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Original Article

Influence of post-disaster evacuation on childhood obesity and hyperlipidemia

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Abstract ***Background*****:** The objectives of this study were to determine the longer-term trends in childhood obesity and hyperlipidemia among residents of Fukushima Prefecture 5 years after the Great East Japan Earthquake.

Methods**:** We evaluated the changes in height, weight, body mass index (BMI) standard deviation score (BMI-SDS), low-density lipoprotein-cholesterol (LDL-CHO), high-density lipoprotein-cholesterol (HDL-CHO), and triglyceride (TG) in residents aged 7–15 years who had lived in the evacuation zone between 2011 and 2015.

Results**:** (i) the mean BMI SDS in all residents in 2011 was 0.113, and the mean BMI-SDS in all residents gradually decreased from 2011 to 2015; (ii) serum LDL-CHO levels and TG levels in all residents with a BMI value ≧ 2SD in 2011 were higher than those in residents with a BMI value <2SD; (iii) the frequency of residents with an LDL-CHO level ≥ 140 mg/dl in 2012, 2013, and 2014 did not decrease in comparison with that in 2011, whereas the frequency of residents with an LDL-CHO level of ≥ 140 mg/dl in 2015 was lower than that in 2011. The frequency of residents with a TG level ≥ 120 mg/dl increased over the 5 years.

Conclusions**:** These results suggest that a number of pediatric residents suffered from obesity and hyperlipidemia. Furthermore, the long-term observation indicated an improvement in obesity, although the improvement in lipid abnormalities was delayed compared with that in obesity. Thus, it is necessary to continue with health checks for these residents with obesity and/or hyperlipidemia.

Key words accident at the Fukushima Daiichi Nuclear Power Plant, child, Great East Japan Earthquake, hyperlipidemia, obesity.

On 11 March 2011, the Pacific coast of the northern area of Japan was struck by the most destructive earthquake ever recorded in Japan at 14:46 (Japan Standard Time). The epicenter was in the Pacific Ocean, approximately 130 kilometers east of the Tohoku coastline, and the hypocenter was at a depth of approximately 32 kilometers below sea level. This earthquake had a magnitude of 9.0 on the Richter scale. It was the most powerful earthquake ever to have hit Japan, and one of the five most powerful earthquakes in the world since modern record-keeping began in 1900.[1–4] The earthquake and subsequent tsunami caused a serious accident at the Fukushima Daiichi Nuclear Power Plant, forcing more than 160 000 residents of Fukushima Prefecture to be evacuated.

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To monitor the long-term health of residents, the Fukushima Health Management Survey (FHMS) was started immediately after the disaster. Early results of the FHMS have already shown increases in body weight and higher incidences of diabetes, dyslipidemia, atrial fibrillation, hypertension, renal dysfunction, and metabolic syndrome among adult residents,[5–9] and some residents aged ≤15 years developed obesity and hyperlipidemia in 2011.[10]

Although more than 6 years have passed since the disaster, over 90 000 residents of Fukushima Prefecture have not yet returned to their homes. Previous assessments of childhood obesity and hyperlipidemia using FHMS data showed that the mean body weight had decreased in both males and females in 201.2 in comparison to 2011; however, there were no differences in the frequency of male or female residents with high low-density lipoprotein-cholesterol (LDL-CHO) or high triglyceride (TG) values between 2011 and 2012. These results reflected only the relatively short-term effects; however, the longer-term effects of the disaster on health and lifestyle, factors associated with obesity and hyperlipidemia remain unclear. Therefore, the objectives of this study was to determine the longer-term trends in obesity and hyperlipidemia among residents of Fukushima Prefecture 5 years after the disaster.

Methods

The study was carried out under the auspices of the Committee for Human Experiments at the Fukushima Medical University (Institutional Review Board approval no. 1319). Informed consent was obtained from all residents aged ≤15 years (or their parents) who received health checks.

The Fukushima Prefectural government decided to conduct the FHMS to assist in the long-term health management of residents, to evaluate the health impact of the accident, to promote the future well-being of residents, and to determine whether long-term low-dose radiation exposure has had any effect on their health.[6–8] The framework of the FHMS is shown in Figure 1. Comprehensive health checks are part of the overall FHMS and we sought to review the data regarding evacuee health, assess the incidence of various diseases, and to improve the residents overall health status.

Target group

The target group consisted of residents aged 7–15 years who had lived in Hirono-machi, Naraha-machi, Tomioka-machi, Kawamata-machi, Kawauchi-mura, Okuma-machi, Futaba-machi, Namie-machi, Kazurao-mura, Iitate-mura, Minami-soma City, Tamura City, or the part of Date city, specifically recommended for evacuation.

The residents aged 7–15 years have received health checks at 656 pediatric medical institutions in and outside the prefecture since January 2011.

Evaluation items

In addition to assessing the effects of radiation, additional variables were specified according to age, to assess health, prevent lifestyle-related diseases, and identify or treat diseases at an early stage. The items surveyed for children aged 7–15 years included height, weight, blood pressure, red blood cell count, hematocrit, hemoglobin (Hb), platelet count, and white blood cell count. Upon request, aspirate aminotransferase, alanine aminotransferase, γ-glutamyl transpeptidase, TG, HDL-CHO, LDL-CHO, hemoglobin A1c (HbA1c), fasting

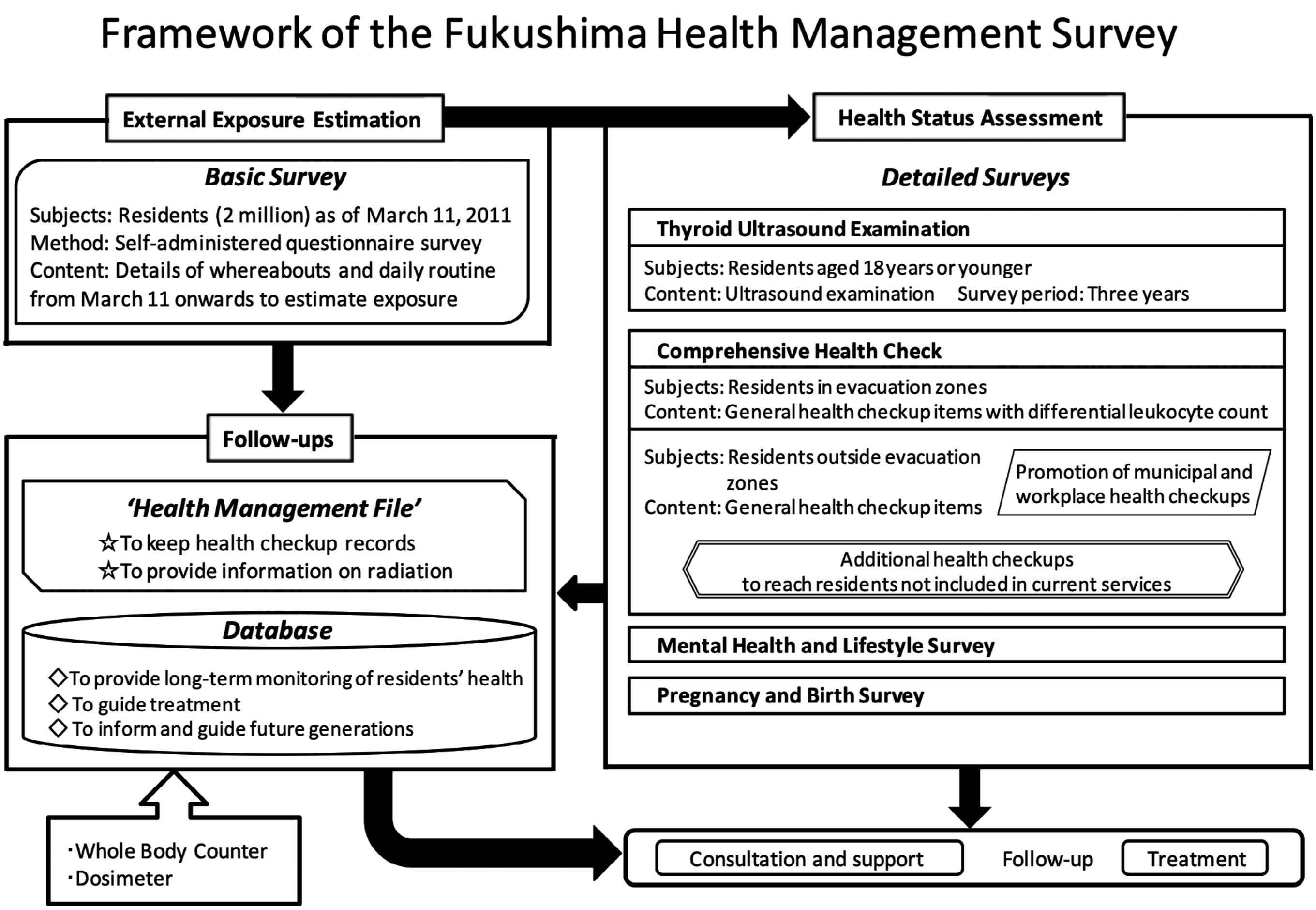

Fig. 1 Framework of the Fukushima health management survey.

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plasma glucose concentration, serum creatinine and uric acid levels were also assessed. In addition, we evaluated the changes in height, weight, body mass index (BMI), BMI standard deviation scores BSID-SDS, LDL-CHO, HDL-CHO, and TG from 2011 to 2015.

Definitions

The following laboratory data were obtained from all participants: height, weight, HDL-CHO, LDL-CHO, and TG. Hyperlipidemia was defined as LDL-CHO ≥ 140 mg/dl, TG ≥ 120 mg/dl, and/or HDL-CHO < 40 mg/dl.

Assessment of body mass index

BMI was calculated as weight in kilograms divided by height in meters squared. Because BMI in childhood changes substantially with age, the comparison of BMI among children of different age groups is difficult. For that reason, it was necessary to standardize the data. Cole constructed centile curves for BMI using the lambda-musigma method, which was adopted by Inokuchi *et al.* for the Japanese population.[11,12] Therefore, we are now able to express BMI as SDS. We converted the BMI of all children to BMI-SDS using calculation software.[13,14]

Statistical analysis

Means or prevalences for baseline variables of interest were compared between the residents with a BMI of >2SD and those with a BMI of <2SD score, using Student's *t*-test or chi-squared tests. Based on 2011 values, changes in LDL-C, HDL-C, and TG each year from 2011–2015 were compared using a Student's paired *t*-test, McNemar's test, or a binomial link model.

SAS version 9.3 (SAS Institute, Cary, NC, USA) was used for all statistical analyses. All probability values for statistical tests were two-tailed and *P* values of < 0.05 were regarded as statistically significant.

Results

Baseline characteristics for residents aged 7–15 years from 2011–2015

In 2011, 11 079 of the residents aged 7–15 years received health checks, whereas 7,007, 6,023, 5,432, and 4,604 of those aged 7–15 years received health checks in 2012, 2013. 2014, and 2015, respectively (Table 1).

BMI-SDS and lipid function including LDL-C, HDL-C, and TG values, in residents aged 7–15 years in 2011

Table 1 A comparison of the characteristics of the residents aged 7–15 years who received health checks from 2011–2015

	2011	2012	2013	2014	2015
Number of residents	11 079	7,007	6,023	5,432	4,604
Mean age ± SD (years)	11.5 (2.6)	11.3 (2.5)	11.2 (2.4)	11.2 (2.4)	11.2 (2.5)
Sex (male: female)	5,575: 5,504	3,590: 3,417	3,085: 2,938	2,772: 2,660	2,396: 2,208

Table 2 The number of residents by BMI-SDS for all residents (n = 11,079), the male group (n = 5,575) and the female group (n = 5,504)

Degree of BMI-SDS	All residents *n* (%)	Males *n* (%)	Females *n* (%)
BMI-SDS ≧ 2.5D	616 (5.6)	346 (6.2)	270 (4.9)
2.5D > BMI-SDS ≧ 1.5D	1,277 (11.5)	632 (11.3)	645 (11.7)
1.5D > BMI-SDS ≧ −1.5D	8,042 (72.6)	4,038 (72.4)	4,004 (72.8)
−1.5D > BMI-SDS ≧ −2.5D	1,135 (10.2)	553 (9.9)	582 (10.6)
−2.5D > BMI-SDS	9 (0.1)	6 (0.1)	3 (0.1)

BMI-SDS, body mass index standard deviation scores.

Table 3 BMI-SDS and lipid function in residents of Fukushima Prefecture in 2011 (n = 11,079)

	All residents	Males	Females
Mean BMI-SDS	0.113 (−2.487to 6.819)	0.116 (−2.487–6.262)	0.109 (−2.105–6.819)
Mean LDL-CHO levels (mg/dl)	94.2 ± 23.1	92.0 ± 23.4	96.3 ± 22.6
Mean HDL-CHO levels (mg/dl)	62.5 ± 13.7	62.2 ± 14.2	62.7 ± 13.2
Mean TG levels (mg/dl)	76.5 ± 50.0	75.5 ± 51.9	77.6 ± 48.0

Scores are mean ± SD (range). BMI-SDS, body mass index standard deviation scores; HDL-CHO, high-density lipoprotein-cholesterol; LDL-CHO, Low-density lipoprotein-cholesterol; TG, triglyceride.

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Table 4 Comparison of serum LDL-CHO, HDL-CHO, and TG levels between residents with a BMI score more than +2SD and those with a BMI score less than +2SD in 2011 (n = 11,079)

	All			Males			Females		
	Residents with a BMI score > +2SD (*n* = 616)	Residents with a BMI score < +2SD (*n* = 10 463)	*P-value*	Residents with a BMI score >2SD (*n* = 346)	Residents with a BMI score <+2SD (n = 5,229)	*P-value*	Residents with a BMI score > +2SD (*n* = 270)	Residents with a BMI score <+2SD (*n* = 5,234)	*P-value*
LDL-CHO (mg/dl)	107.3 ± 27.0	93.4 ± 22.6	<0.001	110.2 ± 28.0	90.8 ± 22.5	<0.001	103.7 ± 25.3	96.0 ± 22.3	<0.001
HDL-CHO (mg/dl)	53.0 ± 11.3	63.0 ± 13.6	<0.001	51.2 ± 11.0	62.9 ± 14.0	<0.001	55.4 ± 11.3	63.1 ± 13.2	<0.001
TG (mg/dl)	114.9 ± 75.5	74.3 ± 47.1	<0.001	127.1 ± 82.2	72.1 ± 47.3	<0.001	99.3 ± 62.6	76.4 ± 46.8	<0.001

Scores are mean ± SD (range). BMI, body mass index; HDL-CHO, high-density lipoprotein-cholesterol; LDL-CHO, Low-density lipoprotein-cholesterol; TG, triglyceride.

The mean BMI-SDSs for all three groups (residents, males, and females) were 0.113 (−2.487 to 6.819), 0.116 (−2.487 to 6.262), and 0.109 (−2.105 to 6.819), respectively (Table 2). The number of residents per degree of BMI-SDS for all residents, males, and females in 2011 is shown in Table 3-Table 2.

The mean LDL-CHO levels for all residents, males, and females were 94.2 ± 23.1 92.0 ± 23.4, and 96.3 ± 22.6 mg/dl, respectively. The number of residents with an LDL-CHO level of >140 mg in the three groups was 390 (3.5%), 190 (3.4%), and >200 (3.6%), respectively, while the number of residents with an LDL-CHO level of <140 mg in each of the three groups was 10 689 (96.5%), 5,385 (96.6%), and 5,304 (96.4%), respectively.

The mean HDL-CHO levels for all residents, males, and females were 62.5 ± 13.7, 62.2 ± 14.2, and 62.7 ± 13.2 mg/dl, respectively. The number of residents with an HDL-CHO level of <40 mg in the three groups was 325 (2.9%), 172 (3.1%), and 153 (2.8%), respectively, whereas the number of residents with an HDL-CHO level of >4 0mg in each of three groups was 10 754 (97.1%), 5,403 (96.9%), and 5,351 (97.2%).

The mean TG levels for all residents, males, and females were 76.5 ± 50.0, 75.5 ± 51.9, and 77.6 ± 48.0 mg/dl, respectively. The number of residents with a TG level >120 mg in the three groups was 1,416 (12.8%), 717 (12.9%), and 699 (12.7%), respectively, while the number of residents with a TG value <120 mg in each of three groups was 9,663 (87.2%), 4,858 (87.1%), 4,805 (87.3%), respectively.

Comparison of serum LDL-CHO, HDL-CH, and TG levels between residents with a BMI score > 2SD and those with a BMI score <2SD in 2011

A comparison of BMI-SDS between residents with a score >2SD and those with a score <2SD in 2011 revealed that serum LDL-CHO level and TG level for all residents, males, and females with a BMI score >2SD were higher than those in residents with a BMI score <2SD. In addition, the serum HDL-CHO level for all residents, males, and females with a BMI score >2SD was lower than that in residents with a BMI score <2SD (Table 4).

The change in BMI-SDS and lipid function including LDL-CHO, HDL-CHO, and TG values, in residents aged 7–15 years from 2011–2015

BMI-SDS

For all residents, the males, and the females, the change in BMI-SDS tended to decrease over the 5-year period ($P < 0.0001$), with the BMI-SDS in 2011 higher than those in 2012, 2013, 2014, and 2015 (Table 5). Furthermore, the frequency of residents with a BMI score of > 2SD in 2011 was higher than that in 2012, 2013, 2014, and 2015, with the

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Table 5 Comparison of serum BMI SDS, LDL-CHO, HDL-CHO and TG levels for all residents, males and females who received health checks from 2012–2015 with those in 2011 (n = 11,079)

	2011	2012	*P*-value	2013	*P*-value	2014	*P*-value	2015	*P*-value
BMI SDS									
All	0.113 (1.05)	0.002 (1.02)	<0.001	−0.016 (1.00)	<0.0001	−0.045 (0.97)	<0.0001	−0.029 (0.97)	<0.0001
Male	0.116 (1.08)	0.026 (1.07)	<0.0001	0.020 (1.06)	<0.0001	−0.021 (1.01)	<0.0001	−0.004 (1.01)	<0.0001
Female	0.109 (1.08)	−0.022 (1.07)	<0.0001	−0.054 (1.06)	<0.0001	−0.070 (1.01)	<0.0001	−0.056 (1.01)	<0.0001
LDL-CHO (mg/dl)									
All	94.2 (23.1)	93.7 (22.7)	0.52	94.0 (23.3)	0.96	93.5 (22.9)	0.30	92.3 (22.9)	<0.0001
Male	92.0 (23.4)	92.1 (22.8)	1.000	92.4 (23.7)	0.92	91.5 (23.1)	0.82	90.9 (23.4)	0.17
Female	96.3 (22.6)	95.4 (22.5)	0.19	95.6 (22.7)	0.48	95.6 (22.5)	0.48	93.7 (22.3)	<0.0001
HDL-CHO (mg/dl)									
All	62.5 (13.7)	61.2 (12.9)	<0.001	61.4 (12.9)	<0.0001	61.6 (12.8)	<0.0001	60.6 (12.5)	<0.0001
Male	62.2 (14.2)	61.3 (13.4)	0.01	61.6 (13.5)	0.19	61.7 (13.4)	0.38	60.9 (13.0)	0.001
Female	62.7 (13.2)	61.2 (12.4)	<0.0001	61.3 (12.3)	<0.0001	61.4 (12.2)	<0.0001	60.4 (12.0)	<0.0001
TG (mg/dl)									
All	76.5 (50.0)	77.2 (48.9)	0.87	78.8 (50.9)	0.02	79.3 (51.6)	0.004	79.1 (53.5)	0.015
Male	75.5 (51.9)	76.2 (49.9)	0.95	77.9 (53.8)	0.14	79.4 (54.8)	0.01	77.3 (50.0)	0.49
Female	77.6 (48.0)	78.2 (47.8)	0.96	79.8 (47.7)	0.16	79.3 (48.1)	0.43	81.1 (57.0)	0.02

P-value: compared to 2011. BMI-SDS, body mass index standard deviation scores; HDL-CHO, high-density lipoprotein-cholesterol; LDL-CHO, Low-density lipoprotein-cholesterol; TG, triglyceride.

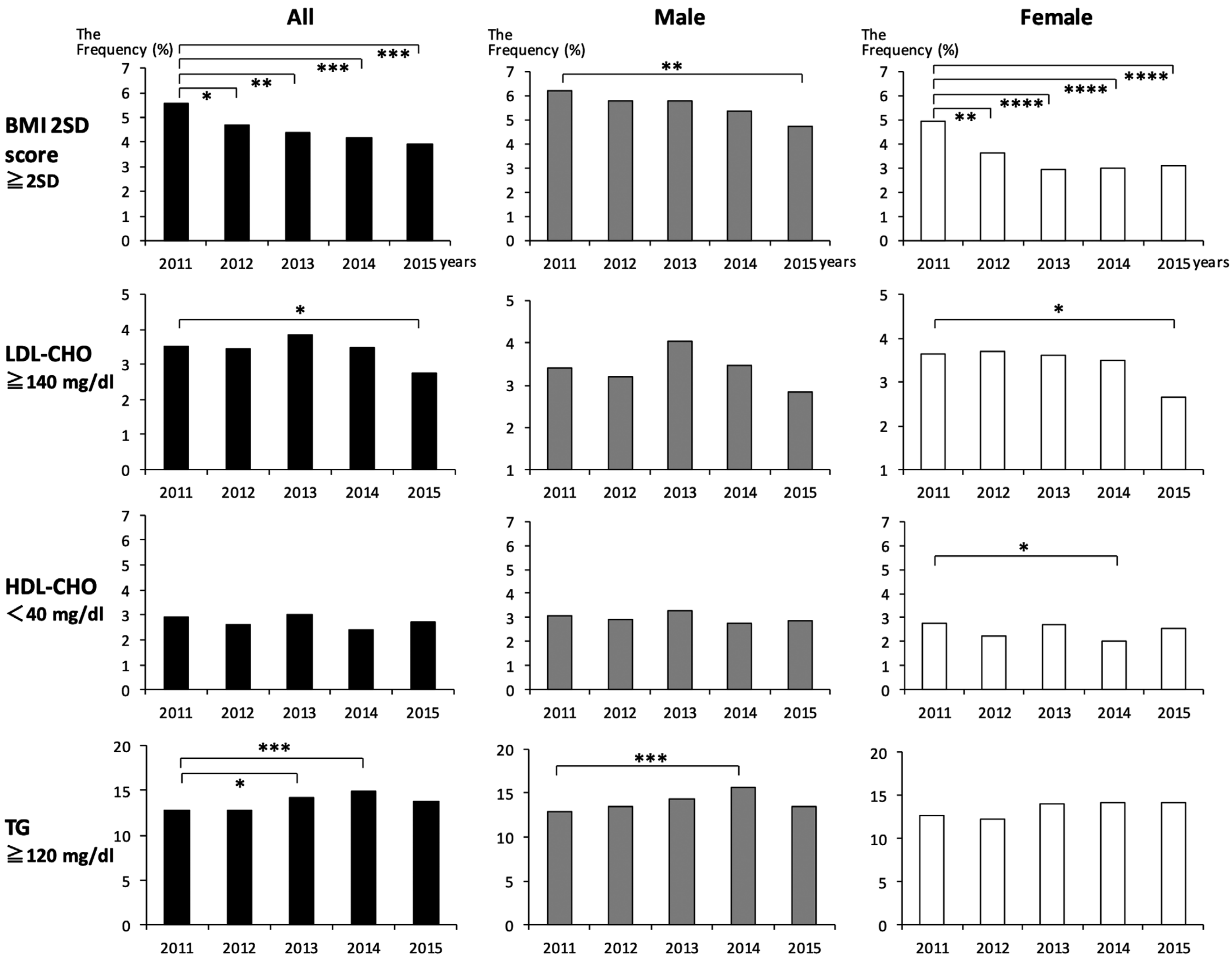

Fig. 2 Changes in body mass index and lipid functions from 2011 to 2015. BMI, body mass index; LDL-CHO, low-density lipoprotein-cholesterol; HDL-CHO, high-density lipoprotein-cholesterol; TG, triglyceride.

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frequency of residents with a BMI score >2SD decreasing with time over the 5 years (Fig. 2).

LDL-CHO

For all residents, the males, and the females, serum LDL-CHO levels in 2012, 2013, and 2014 did not show any decrease compared with those in 2011. However, serum LDL-CHO levels in 2015 were lower than those in 2011 (Table 5). Furthermore, the frequencies of residents with a serum LDL-CHO level >140 mg/dl in 2012, 2013, and 2014 did not show any decrease compared with those in 2011, and the frequency of residents with a serum LDL-CHO level >140 mg/dl in 2015 was lower than that in 2011 (Fig. 2).

HDL-CHO High-density lipoprotein-cholesterol

The mean HDL-CHO levels for all residents in 2011, 2012, 2013, 2014, and 2015 were 62.5 ± 13.7, 61.2 ± 12.9, 61.4 ± 12.9, 61.6 ± 12.8, and 60.6 ± 12.5, respectively (Table 5), and the frequencies of residents with a HDL-CHO level <40 mg/dl in 2011, 2012, 2013, 2014, and 2015 were 2.9, 2.6, 3.0, 2.4, and 2.7 (Fig. 2). The mean HDL-CHO level tended to decrease over the 5-year period; however, there was no clear trend in the frequency of residents with an HDL-CHO level <40 mg/dl over the 5 years.

Triglyceride

The mean TG levels for all residents in 2011, 2012, 2013, 2014, and 2015 were 76.5 ± 50.0, 77.2 ± 48.9, 78.8 ± 50.9, 79.3 ± 51.6, and 79.1 ± 53.5, respectively (Table 5), and the frequencies of residents with a TG level of >120 mg/dl in 2011, 2012, 2013, 2014, and 2015 were 12.8, 12.8, 14.2, 14.9, and 13.8 (Fig. 2). Further, the frequency of residents with a TG level of >120 mg/dl increased over the 5 years ($P < 0.0002$).

Discussion

The Great East Japan Earthquake and Fukushima Daiichi nuclear disaster forced people to evacuate their homes without notice and caused them to change their lifestyle in terms of diet, exercise patterns, and other personal habits, to adapt to a completely new situation, and produced a good deal of anxiety with regard to radiation exposure. In response to this situation, the Fukushima Prefectural Government made the decision to implement what they termed the FHMS to assist in the long-term health management of residents and to evaluate the health impact of the nuclear disaster and forced evacuation. In a comparison study of height and body weight between 2011 and 2012, we previously reported, that the mean height increased whereas the mean body weight decreased in both males and females in 2012 in comparison to 2011. In addition, with regard to lipid function, no significant differences in the prevalence of high LDL-CHO or high TG values were observed in either males or females in the 7–15 years age group between 2012 and 2011. Thus, in order to clarify the influence of obesity and hyperlipidemia over a long period after such a disaster, we evaluated BMI-SDS, LDL-CHO, HLD-CHO, and TG over a 5-year period in residents aged 7–15 years.

Childhood obesity is a serious public health problem, not only in Japan, but worldwide. According to the Central for Disease Control and Prevention, the prevalence of obesity in children aged 6–11 years has increased substantially from 7% in 1980 to nearly 18% in 2012. Likewise, the prevalence of obesity in adolescents aged 12–19 years has increased from 5% to nearly 21% during the same period.[15–17] Strong evidence has indicated the persistence of childhood obesity into adulthood, with childhood obesity considered a multisystem disease.

With regard to pediatric obesity, after the Great East Japan Earthquake, based on our short-term follow-up, we reported that some residents aged 7–15 years developed obesity during the period from 2011 to 2012. Ono *et al*. retrospectively investigated obesity in young children through a survey of the pre-existing health examination data in early childhood (aged 1–3 years) and found that the children who were affected by the Great East Japan Earthquake in early childhood were overweight.[14] In addition, Kikuya *et al.* reported that the incidence of being overweight in young children (3.5–4.5 years) was significantly more common in the three prefectures (Fukushima, Miyagi, Iwate) affected by the Great East Japan Earthquake than in other prefectures after the disaster.[18] However, there have been no reports on the relationship between pediatric obesity and hyperlipidemia after the disaster, based on a long-term follow-up.

BMI is used to evaluate obesity in adults; however, as BMI values change significantly with age in children, we used BMI-SDS to evaluate BMI objectively.[14] Unfortunately, our previous report presented only a review of changes in weight and we could not make any statistical evaluations.

Our findings regarding the mean BMI-SDS in 2011 for all residents, the male group and the female group aged 7–15 years were 0.113, 0.116, and 0.109, respectively, indicating that the mean BMI in each of the three groups was higher than that in standard Japanese children of the same age. Furthermore, as to the change in childhood obesity over the 5 years, the mean BMI-SDS in all residents, males, and females aged 7–15 years gradually decreased from 2011–2015. The causes of the increase in obesity in pediatric participants in Fukushima Prefecture after the Great East Japan Earthquake were shown to be as follows: (i) after the accident at the Fukushima Daiichi Nuclear Power Plant, children ceased to play outside to avoid radiation exposure, and their level of physical activity decreased; (ii) the evacuated children often ate fast food for convenience; (iii) a lack of sleep and excessive mental stress experienced during life as evacuees. However, it seems that these risk factors have gradually decreased and obesity levels have improved over the course of the 5 years since the earthquake. Thus, we think that obesity has gradually improved over the 5-year period after the

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disaster in association with normalization of the residents' lifestyle, diet, exercise patterns, mental stress levels, and sleep patterns.

With regard to the relationship between obesity and hyperlipidemia, our results showed that the number of patients with hyperlipidemia, including high LDL-CHO, low HDL-CHO level, and/or high TG levels was higher in the obese group than in the non-obese group, suggesting a strong association between obesity and hyperlipidemia.

As an onset mechanism of hyperlipidemia in obesity, it has been shown that an increase in visceral obesity increases free fatty acid (FFA) in the portal vein blood, promotes lipoprotein synthesis, and leads to hyperlipidemia. Furthermore, obesity induces insulin resistance. Insulin resistance promotes the development of a highly atherogenic lipid profile, including increased levels of TG and LDL-CHO, as well as decreased levels of HDL-CHO. Second, insulin resistance leads to hyperglycemia by impairing peripheral glucose uptake, promoting hepatic glucose output, and facilitating beta-cell failure.[19]

As to hyperlipidemia in 2011, the frequencies of residents with an LDL-CHO level >140 mg, an HDL-CHO level of <40 mg, and a TG level of >120 mg were 3.5%, 2.9%, and 12.8%, respectively. In addition, regarding the change in hyperlipidemia over the 5 years, clear differences from the change in obesity were observable. Although the frequency of residents with high LDL-CHO level did not show any decline from 2011–2014, the frequency of residents with a high LDL-CHO level in 2015 was lower than that in 2011. In addition, the serum TG level tended to increase throughout the 5 years, whereas the TG level in 2015 tended to be lower than that in 2014. In other words, the improvement in lipid abnormalities was delayed in comparison with the improvement in obesity.

Regarding the obesity and hyperlipidemia in adult participants, Takahashi *et al*. reported a 4-year longitudinal change in obesity, hyperlipidemia, and liver dysfunction in 20 395 adult participants in Fukushima Prefecture after the Great East Japan Earthquake. They found the incidence of obesity in 2013–2014 was lower than that in 2011–2012, and the incidence of dyslipidemia in 2013–2014 was higher than that in 2011–2012. This contradiction between obesity and dyslipidemia in adults was similar to that in children. Although the precise reasons for this finding remain unclear, one possible reason could be differences in the mechanisms of disease onset or the effect of overweight on hyperlipidemia. Thus, it is necessary to continue with the health checks for residents with hyperlipidemia in future and to observe whether improvement in lipid abnormalities can be achieved through continuing improvement in their lifestyle habits.

The limitations of our study include the following: (i) there are no data available on the laboratory findings for pediatric residents who were living in the evacuation zone before the Great East Japan Earthquake, thus, we must judge the impact of the earthquake on residents by using changes in data after the disaster; (ii) there was a decline in the frequency at which residents receive health checks over time. These findings appear to indicate a decrease in interest in the health checks provided by the FHMS. This decrease in the number of child residents who received health checks could affect the results of our study and it is, therefore, necessary to encourage interest in these health checks through advertising and better education.

In conclusion, the findings presented in this study suggest that a number of children living in the evacuation zone at the time of the disaster suffered from obesity and hyperlipidemia, with a strong association observed between the two conditions. Furthermore, long-term (5-year) observation indicated an improvement in obesity, although the improvement in lipid abnormalities was delayed compared to that in obesity. Thus, it is necessary to continue with the health checks for these residents with obesity and/or hyperlipidemia.

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The findings and conclusions of this research are the sole responsibility of the authors and do not represent the official views of the Fukushima Prefecture government.

Disclosure

The authors declare no conflict of interest.

Author contributions

Y.K.i, H.N., and M.H. conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. S.Y., T.O., H.S., H.S., A.S., A.O., A.T., and G.K. designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and revised the manuscript. K.K. conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content. All authors read and approved the final manuscript.

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