

< Review >

Trends in lifestyle-related diseases before and after the Great East Japan Earthquake: the Fukushima Health Management Survey

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Abstract

The Great East Japan Earthquake that occurred on March 11, 2011, was followed by a nuclear accident at the Fukushima Daiichi Nuclear Power Plant. Many residents of the surrounding areas were forced to evacuate their homes and change their lifestyle. The potential influence of the evacuation on the risk factors for cardiovascular diseases (CVD) was investigated through the Fukushima Health Management Survey (FHMS). In the present study, we have reviewed the results of longitudinal studies of lifestyle-related diseases that are based on the FHMS. After the disaster, evacuated residents presented an increased proportion of overweight/obese people and a higher prevalence of hypertension, diabetes mellitus, dyslipidemia, liver dysfunction, atrial fibrillation, and polycythemia than those before the disaster. Furthermore, the prevalence of diabetes mellitus and dyslipidemia increased between FY2011–2012 and FY2013–2014, after the disaster. Results show that disaster evacuees may be more predisposed to CVDs, such as myocardial infarction and stroke. Preventive programs for obesity, hypertension, diabetes mellitus, and dyslipidemia should be implemented in collaboration with local governments and communities.

keywords: disaster, epidemiology, non-communicable diseases, population studies, psycho-social factors

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I. Introduction

The Great East Japan Earthquake occurred on March 11, 2011. As a consequence of the earthquake and a subsequent tsunami, the Fukushima Daiichi Nuclear Power Plant (NPP) was affected and released radioactive elements causing a nuclear accident. Many residents living in the surrounding areas were forced to evacuate their homes and change their lifestyle. The Fukushima disaster involved a major earthquake, a tsunami, and a nuclear accident. The number of disaster-related deaths was considerably high (more than twice the number of deaths in the Miyagi and Iwate disasters (Fukushima: 2,202; Miyagi: 926; and Iwate: 464.

See <http://www.reconstruction.go.jp/topics/main-cat2/sub-cat2-6/20140526131634.html>), whereas the number of deaths directly related to the earthquake and tsunami was less than half those of previous occurrences (Fukushima: 1,613; Miyagi: 9,541; and Iwate: 4,673). It has therefore been hypothesized that lifestyle changes caused by the evacuation, together with the stress and anxiety caused by the NPP accident, may have been associated with an increased risk of disaster-related diseases and/or deaths, given that people's fear of radiation exposure is likely to last longer than their fear of natural disasters, such as earthquakes and tsunamis. Currently, few longitudinal studies have investigated the effects of disaster-related

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evacuation on the risk of cardiovascular diseases.

We addressed this issue, as a part of the Comprehensive Health Check in the Fukushima Health Management Survey (FHMS) [1], by investigating a possible association between evacuation and changes in the risk factors for lifestyle-related diseases in the residents of the Fukushima Prefecture evacuation area. We previously reviewed changes in cardiovascular risk factors before and after the disaster in Fukushima [2]. In the present study, in addition to the review of short-term changes in lifestyle-related diseases, we review the results of four-year longitudinal studies based on the Comprehensive Health Check in the FHMS and discuss future strategies to prevent lifestyle-related diseases in the residents of Fukushima.

II. Methods

1. Study population

The subjects comprised 278,276 Japanese men and women living in communities near the Fukushima Daiichi NPP in Fukushima Prefecture. This area includes 13 municipalities: Hirono-machi, Naraha-machi, Tomioka-machi, Kawauchi-mura, Okuma-machi, Futaba-machi, Namie-machi, Katsurao-mura, Iitate-mura, Kawamata-machi, Tamura City, Minami-Soma City, and Date City. Following the disaster, the government ordered all residents of Hirono-machi, Naraha-machi, Tomioka-machi, Kawauchi-mura, Okuma-machi, Futaba-machi, Namie-machi, Katsurao-mura, and Iitate-mura—and some residents of Tamura City, Minami-Soma City, Kawamata-machi, and Date City—to evacuate their homes (Figure 1, Evacuation zone). Other areas of Tamura City, Minami-Soma City, Kawamata-machi, and Date City were defined as non-evacuation zones (Figure 1, Non-evacuation zone) [3,4].

Within these communities, people insured by the National

Health Insurance and aged 40–74 years and all people aged ≥ 75 years (the target population for check-ups consisted of 91,554 men and women in 2010) have had annual health check-ups for metabolic syndrome since 2008. This number includes 41,633 subjects (18,745 men and 22,888 women; mean age, 67 years) who had health check-ups during a “baseline” period (2008–2010). The rates of participation in check-ups for the initial Census population and for the target population were 25.3% and 45.5%, respectively.

2. Follow-up examinations

According to the Comprehensive Health Check and FHMS, annual health check-ups have been conducted among residents of all ages in these communities since 2011. The detailed methodology of the Comprehensive Health Check and the FHMS has been previously reported. [1,2,3,4] A follow-up survey was conducted countrywide, as evacuation led the subjects to various parts of the country. The number of participants aged 16 years or older before March 2015 was 56,399 in FY2011, 47,009 in FY2012, 43,040 in FY2013, and 41,874 in FY2014. As a result, 27,486 participants (12,432 men and 15,054 women; follow-up proportion: 66%) received follow-up examinations between FY2011 and FY2012, with an average follow-up period of 1.6 years. The participants have been divided into two groups for analysis: evacuees ($n = 9,671$) and non-evacuees ($n = 17,815$). We have used this data set to analyze changes in the prevalence of lifestyle-related diseases before and after the disaster. In addition, we have calculated the prevalence of lifestyle-related diseases for each year (FY2011–FY2014), stratifying the results by age groups.

3. Measures and definitions

Each subject's history of cigarette smoking and weekly alcohol intake was obtained by a trained interviewer.

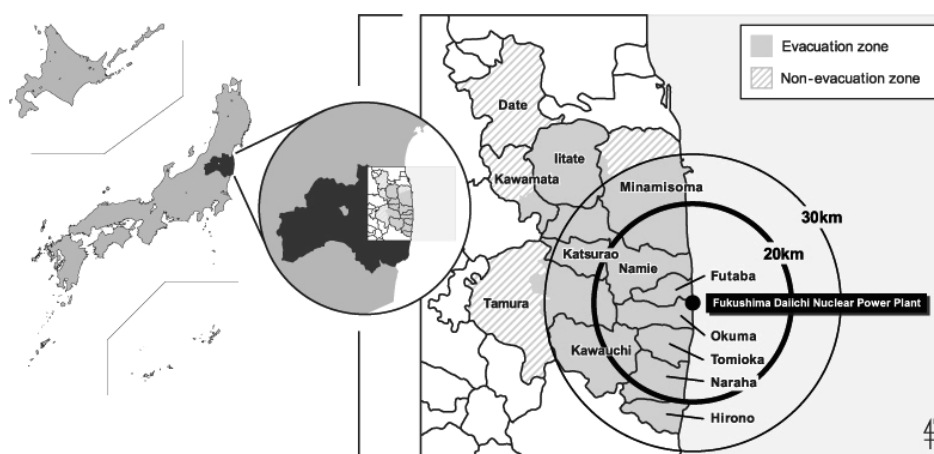


Figure 1 Geographic details of the evacuation zone, non-evacuation zone, and the Fukushima Daiichi Nuclear Power Plant [4]

Participants who consumed ≥ 44 g ethanol per day were classified as current excessive drinkers.

Several physical characteristics and blood parameters were analyzed, including the subject's height, body weight, waist circumference, body mass index (BMI), blood pressure, aspartate aminotransferase (AST), alanine aminotransferase (ALT), γ glutamyl transpeptidase (γ -GT), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), HbA1c, fasting plasma glucose, and urine protein and sugar levels. Additional measurements included serum creatinine levels, the estimated glomerular filtration rate, uric acid levels, and peripheral blood counts, which evaluated the number of red blood cells, platelets, and white blood cells. Overweight/obese individuals were defined as having a BMI ≥ 25 kg/m². Hypertension was defined as a systolic blood pressure (BP) ≥ 140 mmHg, a diastolic BP ≥ 90 mmHg, or the use of an antihypertensive medication. Diabetes was defined as a fasting plasma glucose level ≥ 126 mg/dL (7.0 mmol/L), an HbA1c (NGSP) level $\geq 6.5\%$, or the use of an antihyperglycemic medication. A hypo-HDL cholesterolemia was defined as HDL-C < 40 mg/dL, and dyslipidemia was defined as HDL-C < 40 mg/dL and/or LDL cholesterol ≥ 140 mg/dL and/or fasting serum TG ≥ 150 mg/dL, or being treated for dyslipidemia. The diagnosis of metabolic syndrome (MetS) was based on the definition of the Japanese Committee for Establishing Diagnostic Criteria for MetS, as follows: visceral obesity (waist circumference ≥ 85 cm in men and ≥ 90 cm in women) and the presence of at least two of the following three abnormalities: fasting serum TG ≥ 150 mg/dL and/or HDL-C < 40 mg/dL or being treated for dyslipidemia; systolic BP ≥ 130 mmHg and/or diastolic BP ≥ 85 mmHg or being treated for hypertension; and fasting

plasma glucose ≥ 110 mg/dL or being treated for diabetes.

III. Prevalence of lifestyle-related diseases before and after the disaster

1. Overweight/obese [3]

Figure 2 shows changes in the proportion of overweight/obese people and the prevalence of hypertension, diabetes mellitus, and dyslipidemia among evacuees before and after the Great East Japan Earthquake. After the disaster, both the mean body weight and the proportion of overweight/obese people increased significantly, among both evacuee and non-evacuee subjects. Those changes were higher in evacuees than non-evacuees (body weight: +1.2 kg for evacuees and +0.3 kg for non-evacuees ($p < 0.001$); proportion of overweight/obese people: +7.2% for evacuees and +2.3% for non-evacuees ($p < 0.001$)). Among evacuees, the changes were more significant in men than in women (body weight: +1.8 kg for men and +0.8 kg for women ($p < 0.001$); proportion of overweight/obese people: +9.8% for men and +5.4% for women ($p < 0.001$)) [3]. Furthermore, a prospective analysis using the Cox proportional hazard model revealed that evacuation was significantly associated with an increased risk of becoming overweight/obese (multivariable-adjusted hazard ratio (HR): 1.82 (95% CI = 1.61, 2.07, $p < 0.001$) for men, and 1.52 for women (1.34, 1.74, $p < 0.001$)) [3].

2. Hypertension [4]

Following the disaster, the prevalence of hypertension increased significantly in both the evacuee and non-evacuee groups. For subjects (both evacuee and non-

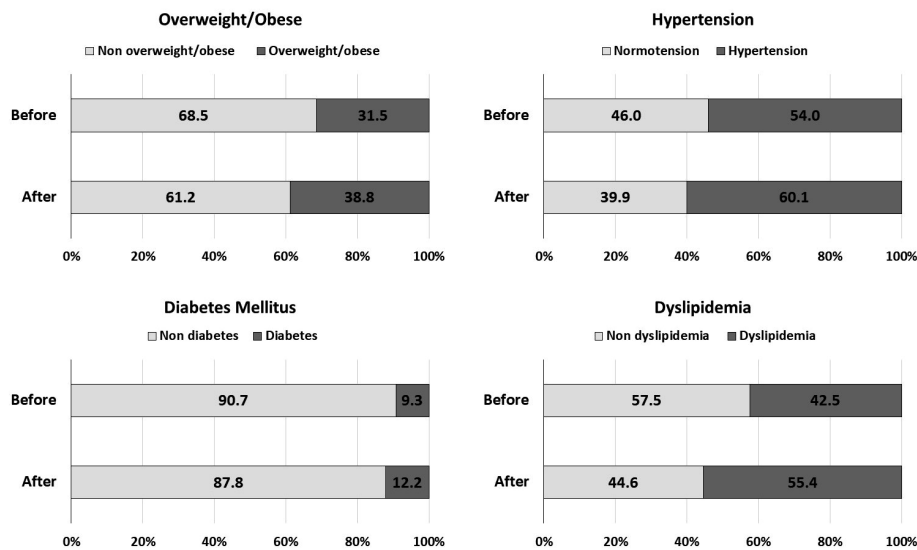


Figure 2 Changes in proportion of overweight/obese people and prevalence of hypertension, diabetes mellitus, and dyslipidemia among evacuees before and after the Great East Japan Earthquake

evacuee) who were non-hypertensive before the disaster, the mean systolic and diastolic BP levels increased significantly after the disaster. Changes in diastolic BP were greater in evacuees than non-evacuees, and greater in men than in women [4]. For men, the changes in diastolic BP among evacuees and non-evacuees were +3.4 mmHg vs +2.1 mmHg ($p < 0.0001$), respectively. For women, these changes were +2.8 mmHg vs +1.7 mmHg ($p < 0.0001$) among evacuees and non-evacuees, respectively. Furthermore, evacuation was significantly associated with the incidence of hypertension among men (multivariable-adjusted HRs: 1.24 (95% CI = 1.10, 1.39, $p < 0.001$) for men and 1.06 (0.94, 1.18, $p = 0.35$) for women, respectively) [4].

3. Diabetes mellitus [5]

After the disaster, the prevalence of diabetes mellitus increased significantly, from 9.3% to 11.0% ($p < 0.0001$), with greater changes in HbA1c levels for evacuees than non-evacuees, especially in the normal glucose group [5]. In the non-diabetes group, the post-disaster incidence of diabetes mellitus was significantly higher among evacuees (3.6%) than among non-evacuees (2.6%) ($p = 0.0002$). Furthermore, an adjustment for confounding factors revealed that evacuation was significantly associated with an increased risk of diabetes mellitus. The multivariable-adjusted HR for the evacuation group was 1.40 (95%CI = 1.20, 1.63, $p < 0.001$) [5].

4. Dyslipidemia [6]

Concerning dyslipidemia, the prevalence of hypo-HDL cholesterolemia increased significantly, from 6.0% to 7.2% after the disaster. Moreover, HDL-C levels significantly decreased, from 56.2 mg/dL to 55.1 mg/dL ($p < 0.0001$) for men, and 62.1 mg/dL to 61.5 mg/dL ($p < 0.0001$) for women [6]. A significant association between evacuation and the incidence of hypo-HDL cholesterolemia was observed for both men and women. The multivariable-adjusted odds ratios for evacuation were 1.41 (95%CI = 1.20, 1.67, $p < 0.001$) for men, and 1.35 (1.08, 1.69, $p < 0.01$) for women [6].

5. Metabolic syndrome [7]

Among men and women who, prior to the disaster, did not present MetS components, the post-disaster crude incidence rate of MetS was significantly greater in the evacuee group (men: 19.2%, women: 6.6%), than in the non-evacuee group (men: 11.0%, women: 4.6%) [7]. Evacuation was significantly associated with an increased risk of MetS in both men and women. The multivariable-adjusted odds ratios for evacuation were 1.89 (95%CI

= 1.55, 2.31) for men, and 1.45 (1.10, 1.92) for women. Furthermore, these associations were also observed when results were stratified by age group, where the adjusted odds ratios were 1.72 (1.46, 2.02) for < 65 years of age, and 1.60 (1.26, 2.03) for ≥ 65 years of age [7].

6. Liver dysfunction [8]

The prevalence of liver dysfunction increased significantly among the participants (16.4% vs 19.2% ($p < 0.001$) [8], with a higher incidence in evacuees than in non-evacuees, regardless of the drinking status. The multivariable-adjusted odds ratios for evacuation were 1.38 (95%CI = 1.20, 1.58) for non-drinkers, 1.43 (1.29, 1.59) for light drinkers, and 1.24 (1.09, 1.42) for moderate/heavy drinkers [8].

7. Other lifestyle-related diseases and variables [9,10]

The prevalence of atrial fibrillation increased significantly after the disaster in both men and women (1.9% vs 2.4% ($p < 0.001$) [9]. The RBC, Hb, and Ht levels also increased significantly after the disaster [10]. In addition, among evacuees, the prevalence of polycythemia increased significantly, from 0.89% to 1.54% ($p < 0.001$), whereas the same increase was not observed for non-evacuees: 0.79% and 1.16% before and after the disaster ($p = 0.10$), respectively [10].

Among lifestyle-related variables, participants' drinking and smoking statuses remained unchanged before and after the disaster [4]. The proportion of evacuees having sufficient sleep decreased significantly after the disaster, changing from 75.8% to 67.5% in men and from 69.9% to 57.4% in women. Among non-evacuees, the proportion of subjects getting enough sleep also decreased, changing from 77.5% to 75.0% in men and from 71.7% to 69.7%, in women. These changes were higher in evacuees than in non-evacuees [4].

IV. Trends in the prevalence of lifestyle-related diseases after the disaster, FY2011 to FY2014

1. Overweight/obese [11]

Both the mean levels of BMI and the proportion of overweight/obese people remained practically unchanged among men and women between FY2011 and FY2014. For men, the age-stratified proportion of overweight/obese people in FY2011, FY2012, FY2013, and FY2014 was 29.8%, 30.7%, 30.0%, and 29.0%, respectively, for men aged 16–39; 41.6%, 40.3%, 40.9%, and 39.3%, respectively, for men aged 40–64; and 39.1%, 36.4%, 36.3%, and 35.8% for men aged 65 and older. For women, the age-stratified

proportion of overweight/obese people in FY2011, FY2012, FY2013, and FY2014 was 17.2%, 17.1%, 17.3%, and 17.6%, respectively, for women aged 16–39; 28.4%, 29.2%, 28.9%, and 27.9%, respectively, for women aged 40–64; and 35.4%, 34.3%, 34.4%, and 33.0%, respectively, for women aged 65 and older [11].

2. Hypertension [12]

The age-stratified prevalence of hypertension peaked one year after the disaster, then started to decrease after 2012. The prevalence of hypertension in FY2011, FY2012, FY2013, and FY2014 was 47.2%, 48.8%, 47.4%, and 45.5% for men and 38.6%, 39.0%, 37.8%, and 35.6%, for women, respectively [12]. At the same time, the age-stratified proportions of patients with treated hypertension and control of hypertension increased after the disaster in both men and women. The proportions of treated hypertension among hypertensives for 2011, 2012, 2013, and 2014 were 55.8%, 59.2%, 65.2%, and 66.3% for men and 61.7%, 63.3%, 69.2%, and 70.6% for women, respectively [12].

3. Diabetes mellitus [11]

The proportion of people with high glucose (HbA1c \geq 6.0) increased for both men and women between FY2011 and FY2014. The age-stratified proportion of men with high glucose in FY2011, FY2012, FY2013, and FY2014 was 2.1%, 2.6%, 2.8%, and 2.6% for men aged 16–39; 16.1%, 17.2%, 18.9%, and 18.1% for men aged 40–64; and 22.4%, 22.9%, 26.7%, and 23.5% for men aged 65 and older, respectively. The age-stratified proportion of women with high glucose in FY2011, FY2012, FY2013, and FY2014 was 1.2%, 1.6%, 1.8%, and 2.1% for women aged 16–39; 8.9%, 10.6%, 13.2%, and 12.2% for women aged 40–64; and 15.8%, 18.2%, 21.8%, and 21.0% for women aged 65 and older, respectively. Four years after the disaster, the risk of diabetes mellitus was 1.8-fold higher in evacuees than in non-evacuees [13].

4. Liver dysfunction and dyslipidemia [14]

The prevalence of liver dysfunction decreased significantly among the participants, changing from 29.9% to 27.1% between FY2011–FY2012 and FY2013–FY2014 ($p < 0.001$) [14]. The incidence of liver dysfunction was significantly higher among evacuees than non-evacuees. Furthermore, an increased level of daily physical activity and the frequency of breakfast consumption were lifestyle factors significantly associated with improved hepatobiliary enzyme abnormality [14]. On the other hand, the prevalence of dyslipidemia significantly increased among the participants—from 49.8% to 53.3% between 2011–2012 and 2013–2014 ($p < 0.001$) [14].

V. Discussion

The main findings of this longitudinal study were the increases in cardiovascular risk factors, such as overweight/obesity, hypertension, diabetes mellitus, and dyslipidemia after the disaster. In addition, the adjustment for confounding factors revealed that evacuation was significantly associated with an increased risk of becoming overweight/obese and presenting other cardiovascular risk factors. Furthermore, 4 years after the disaster, the prevalence of diabetes mellitus and dyslipidemia increased further, whereas the proportion of overweight/obese individuals remained unchanged and the prevalence of liver dysfunction and hypertension decreased. Taken together, these results show that people experiencing disaster-related evacuation may be more predisposed to CVDs, such as myocardial infarction and stroke.

In Fukushima, the Great East Japan Earthquake was a complex disaster that consisted of three incidents: a major earthquake, a tsunami, and the nuclear accident. Although the fear of earthquakes and tsunamis may gradually decrease over time, the fear of radiation exposure effects from the time of the nuclear accident may persist longer [15]. Indeed, the proportion of high levels of psychological distress, evaluated using the Kessler Psychological Distress Scale, (K6) was greater in Fukushima than in Miyagi [16]. Furthermore, in Fukushima, although the proportion of people with high levels of psychological distress gradually decreased between 2011 and 2015 [15], the proportion, even in 2015, was twice as high as in other areas. This may result in long-lasting psychological stress and increase stress-related diseases, such as metabolic syndrome and diabetes mellitus [17]. Furthermore, the long-term evacuation that followed the NPP accident may have forced people's lifestyles to change, in areas such as diet and physical activity. This could lead to future incidence of lifestyle-related diseases including hypertension, diabetes mellitus, and dyslipidemia.

Although the mechanisms by which evacuation increases cardiovascular risk factors are not yet fully understood, the increase in body weight observed in evacuees may have played a role. In the FHMS, the post-disaster increase in body weight was significantly associated with an increased risk of hypertension [4], diabetes mellitus [5], and dyslipidemia [6]. Furthermore, decreases in physical activity may also be associated with a higher incidence of cardiovascular risk factors in the evacuation areas [18]. Given that most evacuees who worked before the disaster lost their jobs, the consequent decrease in physical activity may have contributed to an increase in cardiovascular risk factors, via an increase in body weight. The results of a

mental health and lifestyle survey by the FHMS showed that approximately 70% of the 73,433 evacuees had trouble sleeping, with consequent harmful effects on daytime activities, while 51% did not exercise regularly [19,20]. Thus, health-related behaviors could be an important factor, mediating the influence of evacuation on increased cardiovascular risk factors. Further studies are needed to confirm the association between lifestyle and psychological factors with future incidence of CVD, including stroke and myocardial infarction, in Fukushima residents.

This study has some limitations. First, the number of participants in the FHMS was not high, which may imply that the sample is not representative of the population. Second, this study did not evaluate socioeconomic factors other than evacuation, which may have influenced the association between evacuation and CVD risk factors. Finally, although the mean follow-up time was over 4 years, this may have been insufficient to examine the long-term effects of the evacuation on the incidence of cardiovascular diseases, such as stroke and myocardial infarction. It is therefore necessary to evaluate these effects through a further long-term follow-up, using a larger cohort.

Following the Great East Japan Earthquake, Fukushima's residents have experienced a higher incidence of both physical and psychological problems, including lifestyle-related diseases and anxiety and psychological distress, than residents of other areas. These physical and psychological issues may lead to a future incidence of CVD. Therefore, continuous support in terms of health status management is required from researchers, working together with local governments and communities.

VI. Conclusions

After the Great East Japan Earthquake, the prevalence of people with cardiovascular risk factors, including hypertension, diabetes mellitus, and dyslipidemia, increased among community residents and more so among evacuees from Fukushima Prefecture. Furthermore, evacuation was associated with increased cardiovascular risk factors in the four years following the disaster. As of 2017, more than 50,000 former residents of Fukushima remain evacuated. The prevention of future CVDs among evacuees from Fukushima requires continuous preventive programs for CVD risk factors, carried out in collaboration with local governments and communities.

Conflict of Interests

No financial disclosures were reported by the authors of this paper.

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東日本大震災前後における生活習慣病の推移：福島県県民健康調査

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抄録

2011年3月11日、東日本大震災が発生し、それに引き続き福島第一原子力発電所の放射線事故が起こった。原子力発電所周辺の多くの住民が避難を余儀なくされ、生活習慣に変化が起こってきた。そこで、各市町村で実施している健康診査、及び福島県で実施している県民健康調査のデータを用いて、震災後の避難が循環器疾患危険因子及び生活習慣病に影響する可能性を検討した。本稿では、震災前後における健康診査結果の変化及び県民健康調査の生活習慣病に関する縦断的検討の結果を概説する。震災前後において健康診査データを比較した結果、震災後、避難区域住民においては過体重・肥満の人の割合、及び高血圧、糖尿病、脂質異常、肝機能異常、心房細動、多血症有病率の上昇がみられた。さらに、震災後1～2年間で3～4年間の健診データを比較したところ、糖尿病、脂質異常についてはさらなる増加がみられた。したがって、避難区域住民、特に実際に避難した人においては心筋梗塞や脳卒中などの循環器疾患が震災後に起こりやすくなる可能性が考えられた。また、これらの要因としては震災後の仕事状況の変化、避難による住居の変化などによる身体活動量の低下、心理的ストレスの増加などが考えられた。今後、避難者の循環器疾患を予防するために、地域行政と地域住民が協働して肥満、高血圧、糖尿病、脂質異常の予防事業に取り組む必要がある。

キーワード：災害，疫学，非感染性疾患，ポピュレーションスタディ，心理社会的因子