4.2% of the people where the land was inundated (Ministry of Internal Affairs and Communications). 22,419 houses collapsed or were washed away, which was 38.6% in Ishinomaki.

2. METHODS OF SURVEY

We visited 200 evacuees in evacuee camps of Yamada and 350 refugees in temporal houses of Ishinomaki, and interviewed them concerning how they survived and why their deceased neighbours could not escape from the tsunami. The period of survey for Yamada was May to September, and that for Ishinomaki was October to December, 2011.

At the beginning of each interview, the interviewer handed a “sheet for trust” to the interviewee. The sheet described the purpose of the survey and how the results would be utilized, named the members of the task team, informed the interviewee of his free refusal right, and gave the interviewee the phone number of the interviewer. After obtaining the interviewee’s consent, the interviewer started conversation with the interviewee carefully and tried to elicit his or her answers to the questions during natural flow of communication. During the interview, the interviewer was required to be a listener, to keep his eye-line lower than that of interviewee and to not interrupt the interviewee when he or she wanted to talk about something not directly concerned with the questions. As a result, the interview sometimes exceeded one hour.

We also distributed questionnaires to the evacuees in temporary houses of Ishinomaki. Questionnaires were posted to 3,400 temporary houses and 797 were returned (collection rate 23%).

3. RESULT OF SURVEY

3.1. Evacuation Circumstances

The following Figure 3.1. denotes the sequence of the main shock and aftershocks and the alerts issued by JMA up to the arrival of the giant tsunami. Before the arrival of the giant tsunami, there were several aftershocks, which might have interfered with evacuation. JMA corrected the first alert and raised the expected tsunami height to double height by its second alert, but this was only 7-12 minutes before the arrival of the giant tsunami.

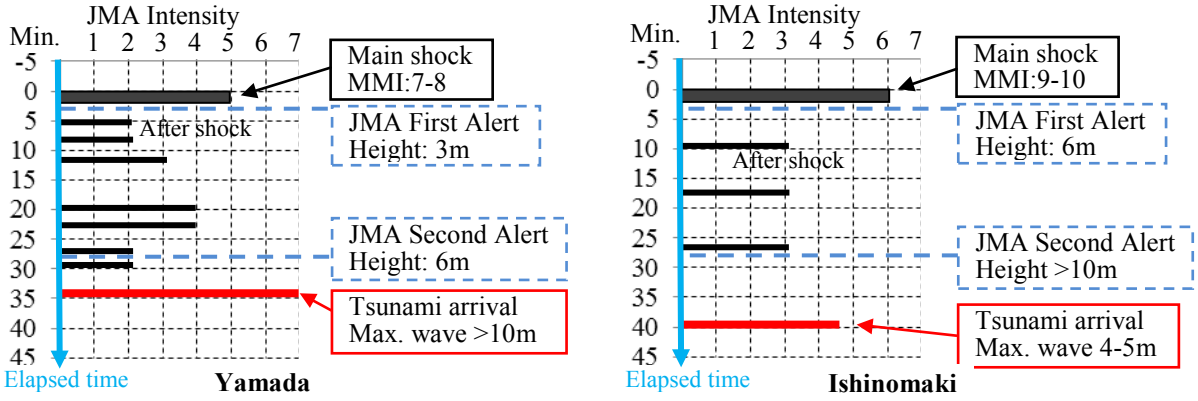


Figure 3.1. Sequence of the main shock, aftershocks, tsunami alert issued by JMA and tsunami arrival

The alert of large tsunami was broadcasted by outdoor loudspeakers of the emergency municipal radio communication systems of these municipalities soon after they received the JMA's tsunami alert. In the case of Yamada, the firebrigade station and the town office broadcasted the alert four times until the giant tsunami arrival. Ishinomaki city office broadcasted the alert 11 times until the tsunami arrival. The content of the broadcasted alert was approximately "Large tsunami alert was issued. Expecting height is more than XX meters. Evacuate. Avoid using cars". Most of the loudspeakers were undamaged by the shaking of the earthquake and functioned until their supporting posts were washed down by the tsunami. However, many of the evacuees complained that they could not hear the sound or could not distinguish the meaning because of echoing.

3.2 Age Distribution of the Victims

Figure 3.2. and Figure 3.3. compare the age distribution of the victims with the age distribution of the whole population. The effect of age is clear. The age distribution of the victims was high, in the 60's-80's, and was more pronounced in Yamada. Originally, Yamada was a more aged society than Ishinomaki, which shows that an aging society is at more risk than a younger society. One of the tragedies in Yamada was that a large-scale care house was washed away by the tsunami, and 74 old people (10% of the dead in Yamada) and 14 staff lost their lives (Iwate Nippou, 2011).

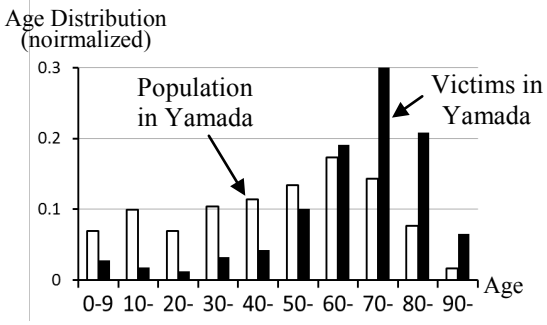


Figure 3.2. Age distribution of population and Victims of Yamada

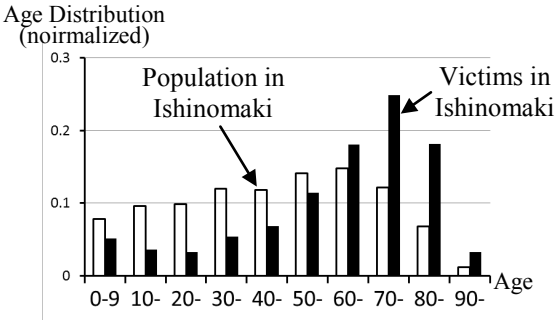


Figure 3.3. Age distribution of population and victims of Ishinomaki

3.3. Disaster Awareness

Disaster awarenesses in the two areas were different. Figure 3.4. shows the risk perception that the people in Yamada and Ishinomaki had during the strong and long-duration earthquake. The recorded seismic intensity of Yamada during the main shock was 7-8 MMI, which was smaller than Ishinomaki, but 80% of people in Yamada were convinced that a tsunami would come. Whereas the strong earthquake of Ishinomaki, MMI 9-10, did not raise the threat of a tsunami in the minds of 54% people.

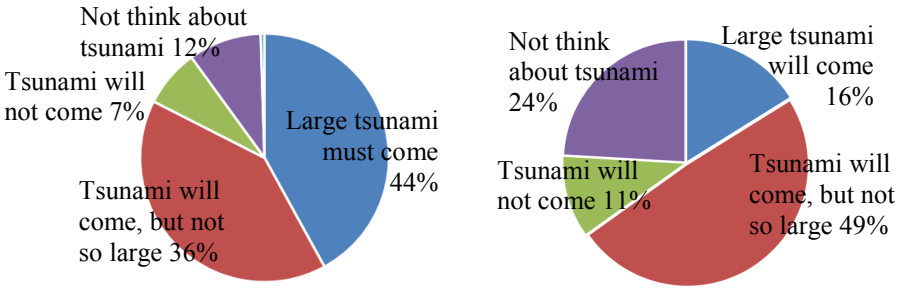
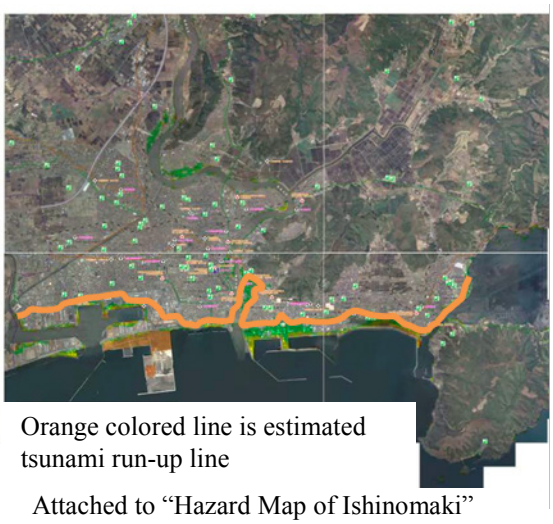


Figure 3.4. Did you think that a tsunami would come just after the earthquake?

Table 3.1. shows actual actions of evacuees in Yamada and in Ishinomaki. In both areas, about two thirds of the people started to evacuate soon after the shaking went down. However, about one fourth of the people in Ishinomaki did not evacuate before the tsunami arrived. Table 3.1. also shows that 14% of evacuees in Yamada started evacuation during the shaking. This may also show high awareness of the people in Yamada.

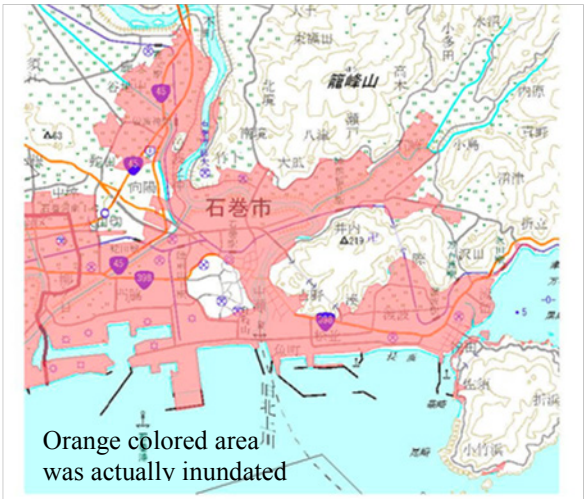
Table 3.1. Timing of beginning evacuation

When did you begin evacuation?	Yamada	Ishinomaki
During shaking	14%	5%
Soon after earthquake stopped	53%	61%
Just before tsunami arrived	17%	14%
After tsunami arrived	9%	16%
Due to fire or others	7%	4%
Number of sample	200	1,050



Attached to "Hazard Map of Ishinomaki"
http://www.city.ishinomaki.lg.jp/static/guide_ishinomaki/tsunami/

Figure 3.5. Hazard Map for south west area of Ishinomaki



Geospatial Information Authority of Japan
http://www.gsi.go.jp/kikaku/kikaku60003.html

Figure 3.6. Tsunami inundated area by March 11, 2011 great tsunami

Figure 3.5. shows the tsunami hazard map in the south west area of Ishinomaki, and Figure 3.6. shows the actually observed area inundated by the giant tsunami of March 11, 2011. The map was published by the city office of Ishinomaki. The risk of tsunami in the south west area of Ishinomaki was not remarked even in public sector.

The difference of disaster awareness also appeared in the rate of participation in disaster drills (Figure 3.7.). The ratio of people who had never participated in a disaster drill was one third in Yamada, but two thirds in Ishinomaki. In Ishinomaki, disaster drills were conducted by communities supported by the city office, but participation of people had been generally low. Moreover, almost all the drills had focused to earthquake and fire.

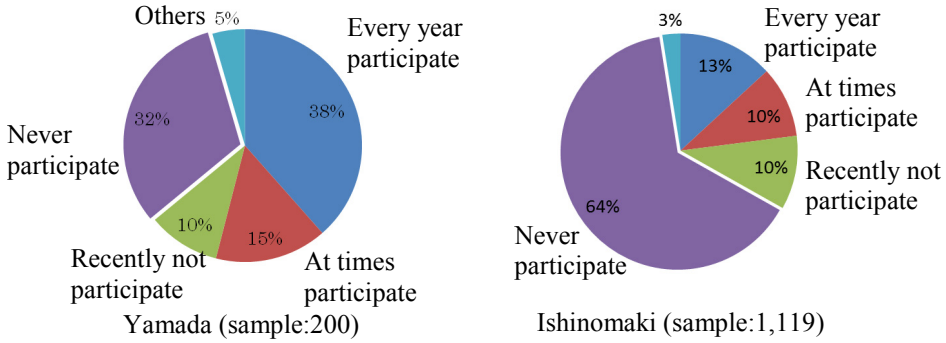


Figure 3.7. Did you participate in disaster drill?

3.4. Outcome of Disaster Preparedness

Figure 3.8. shows the relation between quick evacuation and ratio of participation in annual disaster drills in Yamada. People who had participated in disaster drills every year evacuated quickly. In Yamada, evacuation drills had been conducted every year by the town office, and were participated in by 10-15% of its population.

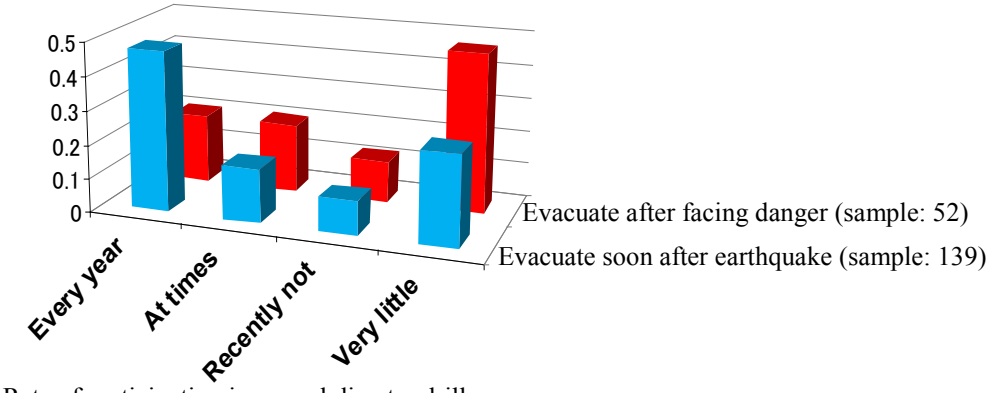


Figure 3.8. Quick evacuation vs. rate of participation in annual disaster drill

Another outcome of disaster drill can be seen in Table 3.2. One of the communities in Yamada had pursued its own disaster drill. The communities from A to E (Figure 3.9.) were located along the coast and were estimated to suffer same level of tsunami intensity, whereas other communities were located in safer area. Among these communities, the community B had been elected as a model disaster management area and had executed its own drills to raise the disaster preparedness. Each sub-community leader had a list of vulnerable people in the area and reserved a wheel chair. The disaster prevention manager of the community was a retired person of the Self Defence Force (Japanese army) and the people in the community had walked around and watched the vulnerable part of their village, made their own hazard map, executed their own drills including the evacuation drill in

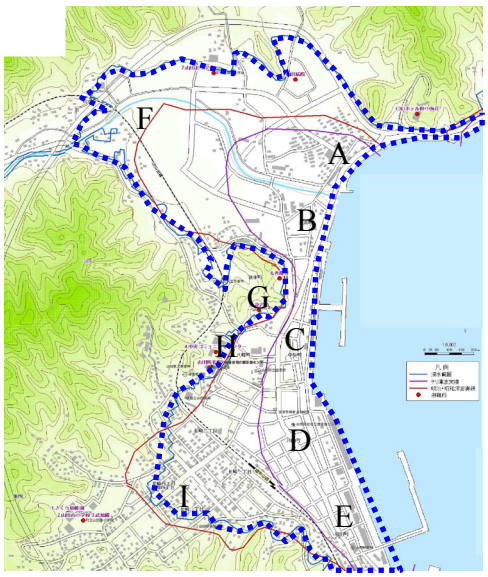


Figure 3.9. Central part of Yamada

night in addition to the town office drill and had moved their emergency supplies from the warehouse in a low land to that on a hill. Table 3.2. shows the death rates due to the tsunami. Community B was clearly lower death rate among A – E.

Table 3.2. Death rate of communities

	Population	Victims	Death rate (%)
A	562	43	7.7
B	693	27	3.9
C	403	37	9.2
D	375	36	9.6
E	838	65	7.8
F	678	7	1.0
G	289	10	3.5
H	553	24	4.3
I	1385	16	1.2

3.3. "Tsunami Tendenko" and Mutual Cooperation

Figure 3.10. shows the answers to the question about with whom the evacuee evacuated. In Yamada, evacuation alone was about twice that of Ishinomaki. That is, "Tsunami Tendenko", which is a traditional tsunami disaster phrase meaning "evacuate by oneself and do not care about others", was carried out more honestly. However, it is also important to note that families, neighbors and community leaders helped people to begin to evacuate (Table 3.3.) in Ishinomki.

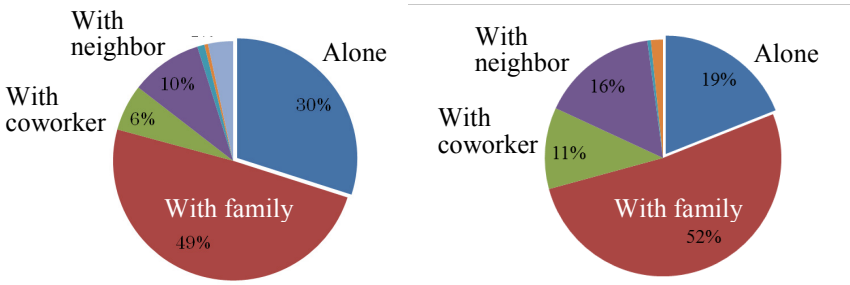


Figure 3.10. With whom did you evacuate?

Table 3.3. Trigger let people evacuate

What was the trigger to let you evacuate?	Yamada	Ishinomaki
Feeling large and very long shaking	54%	29%
Hearing alert of large tsunami	10%	24%
Guide of head of family	6%	12%
Following neighbor's evacuation	3%	7%
Community leader's guide	6%	8%
Seeing receding tide	1%	1%
Seeing tsunami coming	11%	11%
Seeing tsunami crashing over seawall	1%	-
Fire, others	8%	10%
Number of sample	179	866

Table 3.4. shows what the evacuees were doing until evacuation or being caught in the tsunami. It should be mentioned that in Ishinomaki the ratio of evacuees who tried to pass alert of risk to neighbors and helped others to evacuate was considerably larger than that of Yamada. However, it might be oversimplifying to explain this discrepancy by the difference of humanity in these two areas. Only 7% of Yamada evacuees tried to gather up mess caused by the earthquake, while 18% of Ishinomaki evacuees did. People in Yamada might have much more feeling of crisis and might not be able to afford to think of helping others.

Table 3.4. What the evacuees were doing until beginning evacuation or being caught in the tsunami.

What were you doing until starting evacuation?	Yamada	Ishinomaki
Going back to home	23%	20%
Going to collect family in school or somewhere	6%	12%
Going to sea side to look at sea	7%	2%
Collecting important goods, locking my house	52%	26%
Picking up items scattered by the earthquake	7%	18%
Making phone calls or sending e-mail to relatives	3%	13%
Remember nothing	2%	1%
Doing nothing, evacuated immediately	20%	23%
Passing alert of risk to neighbors	2%	15%
Helping handicapped people to evacuate	3%	5%
Number of sample (multiple answer)	200	1,147

3.4. Information Source Concerning Tsunami Alert

Figure 3.11. shows the evacuees' information sources of the tsunami alert. TV was no use because electric power went down after the earthquake in both Yamada and Ishinomaki. Therefore, outdoor loudspeaker of the emergency-municipal-radio-communication-system (hereafter EMRCS) was most important for transmitting the alerts to people. The second most important information source in Yamada was portable radios or car radios, but in Ishinomaki it was word of mouth from neighbors.

Many evacuees, especially in Ishinomaki, complained that they could not hear the sound or could not understand announcements from outdoor loudspeakers. Although most of the speakers were functioning before the tsunami arrived, the volume might have been too low for people indoors or might have had too much echo for people outdoors. Many evacuees stated that the speech tone lacked a sense of crisis for a person who was in a hurry to evacuate.

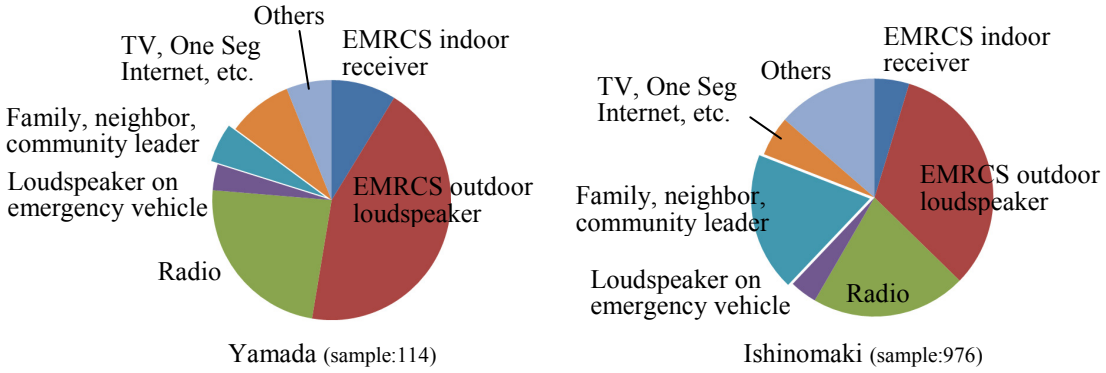


Figure 3.11. Information source of large tsunami alert

3.5. Evacuation Method

Figure 3.12. and Table 3.5. denote evacuation methods and their efficiencies. One third of the evacuees in Yamada and 51% of those in Ishinomaki did use cars to evacuate. In Ishinomaki, many encountered traffic jams. 21% of car evacuees were forced to leave their cars to escape, or stay in their cars and be caught by the tsunami. We must note that these data came from survivors. If data from the dead were included, the ratio of those caught in their cars would somewhat increase. There have been many discussions about the demerits of evacuation by car. However, during our interview survey and questionnaire survey, we received many opinions which stressed the need for evacuation by car of old persons and/or disabled persons.

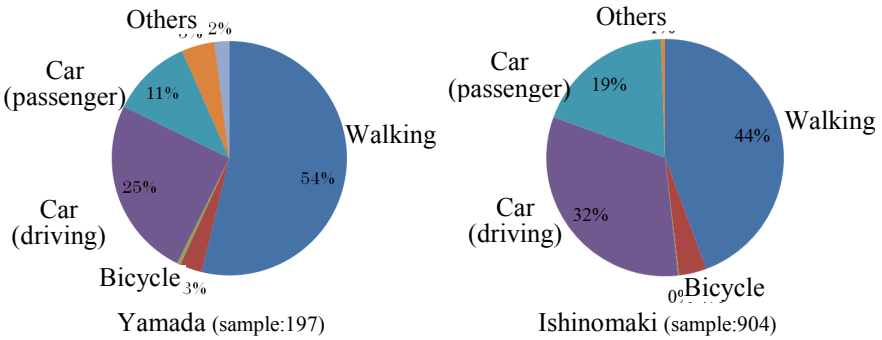


Figure 3.12. Evacuation methods

Table 3.5. Effect of traffic jam

Was your car been trapped by traffic jam?	Yamada	Ishinomaki
Trapped in a traffic jam	11%	45%
Saw traffic jam but not trapped in it	14%	31%
Saw some rubbles tying up traffic	4%	8%
Did not see traffic jam	75%	26%
My car and I were caught in the tsunami	4%	7%
Trapped in traffic jam, escaped from car and ran	3%	14%
Number of sample (multiple answer)	71	332

3.6. Behavior of Victims at the Time of the Tsunami Inundation

In order to find out the behavior of the victims at the time of the tsunami, the authors asked survivors to talk about their neighboring people who died due to the tsunami through the interview and the questionnaire. It was difficult for survivors to answer, and some of the answers overlapped to a same dead person. The obtained information was carefully checked on the map, and the behaviors of 671 victims, about 19% of the dead in Ishinomaki, were summed up and shown on Figure 3.13.

About 60% of the dead had remained at their house. Many of them might have thought that tsunami would not come, and some of them could not easily escape by themselves because of advanced age or disease. About 7% of the dead were the people who returned home to pick up something although they evacuated at first to the safe place. There was about 45 minutes after the earthquake until the tsunami, and the effective information about the tsunami coming might not have reached to these people. Moreover, some of them might have suspected the tsunami alert itself because they experienced overestimated alert several times before. Most of the dead who returned to home from the downtown had been in their working place, and whether they could reach their home or could not was not clear. 21% of the dead were supposed to be on the way of evacuation. Some of them were slow to start, were slow to walk, were trapped by traffic jam or evacuated not to safe place. 3% of the victims, about numbered 100 souls, were lost for helping others.

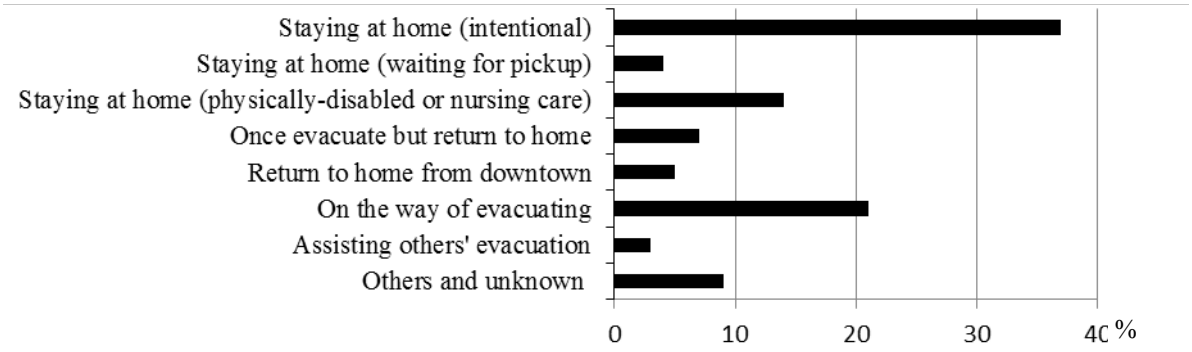


Figure 3.13. Behavior of victims at the time of the tsunami inundation in Ishinomaki (sample: 671)

3.7. Effect of Past Tsunami Experience

Some survivors did not evacuate but stayed on the second floor or roof of their house. They described why they did not evacuate. The results are shown in Table 3.6.

In both areas, more than one third of the evacuees who did not evacuate thought that the tsunami would not reach their houses. Many of the old people in these areas had suffered damage in the 1960 Chile Earthquake Tsunami, there had not been any destructive tsunami for 50 years and they thought that the tsunami height on that occasion was something like a standard. However, the height of the March 11, 2011 giant tsunami was three to five times larger than that standardized height. To make the situation worse, JMA had issued large tsunami alerts into this area several times in recent years, but people had not experienced a destructive tsunami.

Figure 3.14. clearly shows the situation. The houses of persons who were washed out and died are shown by a blue dot on the figure. People living near the sea or river mouth did evacuate soon after the earthquake because they well knew the tsunami risk. As a result, there were few of casualties in these areas. However, along the foot of the hills, i.e. slightly higher land, there were many casualties. Apparently, people in these areas thought that as past tsunami run-ups did not reach the heights of their houses they did not need to evacuate. However, the run-up of the March 11 giant tsunami was much higher than previous ones.

Table 3.6. The reasons why the people (survivors) did not evacuate

I did not evacuate because;	Yamada	Ishinomaki
I thought tsunami would not reach my home.	42%	35%
I thought sea wall would protect us.	3%	1%
I was waiting and seeing	10%	14%
I was taking much time to prepare evacuation	6%	4%
I was looking for or waiting for my family	7%	5%
I didn't know how to do	0%	7%
If tsunami came, I thought I could go up second floor	3%	6%
I would not have time to reach a safe place before tsunami arrived	3%	3%
I could not leave my work place	4%	8%
I evacuated due to fire, not by tsunami	11%	-
Others	16%	17%
Number of sample	28	291

Figure 3.14. People living at foot of hills believed their houses would be safe, but --.

4. CONCLUSIONS

1) The age distribution of the dead was concentrated in the 60's-80's. Many of these old persons could not move well. Even if they could walk, they tended to avoid it and preferred to go up to the second floors of their houses. However, the giant tsunami easily washed away their wooden houses.

2) Young families of these old persons, went back home from downtown in order to rescue them. Some of them succeeded and some of them were washed away with their old relatives. We should discuss "Tsunami Tendenko" after learning this fact, and must deepen our thinking concerning reduction of car evacuation after learning that cars were indispensable to save these families.

3) Experience of past tsunami disaster was not always helpful. People living in high risk regions such as coastal areas and river mouths quickly evacuated after the earthquake. However, people living on slightly higher land where the tsunami run-up of the 1960 Chile Earthquake Tsunami did not reach over-estimated the safety of their houses.

4) The large-tsunami alert broadcast by the emergency-municipal-radio-communication-system was not effective. Many people decided to evacuate based on their feeling about the strong and abnormally long earthquake. Many people also could not understand the echoing voice from the loud speakers.

5) There was a clear difference between the tsunami risk awareness of the people in the two regions, one of which has a sawtooth coastline facing the Pacific Ocean and another of which has a plain coastline facing Sendai bay. In the latter case, not only individual citizens but also local communities and sectors lacked tsunami risk awareness. Disaster drills were conducted every year but most of them focused on earthquake and fire. Some public refuge places were located in low land near the sea.

6) This low awareness might have resulted from the hazard map compiled by the local government. This map was of course based on advanced scientific knowledge and technology at that time and actually this area had not experienced a very large tsunami in recent years. However, still the past inadequate contribution of science and engineering on raising disaster awareness is regretted.

7) In the high-risk area, people's tsunami awareness was high but their spirit of mutual aid was relatively low when compared to that of the people in what was thought to be the lower risk area. This discrepancy must be surveyed more deeply.

8) This paper is based on a part of the data surveyed by the task team on Yamada-machi and Ishinomaki-shi, Tsunami Evacuation Survey Group of the Great East Japan Earthquake Disaster.

ACKNOWLEDGEMENTS

Our task team visited many evacuees in their camps or temporary houses and we received positive cooperation from most of them, who may have been bottling up their emotions when talking to us. We also received much cooperation from Yamada town office and Ishinomaki city office. We will express our real thanks to them by carefully analyzing the data and distributing the results for use in tsunami risk areas around the world. This study has been supported by J-RAPID of JST (http://www.jst.go.jp/inter/english/project/country/j-rapid.html) and partially supported by JSCE.

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