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(Citation)
International Journal of Disaster Resilience in the Built Environment,10(4):260-275

(Issue Date)
2019-08-29

(Resource Type)
journal article

(Version)
Accepted Manuscript

(URL)
https://hdl.handle.net/20.500.14094/90008126

Effectiveness of early warning and community cooperation for evacuation preparedness from mega-risk type coastal hazard in childcare centers

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Abstract Purpose: This paper aims to investigate the effectiveness of early warning and community cooperation for evacuation preparedness from mega-risk type coastal hazard in childcare centers, focusing in the evacuation of childcare centers from tsunami at the time of the Great East Japan Earthquake occurred on March 11, 2011. Design/methodology/approach: As the research method, surveys were conducted in public childcare centers affected by tsunami in Kesennuma city in Miyagi Prefecture and Kamaishi city in Iwate Prefecture. Findings: As the main findings, facilities, where teachers and children started evacuation immediately after the earthquake, could have more conditions to get cooperation from the local community to evacuate children in wide-scale urban environment. Children 3-5 years old tended to be instructed to walk two abreast under the lead of teachers, and children 0-2 years old tended to be carried by the piggyback ride and multi- passenger baby strollers. The destination of evacuation needed to be changed several times because of the risks for higher tsunami and fire outbreaks. Research limitations/implications: As future issues, it is necessary to analyze the walking capability of children and the transportation capability of multi-passenger baby strollers by teachers, to address strategies to quantify the necessary community cooperation based on the severity of early warning. Originality/value: Most of the past studies regarding disaster preparedness of nursery children are limited within the facility in case of fire. This work has importance as it focused on the emergency responses that require urban-scale evacuation in ascending route that differ from that which are required in the case of fire.

Keywords 2011 Tōhoku earthquake and tsunami in Japan, Multi-hazard risk, Community partnership, Vulnerable group, Evacuation preparedness.

1. Introduction

Childcare centers are facilities that take care of children 0-5 years of age, who have reduced capability on autonomous walking in case of an emergency evacuation. Therefore, it is even more difficult to ensure their safety in case of mega-risk type coastal hazard, such as storm surge and tsunami, in which damages tend to spread widely and evacuation in a wide-scale urban environment are required. Especially in case of tsunami resulted by strong earthquake, as the further away and higher the sheltering place, it would take even longer time to complete the evacuation, being exposed to the secondary risks such as aftershocks and tsunami fire (fire outbreaks in the flooded area, reported by Hokugo et al., 2011). A quick decision to start the evacuation, as well as the early-warning for hazards and the availability of community cooperation, can make a difference in these cases, as observed in actual evacuation cases reported by Japan Committee for UNICEF (2013) and Amano (2011). During the 2011 Great East Japan Earthquake (GEJE), occurred on March 11, 2011, 722 childcare centers were affected by the earthquake, of which 78 facilities severely damaged by tsunami in Prefectures of Fukushima, Miyagi and Iwate. Despite the devastating damage, there were only three casualties of children under the care of nursery (Kahoku Shimpo, 2011). To evaluate the evacuation capabilities of childcare centers that are exposed to coastal hazards, it is crucial to understand the survival experiences from past disasters. In terms of research studies related to the evacuation of childcare centers, most of the studies are limited within the facility in case of fire, such as studies conducted by Murozaki and Ohnishi (1985) and Larusdottir and Dederichs (2012). In the case of coastal hazards, nursery teachers need to lead children along long-distance ascending route, resulting in evacuation responses that differ from that which are required in the case of fire. This paper aims to investigate the situation of the evacuation of childcare centers from tsunami at the time of 2011 GEJE, to understand the effectiveness of early warning and community cooperation for the successful evacuation.

2. Methods

As the research method, surveys were conducted in all public childcare centers affected by tsunami at the time of GEJE in Kesennuma city (Miyagi Prefecture) and Kamaishi city (Iwate Prefecture), conducting interviews to the teachers who were involved in the evacuation. The interviews took place at the childcare centers where they were relocated after the disaster. Table I shows the list of childcare centers in which surveys were conducted.

Table I. List of surveyed childcare centers

Nursery (location)	Number of stories	Altitude above sea	Distance from seaside / river	Number of teachers	Number of children (age)
I (Shiomicho) [*1]	1	0.5 meter	0.2 km / 0.3 km	12	71 (0-5 years old)
U (Unosumai) [*2]	1	3.5 meter	1.2 km / 0.1 km	21	73 (0-5 years old)
K (Owataricho) [*2]	2	1.0 meter	0.6 km / 0.2 km	29	75 (0-5 years old)
S (Shishiori) [*1] [*3]	1	0.7 meter	0.8 km / 0.3 km	2	8 (3-6 years old)
N (Hongo) [*1]	2	2.1 meters	1.2 km / 0.2 km	9	37 (0-5 years old)
H (Hajikami) [*1]	1	6.8 meters	0.5 km / 0.4 km	3	20 (3-5 years old)

Notes: [*1]Kesennuma city, Miyagi Prefecture (surveyed in November 2012). [*2]Kamaishi city, Iwate Prefecture (surveyed in September 2016). [*3]All facilities were nursery schools, except Nursery S that was an after school children's center.

3. Results

According to the interviewees (teachers involved in the evacuation of childcare center at the time of GEJE, hereinafter referred to as teachers), not all facilities were able to receive appropriately tsunami warnings announced by authorities. Table II shows the overview of the pre-existent evacuation plan and the actual evacuation behavior that occurred during GEJE.

In all cases, it was possible to do a successful evacuation, without resulting in human losses. However, facilities that had previously agreed with children's parents to designate the emergency parents meeting place to hand over their children in case of major disaster (hereinafter referred to as "emergency parents meeting place") outside the childcare centers such as nurseries I, U and K, had relatively more conditions to initiate wide-scale evacuation in urban environment earlier, as well as receiving tsunami warning properly and getting cooperation of local community, than other facilities that designated "emergency parents meeting place" inside the childcare center. Aiming to understand the effectiveness of early warning and community cooperation, the first part of the analysis will focus on the facilities where people started evacuation in the urban environment relatively earlier, and the second part will focus on facilities where people were relatively delayed to start evacuation in the urban environment.

Table II. Situation of childcare centers at the time of GEJE

Nursery	Damage by tsunami	Pre-existent evacuation plan		Destination of evacuation at the time of GEJE
		Destination of evacuation	Emergency parents meeting place*	
I	Swept away	Both Earthquake / Tsunami: Tsunami Evac. Building	Outside facility (Tsunami Evac. Building)	Tsunami Evac. Building (2nd floor →3rd floor →rooftop)
U	Swept away	Earthquake: Playground Tsunami: Daycare center Y	Outside facility (Day Care Center Y)	Day care center Y →Stone Store N →Elementary School
K	Swept away	Earthquake: Playground Tsunami: Hill (Park Y)	Outside facility (Elementary School)	Park Y in top of a hill →Hospital N
S	Swept away	Earthquake: Playground Tsunami: Nearest hill	Inside facility (playground)	Nearest hill →Elementary School
N	Partially flooded	Both Earthquake / Tsunami: 2nd floor of facility	Inside facility (2nd floor of facility)	2nd floor of facility →Junior High School
H	Partially flooded	Earthquake: Playground Tsunami: Jr. High School	Inside facility (playground)	→ Junior High School

Note: *Emergency parents meeting place to hand over their children in case of a major disaster.

3.1. Facilities where people started evacuation in the urban environment relatively earlier

3.1.1. Evacuation of Nursery I

According to the teachers, a three-storey reinforced concrete building (a community center), designated as tsunami evacuation building (T.E.B.) by municipal government, located 60 m from childcare center, had been chosen as destination of the evacuation of teachers and children in the case of both earthquake and tsunami, conducting evacuation drill to there twice a year with participation of local community. The earthquake occurred when 12 teachers were taking care of 71 children 0-5 years of age. The evacuation was initiated immediately after the quake. All teachers and children get together in the playground, then they did the primary evacuation to the second floor of the T.E.B. Details of the evacuation response are shown in Table III and Figure 1.

Table III. Evacuation of nursery I

Evacuation	Destinations
Primary	To the Tsunami Evacuation Building (T.E.B.) ◆ Distance along the walking route, measured in the horizontal direction: 60 m* ◆ Cumulative elevation gain: less than 1 m*
Secondary	From the 2nd to the 3rd floor of T.E.B.
Tertiary	From the 3rd floor to the rooftop of T.E.B.

Note: *Measured with cartographic data of Geospatial Information Authority of Japan (GSI).

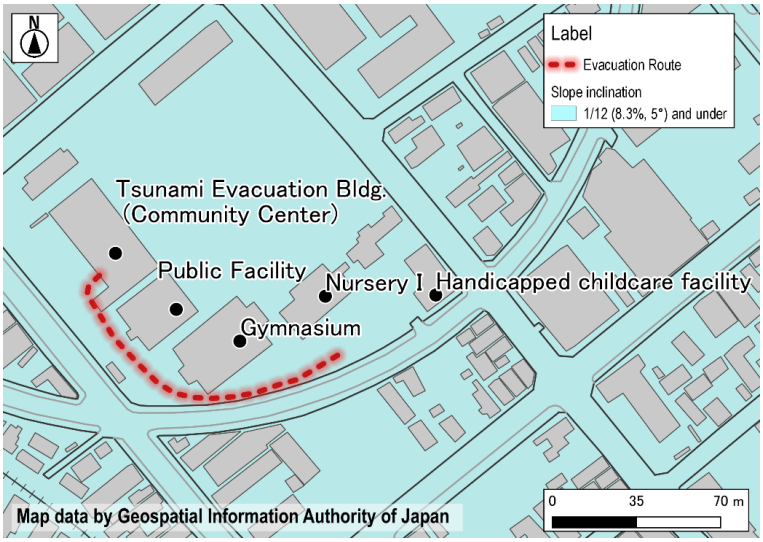

Figure 1. Evacuation route of nursery I

Overview of the primary evacuation (to the second floor of tsunami evacuation building)

As soon as a strong earthquake happens, the director of the facility ordered all teachers to start the "emergency evacuation due to the risk of tsunami," and evacuation to the T.E.B. was initiated even as the earthquake continued, started by each class group, separated by age, they were ready to leave the facility: a group formed by children 5 years of age going forward, followed by a group of children 4 years old, and another formed by children 3 years old, walking in two abreast under lead of teachers (positioned in front, middle and final part of each group), and at the end, teachers carried children 0-2 years old by piggyback ride and three multi-passenger baby stroller (each vehicle carrying about four children and being handled by one teacher). Plate 1 shows a multi-passenger baby stroller similar to what was used during the evacuation. As the previous drills, three employees of a handicapped childcare facility located in the same childcare center site went to support the evacuation of children 0-2 years of age. Besides that shortly leaving the facility, nursery teachers could receive assistance from employees of other nearby companies to handling heavy multi-passenger baby strollers in unpaved surfaces. Arriving at the T.E.B., children 2-5 years old walked under the lead of teachers to climb stairs, and children 0-1 year old were carried by piggyback ride to reach the second floor. On the second floor, teachers and children got together with other evacuees, including about 60 children's parents and some dozens of neighborhood residents.

Plate 1. Multi-passenger baby stroller similar to what was used during GEJE

Overview of the secondary evacuation (to the third floor of tsunami evacuation building)

Some minutes after arriving on the second floor, evacuees received the alert of "major tsunami warning" through J-alert (satellite-based Japanese nationwide warning system) that was broadcasted via public loudspeakers, television, radio, email and mobile phones, triggering the secondary evacuation, from the second to third floor of T.E.B. Some parents of children, thinking that there was no real risk of tsunami, tried to return home with their children, but were prevented by the teachers from leaving the evacuation building.

Overview of the tertiary evacuation (to the rooftop of tsunami evacuation building)

About 30-40 min after arriving on the 3rd floor, the first wave of tsunami was observed, and warnings for even higher successive waves were announced by authorities, triggering the tertiary evacuation to the rooftop. After arriving there, it was verified that the childcare facility was completely destroyed by tsunami and the T.E.B. was flooded up to the second floor. Some hours after arriving on the rooftop, it begins to snow, and at 17:15, some oil tanks of industrial facilities were dragged by tsunami until the proximity, occurring numerous explosions in contact with debris and starting a fire outbreak over the flooded surface surrounding the building. When sparks began to fly over the rooftop, it was decided to return to the third floor for safety. The external facade was partially burned, but there was no fire spread inside the building, thanks to the effort of evacuees in pushing floating flammable debris away from the building all through the night. On next day, helicopter rescues teams arrived at the building, taking two days to rescue all evacuees.

Post-disaster considerations

In nursery I, the primary evacuation was concluded about 10 min after the earthquake, being "faster than the time registered during drills." Following factors contributed to the quick response: having a single destination in any disaster scenario, without having to wait for tsunami warning; having agreed with parents in designating the T.E.B. as "emergency parents meeting place"; having implemented shortcut route from childcare care site to adjacent facilities; having initiated evacuation quickly, which made it possible to avoid traffic jam and get support from community. Furthermore, there was an elevated ground in a hill located 1.4 km away, however, according to the teachers, as it was not possible to know if they were capable of managing evacuation in roads with steep inclination (that include segments with 200 m of distance with inclination over 10 per cent), the possibility of going to the hill had been discarded, having the nearest T.E.B. as destination during GEJE. However, they needed to change the sheltering place inside the building several times due to the increasement of the risk of higher tsunami and fire outbreaks. Some doubt has arisen, as follows:

> *At the time of the earthquake, it was difficult to handle the multi-passenger baby strollers even on the flat route to the Tsunami Evacuation Building, therefore, the evacuation to the hill would probably have failed if it depended only on the human resources that were available. However, considering the adversities we suffered in the evacuation building, the possibility of evacuation to the hill, with the cooperation of local community, should have been studied in advance.*

3.1.2. Evacuation of Nursery U

According to the teachers, before GEJE, the facility was conducting once a year a wide-scale evacuation drill to the day care center Y, where was the place designated by the municipal government as the nearest evacuation place from the nursery. The earthquake occurred when 21 teachers were taking care of 73 children 0- 5 years of age. Immediately after the earthquake, all teachers and children got together in the playground, then they did the primary evacuation to the day care center Y, secondary evacuation to the stone store N and tertiary evacuation to the Kamaishi elementary school. Details of the evacuation response are shown in Table IV and Figure 2.

Table IV. Evacuation of nursery U

Evacuation	Destinations
Primary	To the Day Care Center Y ◆ Distance along the walking route, measured in the horizontal direction: 568.4 m[*1] ◆ Cumulative elevation gain, measured in 9 segments: 10.8 m[*1] ◆ Inclination of the steepest segment: 7.6%[*]; and average inclination of ascending segments: 2.1%[*1]
Secondary	To the Stone Store N ◆ Distance along the walking route, measured in the horizontal direction: 510.2 m[*1] ◆ Cumulative elevation gain, measured in 9 segments: 28.7 m[*1] ◆ Inclination of the steepest segment: 10.8%[*1] ◆ Average inclination of ascending segments: 5.6%[*1]
Tertiary	To the Kamaishi Elementary School ◆ Height / inclination of retaining wall on the back of the stone store to reach the expressway: 5.3m / 61%[*1] ◆ Distance to the Kamaishi Elementary School: about 7-10 km to south[*2]

Notes: [*1]Measured with laser scanning survey. [*2]Estimated with cartographic data of GSI Japan.

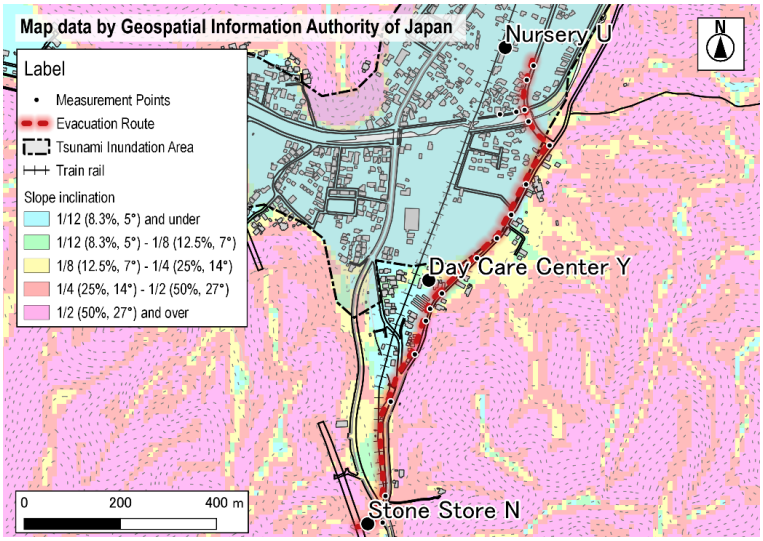

Figure 2. Evacuation route of nursery U

Overview of the primary evacuation (to the day care center Y)

Teachers perceived "a real danger of tsunami because of the seismic shaking that was extremely stronger than usual," and decided to start the evacuation until day care center Y immediately. They could listen to the announcement of "major tsunami warning" that was broadcasted by public loudspeakers when they were already preparing to leave the facility. The evacuation was started by class group separated or combined by age, in the order they were ready to leave the facility: a group formed by children 5 and 3 years of age going forward, followed by a group of children 4 years of age, and another formed by children 2 years of age (holding teacher's hands). Four employees that work in an afterschool children's center located adjacent to the childcare center assisted the evacuation of part of children 2 years of age. In the end, children 0-2 years of age were carried by the piggyback ride and two multi-passenger baby strollers (each vehicle carrying about eight children and being handled by two teachers). Teachers had difficulty in handling baby strollers in roads with steep inclination, however, some of the children were handed over to parents that came to pick up during the evacuation, which contributed to reduce the weight and facilitate the handling of strollers. Figure 3 shows the situation of steep route with access to the day

care center Y. Along the evacuation route, a severe traffic jam was taking place. Teachers and children had to move around on the pedestrian's side, diverting from paralyzed vehicles, and it was difficult to move in part of segments without raised curbs that separate footpath from the road.

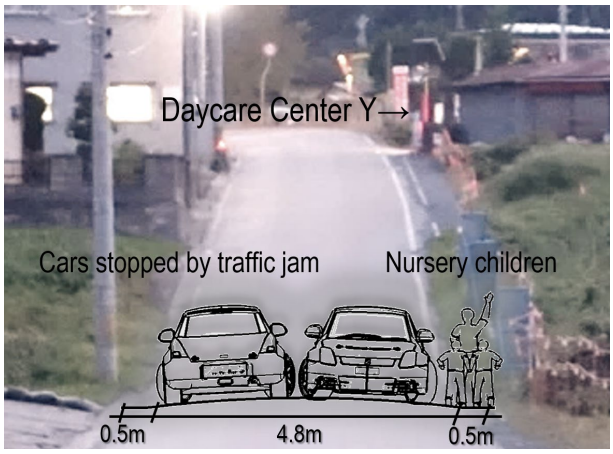

Figure 3. Representation of the steep route with access to the day care center Y during evacuation

Overview of the secondary evacuation (to the stone store N)

About 5 min after arriving in the day care center Y, it was observed that the surrounding area was flooded by tsunami. Considering the risk of inundation in the day care center, it was decided to evacuate to the higher place of stone store N. Shortly after start leaving the day care center, students and teachers of an elementary school reached there, and some of students assisted the evacuation of children by holding their hands and walking together, and school teachers supported the transportation of multi-passenger baby strollers. Arriving at the stone store, they could get together with parents of some children, residents of neighborhood and employees of medical facilities.

Overview of the tertiary evacuation (to the Kamaishi elementary school via expressway)

In the stone store, there was a risk of falling stone artifacts by aftershocks. Around 16:30, firefighters came to the store and oriented nursery group to move to the Kamaishi elementary school. Teachers and children needed to climb a retention wall with more than five meters high that was on the back of the stone store site, to reach higher ground, where there was an expressway that was not affected by tsunami. Employees of stone store secured access to the retaining wall by cutting and removing the fence between the wall and store site, and teachers of elementary school climbed the wall to fix ropes until the guardrail of the expressway. Posterity, nursery and school teachers started carrying children one by one along the rope until the expressway, where the nursery group could hitch rides to move by car to the Kamaishi elementary school. The last children were handed over to their parents in the school two days after the earthquake.

Post-disaster considerations

In nursery U, the evacuation drill to the day care center that was done one month before the earthquake took about 13 min, however, at the time of GEJE, they were able to complete in about 10 min. According to the teachers:

> *The rapid response was possible since teachers and children were able to keep unity as a group, without interrupting movements while walking, and the cooperation of teachers and students of elementary school was indispensable to the success of evacuation in routes with severe slope.*

3.1.3. Evacuation of Nursery K

According to the teachers, before GEJE, the facility was conducted once a year a wide-scale evacuation drill to the "park Y" located at the top of a hill, where was the place designated by the municipal government as the nearest evacuation place from the nursery. On the day of the earthquake, 29 staff were taking care of children 0-5 years of age. The evacuation was initiated immediately after the quake. All teachers and children get together in the playground, then they did the primary evacuation to the park Y located in an elevated ground, and the secondary

evacuation to the hospital N located adjacent to the hill. Details of the evacuation response are shown in Table V and Figure 4.

Table V. Evacuation of nursery K

Evacuation	Destinations
Primary	To the begging of hill access stairs/slopes (to reach the Park Y on the top of a hill) ◆ Distance along the walking route measured in the horizontal direction: 148 m* ◆ Elevation gain: +0.4 m*; Inclination: +0.3%* To the Park Y ◆ Distance along the walking route measured in horizontal direction: 190 m* ◆ Cumulative elevation gain measured in 14 stairs segments: +28.2 m* ◆ Cumulative elevation gain measured in 10 slope segments: +11.6 m*
Secondary	To the Hospital N located adjacent to the hill (via bridge connected to the 5th floor of the hospital)

Note: *Measured with laser scanning survey.

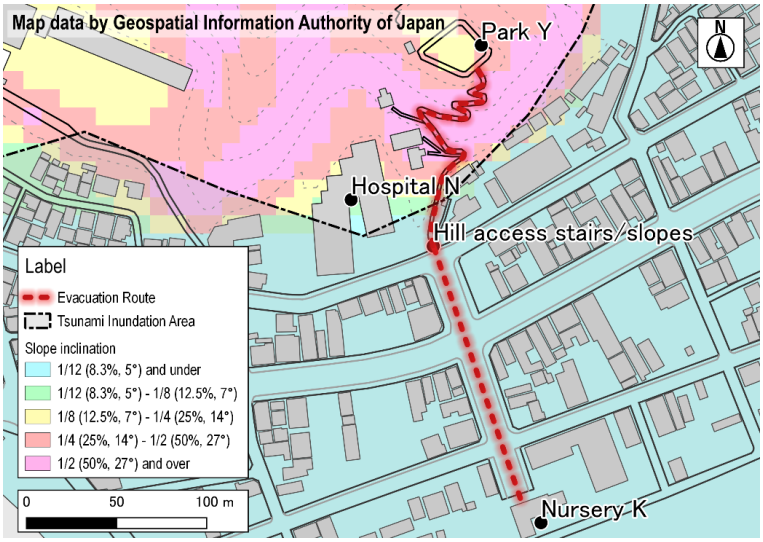

Figure 4. Evacuation route of nursery K

Overview of the primary evacuation (to the park Y located on the top of a hill)

Immediately after the earthquake, teachers recognized the risk of tsunami and guided children to the playground. One of the oldest staff, who had already experienced tsunami calamities in the past, alerted other staff, saying "with absolute certainty, a huge tsunami is coming." This alert triggered to initiate the evacuation to the park Y, as soon as children could get together in the playground. Before starting the evacuation, some of the parents came to the childcare center to pick up their children. Parents were also oriented to evacuate together. The evacuation was started by each class group, separated by age, in the order they were able to get together in the playground and complete the preparation to leave the facility: class of 5 years of age going forward, followed by class of 4 years of age and class of 3 years of age, walking in two abreast under the lead of teachers; and at the end, teachers carried 0-2 years of age children by piggyback ride, baby wrap rope and 3 multi-passenger baby strollers. At the time of GEJE, all of three multi-passenger baby strollers were parked next to the classroom of children 0-2 years of age, as a precaution for an eventual emergency. Before GEJE, these vehicles were being used as recreational rides, each stroller transporting six children with one teacher as a conductor, however, during GEJE, each stroller carried 10 children and was conducted by two teachers. Due to the excessive transportation weigh, teachers were having extreme difficulty in maneuvering strollers. However, when they were leaving the facility, they could get together with employees of neighboring companies who ended up supporting in handling strollers. Immediately after starting evacuation outside childcare center, teachers listened to the alert of "major tsunami warning" that was broadcasted by public loudspeakers. Traffic congestion has occurred along public roads, which cross the evacuation route, making it difficult to cross intersections. To secure the evacuation route, it was necessary to block the intersection temporarily and force vehicles to stop. When arrived at the edge of hill access stairs/slopes, nursery teachers and children could get together with residents of the neighborhood who were also

evacuating. With the cooperation of these residents, all children could be evacuated in safety through the stairs and severe slopes to the park Y. Figure 5 shows an overview of the hill where park Y is located.

Figure 5. Overview of the hill where park Y is located

Overview of the secondary evacuation (to the hospital N)

At around 17:00, government officials and firefighters came to the park, and oriented nursery group and other evacuees to move to the hospital N, located adjacent to the hill. The evacuation of nursery children has become a priority, and they were moved through the bridge that connects the intermediate part of the hill access stairs with the fifth floor of the hospital. The emergency parents meeting place with children's parents that had been preventively designated was the Kamaishi elementary school. As the school staff came to visit the hospital in the evening, nursery teachers requested them to announce at the school the situation of children in the hospital N, ready to be handed over to their parents. The last children were handed over to their parents two days after the earthquake.

Post-disaster considerations

In nursery K, the evacuation to the park Y was concluded in 19 min after the earthquake, and 15 min before surrounding area being flooded by tsunami. According to the teachers:

The traffic congestion was the biggest problem, and the cooperation of community to handling multi-passenger baby strollers and assisting children in stairs and slopes were considered crucial to the success of evacuation.

3.2. Facilities where people were relatively delayed to start evacuation in the urban environment

3.2.1. Evacuation of Nursery S

According to the teachers, before GEJE, in this facility, they had conducted once a year an evacuation drill to the nearest hill with parents and local residents. At the time of GEJE, three nursery staff were taking care of eight children, and the quake occurred just after one teacher ended working and two children left the facility. Remaining children were evacuated to the playground, and some parents came to pick up them. After handed over four children 3 years of age to their parents, teachers listened to the "major tsunami warning" broadcasted by public loudspeakers, announcing that there was a risk of "waves with six meters of height," triggering the primary evacuation to the nearest hill, and secondary evacuation to the Shishiori elementary school. Details of the evacuation response are shown in Table VI and Figure 6.

Table VI. Evacuation of nursery S

Evacuation	Destinations
Primary	To the nearest hill ◆ Distance along the walking route measured in the horizontal direction: about 780 m* ◆ Elevation gain: about +5.9 m*
Secondary	To the Shishiori Elementary School ◆ Distance along the walking route on train rail measured in horizontal direction: about 940 m*

Note: *Estimated with cartographic data of GSI Japan.

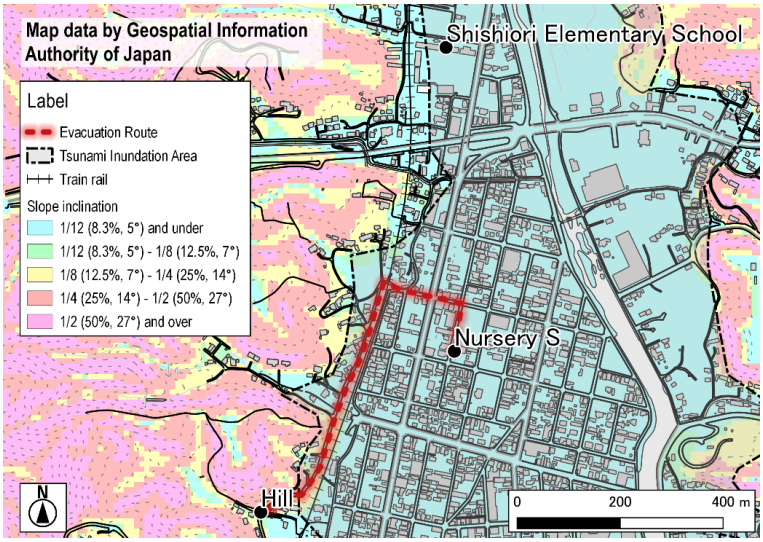

Figure 6. Evacuation route of nursery S

Overview of the primary evacuation (to the nearest hill)

Because of the announcement of "major tsunami warning," it was decided to start evacuation to the nearest hill. The preparation to leave the facility took 5 min, and during this time, two remaining children were handed over to their parents. However, teachers got together again with them in an intersection located 150 m along the route. As soon as they arrived at the hill together, they noticed that the surrounding area was already being flooding by tsunami.

Overview of the secondary evacuation (to the Shishiori elementary school)

It began to snow on the hill, and they needed to look somewhere for shelter. However, it was difficult to find other places, as potential shelters such as nearby houses, were already full of evacuees. They decided to go down the hill, to reach a raising train rails and walk along the rail to get to the Shishiori elementary school. The tsunami had flooded the train rails, however, as the waves already pulled back, it was possible to proceed with the evacuation. The surrounding areas were severely destroyed by tsunami and a fire outbreak, with the risk of exposure to smoke and sparks, but they could get to the school with safety.

Post-disaster considerations

In a subsequent reconsideration after the disaster, some doubt has arisen, as follows: "if parents did not come and children 3 years of age remained, maybe it would not have been possible to evacuate to Shishiori elementary school"; "maybe it was better if we had previously planned the destination of secondary evacuation, after arriving at the hill."

3.2.2. Evacuation of Nursery N

According to the teachers, there was no specific evacuation plan in the urban environment in case of risk of tsunami. In case of a strong earthquake, in which seismic intensity is greater than JMA-5 (Japan Meteorological Agency seismic intensity scale), there was a plan to evacuate children to the second floor and parents should come

and pick up their children, as previously agreed in case of emergency. The earthquake occurred when nine staff were taking care of 37 children 0-3 years of age. All teachers and children did the primary evacuation to the second floor of the facility. After the first floor was flooded by tsunami, they did the secondary evacuation to the non-flooded area and reached the Kesennuma high school. Details of the evacuation response are shown in Table VII and Figure 7.

Table VII. Evacuation of nursery N

Evacuation	Destinations
Primary	To the 2nd floor of the childcare center
Secondary	To the non-flooded area to reach the Kesennuma High School ◆ Distance along the walking route measured in horizontal direction: about 1.13 km* ◆ Elevation gain: about +35.9 m*

Note: *Estimated with cartographic data of GSI Japan.

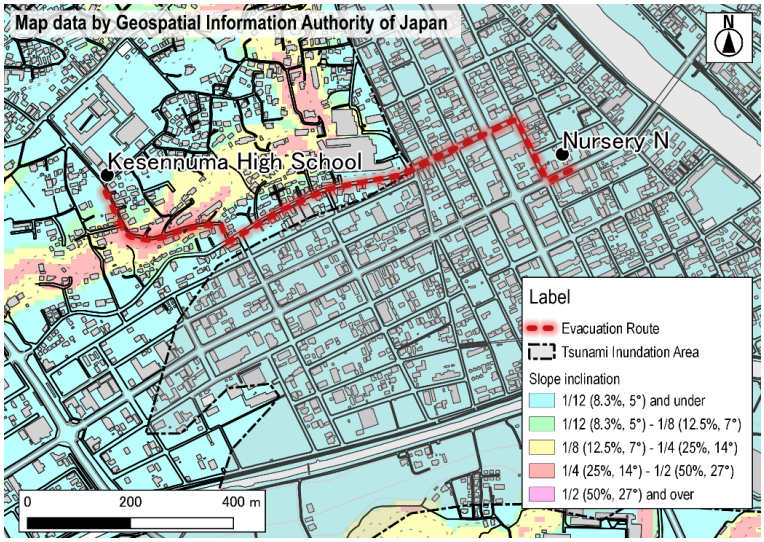

Figure 7. Evacuation route of nursery N

Overview of the primary evacuation (to the second floor of childcare center).

Immediately after the quake, all children were evacuated to the second floor, staying there to wait for their parents. Teachers were overwhelmed to attend dozens of parents who came to pick up their children, and no one could notice if any tsunami warning was being announced or not. According to the local tsunami hazardous map, the childcare center was located outside of flood-prone area, but nearby hazardous boundary. When parents of the last two remaining children arrived on the second floor, the first floor was flooded by tsunami, and the area surrounding the facility was filled with debris. Innumerous vehicles from a nearby car store were dragged, colliding and knocking down electricity poles, and part of this debris invaded the outer staircase of the nursery building. Without conditions to escape from the nursery, two children 0-1 year of age, one parent, nine nursery teachers and another two teachers that went to the childcare center to support the nursery after the earthquake (they were outside the facility at the time of earthquake), totalizing 14 people, have become isolated on the second floor.

Overview of the secondary evacuation (to the non-flooded area to reach the Kesennuma high school)

Later, at 17:30, a large smoke caused by fire outbreaks in flooded areas was seen at a remote place, causing safety concern at the childcare center. Also, considering that emergency stocks for foods and heating equipment were insufficient, they decide to escape from the facility and initiate secondary evacuation in the urban environment. Deviating the accumulated debris in stairs, the nursery group went to the first floor, which was partially flooded up to 1 m height. They found a window facing the parking lot, where there was relatively less amount of debris, through which they could escape outside. At that time, two remaining children were carried by the piggyback ride. The multi- passenger baby strollers were found submerged and broken next to the entrance. In the urban environment, they managed to move about 250 m to reach an intersection where the flood area ended, walking carefully to avoid accidental falls in gutters below flooded areas. They initially tried to reach the nearby

municipal hospital to shelter, however, they were informed that the hospital was completely full of evacuees. In the end, they needed to move to the Kesennuma high school, where the safety of the nursery group was guaranteed. While they were moving to the school, it happened to get together with father of one of the last remaining children, for whom the child was returned.

Post-disaster considerations

In a subsequent reconsideration after the disaster, some doubt has arisen, as follows: “if having chosen the second floor of the childcare center was really adequate or not”; “if the tsunami was even stronger, the childcare center could have been dragged by waves.”

3.3. Evacuation of Nursery H

According to the teachers, the earthquake occurred when three staff were taking care of 20 children 3-5 years of age. Immediately after the quake, all children were evacuated to the playground, according to the evacuation planning and drills that were carried out periodically, then they did the primary evacuation to the Hashikami junior high school. Details of the evacuation response are shown in Table VIII and Figure 8.

Table VIII. Evacuation of nursery H

Evacuation	Destinations
Primary	To the Hashikami Junior High School ◆ Distance along the walking route measured in horizontal direction: about 1.25 km* ◆ Elevation gain: about + 23.2 m*

Note: *Measured with cartographic data of GSI Japan.

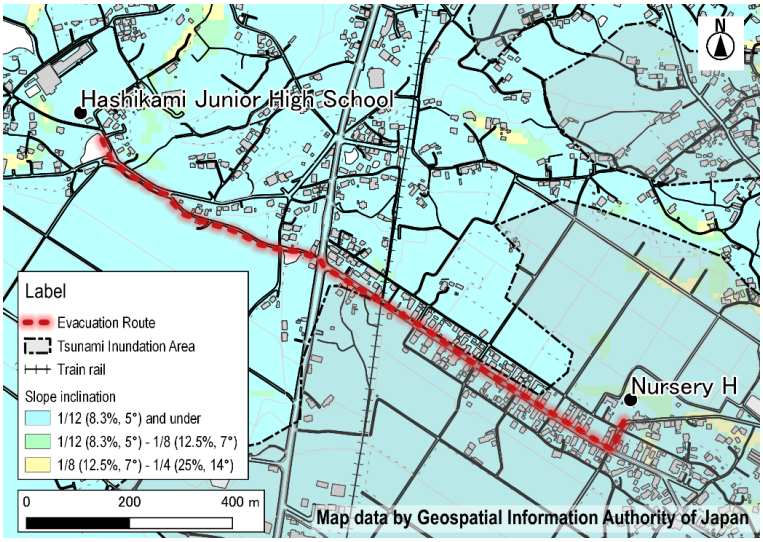

Figure 8. Evacuation route of nursery H

Overview of the primary evacuation (to the Hashikami junior high school)

When the earthquake occurred, children initially did not obey the guidance for evacuation, standing still. While the earthquake continued, children 3-5 years of age began to walk to go outside after teachers shouted, and children 3 years of age had to be carried by teachers to leave the building. Shortly after arriving at the playground, some of the children were handed over to their parents who came to pick up them. One child 4 years of age remained at the facility, and at that time, they recognized the risk of tsunami, when teachers noticed that students of nearby high school were doing massive evacuation in proximity, going in the direction of the Hashikami junior high school, located in the elevated ground. Three teachers decided to leave the childcare center and started evacuation to the junior high school with a remaining child. However, two teachers those were already on the way of evacuation needed to return to the childcare center to place the notification about the destination of evacuation in the garden gate. One teacher and one child continued walking for evacuation through the route surrounded by many old houses. Because of continuous aftershocks, they had to stop many times to protect from the tiles that fell from these houses. Most of the local residents of surrounding area had been evacuated earlier, and it was not able to see those residents

walking for evacuation along the route. When the teacher and the child were walking along the route, they were alerted by other people who were driving cars for evacuation that "the tsunami has was already reached the area nearby," but they did not let them ride on their cars. After walking 600 m and arriving in the area next to the train rail, it was possible to get a ride from a resident who was evacuated by car, taking them safely to the junior high school. Posterity, other two nursery staff were also able to ask to ride on another car. Around 16:00, all three teachers, one child and his parents were able to get together at the school.

Post-disaster considerations

In a subsequent reconsideration after the disaster, some doubt has arisen, as follows: "some residents found that our childcare center was a designated evacuation shelter in case of tsunami, and one elderly came there to evacuate by mistake"; "if the relatives of this elderly had not come to get him immediately, perhaps, our evacuation could have been compromised."

4. Conclusions

This study addressed the effectiveness of early warning and community cooperation as factors that contribute to strengthening the resilience of childcare centers from mega-risk type coastal hazards, by investigating evacuation cases of childcare centers that were affected by tsunami at the time of the 2011 GEJE in municipalities of Kesennuma and Kamaishi. Figures 9 and 10 show the overview of nursery group formation for wide-scale evacuation in urban environment and the destination of evacuation at the time of 2011 GEJE. Main findings are as follows:

- Facilities located near seaside tend to be more concerned about the risk of tsunami, and there was a tendency to start evacuation even before the announcement of tsunami warning by authorities (broadcasted via public loudspeakers, television, radio, email and mobile phones through nationwide warning system "J-alert").
- Facilities that had been preventively designated as the emergency parents meeting place outside childcare centers tend to initiate evacuation more quickly, while facilities that had been designated as the emergency parents meeting place within the facility tend to delay response.
- Facilities, where nursery teachers and children started evacuation immediately after the earthquake, could have more conditions to receive tsunami warnings appropriately and decide the destination of evacuation according to the severity, and get more cooperation from the local community to evacuate children.
- Children 2 and 3 years of age or higher tended to be instructed to walk two abreast under the lead of teachers, and children 2 years of age, 1 year of age or younger tended to be carried by the piggyback ride and multi-passenger baby strollers, with the capacity to carry four to eight children (Figure 9).
- The destination of evacuation that had been indicated in pre-existent evacuation plan needed to be changed several times, to areas located in higher places and even far from the flood-prone areas according to tsunami hazard map released by the local government, because of the increment of risks for higher tsunami and fire outbreaks (Figure 10).

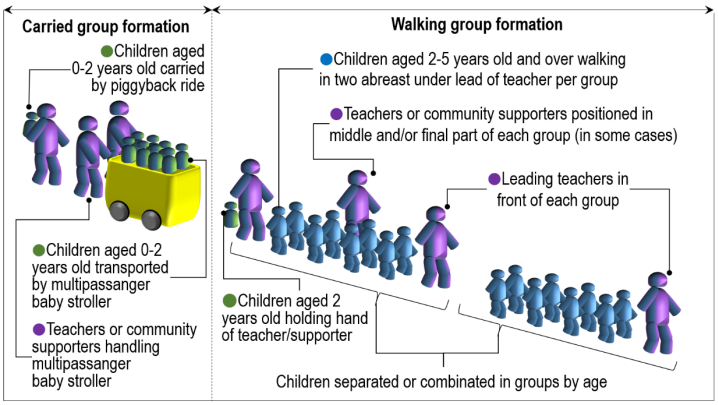

Figure 9. Overview of nursery group formation for wide-scale urban evacuation at the time of 2011 GEJE

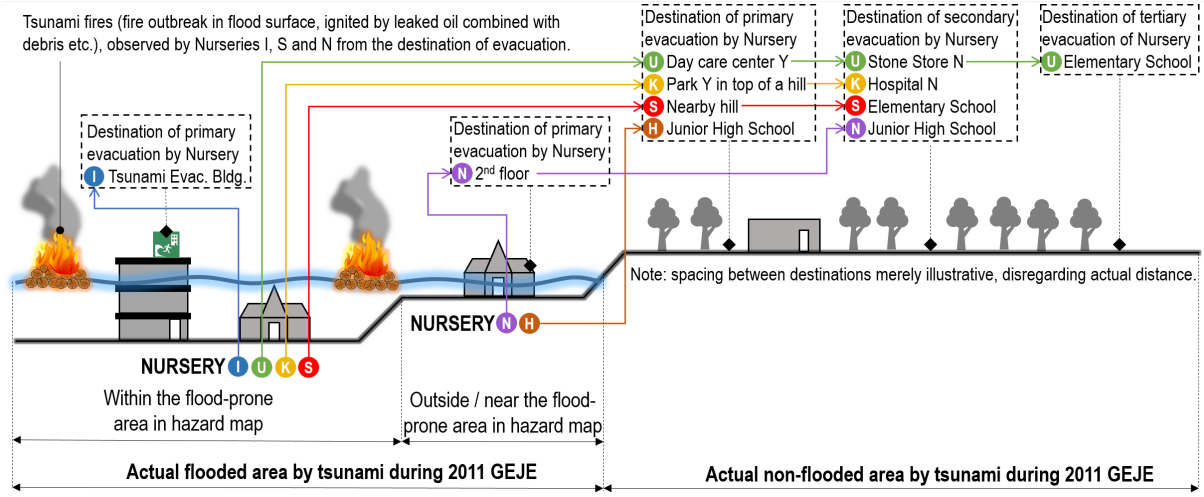

Figure 10. Overview of destinations of the evacuation of nursery teachers and children at the time of 2011 GEJE

Considering these findings, as disaster preparedness effort for the potential mega-risk type coastal hazard in future, if a childcare center is located near seaside, designating a shelter in elevated places even far from the flood-prone areas should be considered as a priority (except when T.E.Bs. within flood-prone area remain as the only alternative place for shelter). This may imply in more steep and distant evacuation routes in an urban environment, as well as in longer time required to complete the evacuation – a situation, which tends to worsen even more in case of lack of human resources to recognize risks, start the evacuation and guide children to the shelter. Therefore, the receptivity of early warnings and the availability of community cooperation should be considered as essential factors for the effectiveness of evacuation. As future issues, it is necessary to understand the walking capability of children under the lead of teacher, as well as the transportation capability of multi-passenger baby strollers by teachers, to address strategies to quantify the necessary community cooperation based on the severity of early warning, contributing to the development of wide-scale urban evacuation plans that are more effective in their conditions.

Acknowledgments

The authors thank all teachers of childcare centers and people related to the facilities that were the destinations of evacuations of people from childcare centers that contributed to the survey. This work was supported by JSPS No. R2904 in the program for fostering globally talented researchers.

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