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Persistent prevalence of polycythemia among evacuees 4 years after the Great East Japan Earthquake: A follow-up study

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ABSTRACT

We previously reported that the lifestyle of evacuees significantly increased the prevalence of polycythemia compared with non-evacuees at an average of 1.6 years (2011–2012) from the previous annual health checkup before the Great East Japan Earthquake (GEJE). Here we analyzed how the prolonged evacuation affected the prevalence of polycythemia an average of 2.5 years (2013–2014) after the previous data. Subjects were individuals aged 40–90 years living in the vicinity of the Fukushima Daiichi Nuclear Power Plant in Fukushima Prefecture who had attended the annual health checkups since 2008. The prevalence of polycythemia and changes in its defining factors of red blood cell count (RBC), hemoglobin (Hb) level, hematocrit (Ht) level were compared between before and after the GEJE in 7713 individuals (3349 men and 4364 women) receiving follow-up examinations both 2011–2012 and 2013–2014. RBC, Hb levels and Ht levels in 2011–2012 were higher among evacuees than non-evacuees in both men and women. However, all levels in 2013–2014 were on the decline from those in 2011–2012. On the other hand, among evacuees, Hb and Ht levels continued to be higher than before the GEJE in both men and women evacuees. The prevalence of polycythemia, which was diagnosed if one of the defining factors was beyond the standard value, was significantly higher among evacuees than non-evacuees regardless of the presence or the absence of overweight/obesity, smoking, and hypertension. Therefore, prolonged evacuation is a cause of polycythemia even 3 to 4 years after the GEJE and regular health management of evacuees is important.

1. Introduction

Four years have already passed since the Great East Japan Earthquake (GEJE) and the Fukushima Daiichi nuclear disaster, after which many individuals were forced to evacuate their homes. For the past 4 years, the Fukushima Health Management Survey (FHMS) has continued to perform health check-ups and support the prevention of

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lifestyle-related diseases among individuals living in the vicinity of the Fukushima Daiichi Nuclear Power Plant in Fukushima Prefecture (Yasumura et al., 2012). Based on the data from the FHMS, we previously reported that evacuation is a cause of hypertension (Ohira et al., 2014; 2016a, b), diabetes mellitus (Satoh et al., 2015), atrial fibrillation (Suzuki et al., 2015), hypo-high-density lipoprotein cholesterolemia (Satoh et al., 2016), and obesity (Ohira et al., 2016a, b). Furthermore, we reported that the lifestyle of the evacuees is a cause of polycythemia after adjusting for age, gender, smoking status, alcohol intake, body mass index (BMI), and hemoglobin (Hb) level before the GEJE disaster (Sakai et al., 2014).

Polycythemia is divided into three types: Polycythemia vera (PV); secondary polycythemia mainly due to the increase in erythropoietin in patients with low oxygen level caused by chronic obstructive pulmonary disease or erythropoietin-producing tumor; and relative polycythemia caused by smoking, obesity and anxiety. The first two types and the last type show an absolute and a relative increase in the number of RBC, respectively.

In our previous study (Sakai et al., 2014), the prevalence of polycythemia, which was supposed to be relative polycythemia, significantly increased among GEJE evacuees compared with non-evacuees stratified by both the presence and absence of smoking or obesity. Although it was not clear why evacuation is a cause of polycythemia, we assumed that mental stress might be a reason. Generally, hypertension is a well-known cause of relative polycythemia, and from results reporting increases in hypertension among evacuees (Ohira et al., 2014, 2016a, b), we decided to analyze the influence of evacuation on the prevalence of polycythemia and changes in its defining factors in relation to hypertension in this study. A previous study reported that an increase in hematocrit (Ht) level was observed in individuals living near the epicenter of the Hanshin-Awaji Earthquake just after the disaster, which was related to an increase in the incidence of cardiovascular attacks (Kario and Matsuo, 1995). Although there might be reasonable evidence of the increased incidence in cardiovascular attacks in the acute phase after a disaster, it is necessary to confirm whether there are similar findings in the chronic phase after the GEJE. Therefore, we have to address the concern that prolonged polycythemia among GEJE evacuees in the chronic phase after the disaster may lead to an increase in cardiovascular disease in Fukushima Prefecture in the future.

The FHMC then has to investigate how the prolonged evacuation affected the prevalence of polycythemia and changes in its defining factors 3 to 4 years (2013–2014) after the GEJE and to compare the results with previous findings from 1 to 2 years (2011–2012) after the disaster. Therefore, the objective of the present work was to compare RBC, Hb level, Ht level, and the prevalence of polycythemia based on those factors in relation to overweight/obesity, smoking status, and hypertension between evacuees and non-evacuees.

2. Methods

2.1. Subjects

The subjects in this study were Japanese men and women living in the following communities in the vicinity of the Fukushima Daiichi Nuclear Power Plant in Fukushima Prefecture; Tamura, Minami-Soma, Kawamata, Hirono, Naraha, Tomioka, Kawauchi, Okuma, Futaba, Namie, Katsurao, Iitate, and Date (Fig. 1). All residents of Hirono, Naraha, Tomioka, Kawauchi, Okuma, Futaba, Namie, Katsurao, and Iitate, and some of the residents of Tamura, Minami-Soma, Kawamata, and Date were forced to evacuate their homes due to a governmental order after the disaster. In these communities, annual health checkups with a focus on metabolic syndrome for insured persons/dependents aged 40 or older by health care insurers have been conducted since 2008; data from these annual health checkups were used in the present study.

All analyses in this study were limited to men and women aged 40–90 years because this age group had Specific Health Examination already data already available from before the GEJE. Between 2008 and 2010, 41,633 individuals (18,745 men and 22,888 women, mean age of 67 years) in the above communities participated in the health checkups. The initial exclusion criteria were persons without peripheral blood Hb data (n = 23.270), those with a past history of or current treatment for hematologic disease (n = 70), and those undergoing dialysis due to renal impairment (n = 37). The remaining data for 18,256 individuals (7647 men and 10,609 women, mean age of 68 years) were used for the analyses as baseline data. Informed consent was obtained from the community representatives to conduct an epidemiological study based on guidelines of the Council for International Organizations of Medical Science (International Guidelines for Ethical

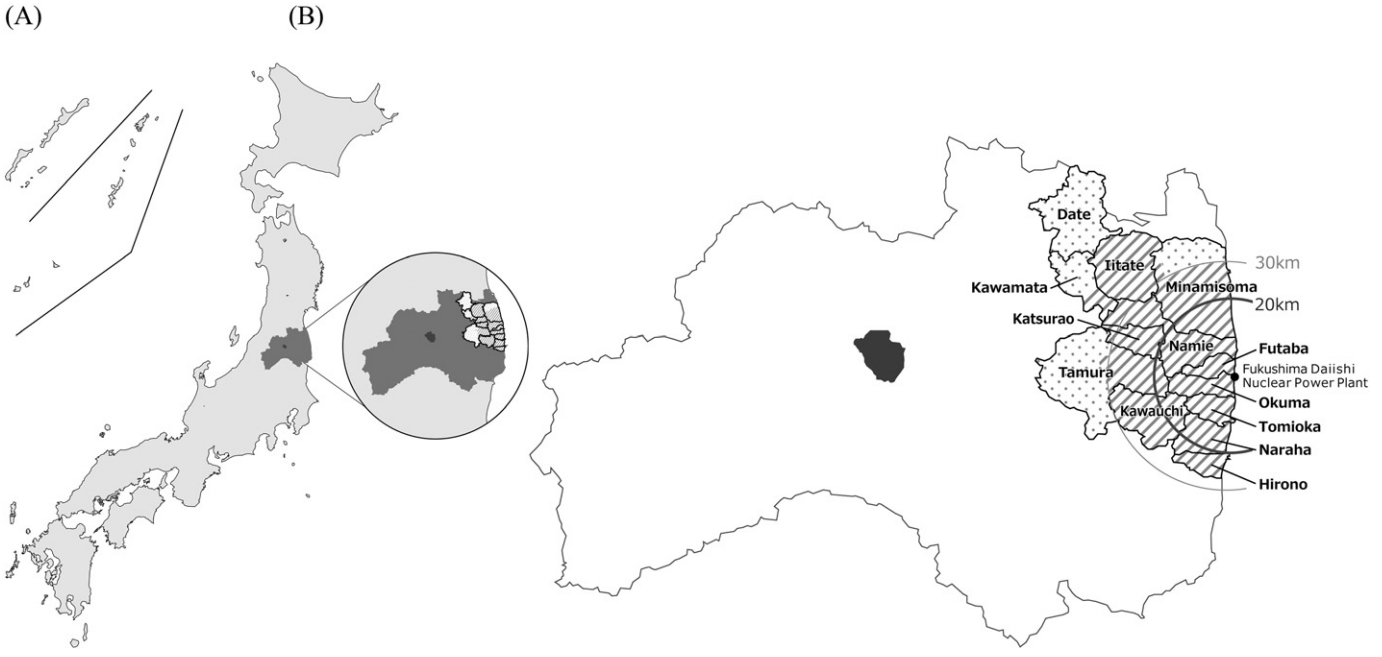

Fig. 1. Location of the government-designated evacuation zone. (A) Location of Fukushima Prefecture in Japan. (B) Location of the 13 municipalities in the evacuation zone in Fukushima Prefecture.

Review of Epidemiological Studies, 1991). This study was approved by the Ethics Committee of the Fukushima Medical University School of Medicine (approval number 1916).

Follow-up examinations were conducted between 2011 and 2014 as part of the Comprehensive Health Check (CHC). A detailed description of the CHC methods can be found in a previous report by Yasumura et al. (2012). Basically, the CHC performed health examinations on individuals of all ages who were officially registered residents living in the government-designated evacuation zone at the time of the earthquake. 7713 individuals (3349 men and 4364 women, follow-up rate: 42%) received a follow-up examination after the disaster, and the average follow-up period was 4.1 years. Subjects included in the present analysis were individuals who received a medical health check in 2008–2010 (baseline, before the GEJE) and also received a medical health check in 2011–2012 or in 2013–2014 (after the GEJE). For individuals who received a medical health check in both 2013 and 2014, we used the 2014 data for analysis. Both the annual health checkups and the CHC were conducted by the same inspection company, and those results were kept by the municipalities.

There were some differences in baseline characteristics between individuals who received follow-up examinations and those who did not, such as mean age (67.1 vs 69.3 years, respectively); the ratio of women (56.6% vs 59.3%, respectively); and prevalence of hypertension (54.8% vs 59.4%, respectively), diabetes mellitus (9.9% vs 12.0%, respectively), smoking (11.4% vs 13.1%, respectively) and drinking (22.2% vs 18.5%, respectively), while there were no differences in baseline body mass index (BMI) and overweight/obesity. The baseline characteristics of individuals who received the follow-up examinations are shown in Table 1.

2.2. Measurements

Individuals were evaluated according to items in the Specific Health Examination list based on the *Act on Assurance of Medical Care for Elderly People* (Act No. 80, 1982). These items are listed in Supplementary Table 1. Additional items for assessment included serum creatinine, estimated glomerular filtration rate, uric acid, urine testing for occult blood, and peripheral blood count, which included RBC, Ht, Hb, platelet count, and white blood cell count with subpopulations of white cells. All peripheral blood cell counts before and after the disaster were measured using the Autoanalyzer XN9000 (Sysmex Co. Inc., Kobe, Japan) and conducted at the laboratory of the Fukushima Preservative Service Association of Health laboratory, except for tests for the residents in Futaba (n = 702). Since the trends in blood cell counts before and after the disaster in Futaba were essentially same as the other communities, we included the data for Futaba in our analyses. The quantitative definition of polycythemia differs between research institutes and laboratories. The standard values for peripheral blood in the CHC were as follows: RBC, 400–579 × 10^4/μL; Hb, 13.1–17.9 g/dL; and Ht, 38.0–54.9% in men; RBC, 370–549 × 10^4/μL; Hb, 12.1–15.9 g/dL; and Ht, 33.0–47.9% in women. Polycythemia was diagnosed if one of these items was beyond the standard value. In this study the standard values for overweight/obesity were a BMI of 25 kg/m^2 or more and an increase in BMI of 1 kg/m^2 or more, respectively.

Table 1
Baseline characteristics of the individuals who received follow-up health examinations.

	Total (n = 7713)				
Basic Characteristics	Evacuee		non-Evacuee		$p^{\#2}$
Number	5364		2349		
Age ± SD (years)	66.2	±9.1	69.1	±8.3	<0.0001
Sex (% woman)	55.8		58.4		0.03
BMI ± SD (kg/m^2)	23.6	±3.1	23.3	±3.3	<0.0001
Overweight/Obesity$^{\#1}$ (%)	31.8		28.4		<0.01
Hypertension (%)	54.1		56.3		0.08
Diabetes Mellitus (%)	10.4		8.9		0.05
Current smoker (%)	12.1		9.9		<0.01
Current drinker (%)	22.8		20.9		0.07

BMI, body mass index; SD, standard deviation; $^{\#1}$BMI ≥ 25.0 kg/m^2; $^{\#2}$Student *t*-test or Chi-squared test.

2.3. Statistical analysis

Means or prevalence for baseline variables of interest were compared between the evacuees (n = 5364) and non-evacuees (n = 2349) using Student *t*-tests or chi-squared tests. Changes in RBC, Hb levels, Ht levels, and prevalence of polycythemia between before and after the disaster were compared using a Student's paired *t*-test or McNemer's test. Analysis of covariance (ANCOVA) was used to examine the differences in the variables between the evacuees and non-evacuees adjusted for age (years), gender, and smoking status. The potential confounders were age (years), gender, smoking status, excess ethanol intake (≥44 g/day), BMI, hypertension and baseline Hb level (Model 1), and further adjustment for changes in BMI between before and after the disaster (Model 2). Furthermore, logistic regression analysis was used to test for an association between evacuation and the development of polycythemia after the disaster adjusting for the potential confounders.

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

3. Results

3.1. Baseline characteristics of the individuals who received follow-up health examinations

Because obesity, smoking, and hypertension are well-known causes of relative polycythemia, we analyzed the ratios of these variables in both evacuees and non-evacuees (Table 1). Compared with non-evacuees, the mean age was significantly younger ($p < 0.0001$) and the ratio of women was significantly lower ($p = 0.03$) in evacuees. Furthermore, BMI was higher ($p < 0.0001$) in evacuees, and the ratios of overweight/obesity individuals and current smokers were significant higher ($p < 0.001$, respectively) in evacuees. The ratios of individuals with hypertension or with others characteristics, such as diabetes mellitus or current drinkers, tended to be higher in evacuees.

3.2. Changes in RBC, Hb level, and Ht level according to evacuation status

First, the data for RBC, Hb level, and Ht level for 2011–2012 and for 2013–2014 were compared with the baseline data from before the GEJE based on the presence or absence of evacuation (Table 2). For non-evacuee men, RBC significantly decreased in 2011–2012 ($p = 0.0133$) and significantly further decreased in 2013–2014 ($p < 0.0001$) and Hb level significantly increased in 2011–2012 ($p < 0.0034$) and significantly decreased in 2013–2014 ($p = 0.0001$), and Ht level significantly decreased in 2011–2012 ($p = 0.0352$) and significantly further decreased in 2013–2014 ($p < 0.0001$). For evacuee men, RBC, Hb level and Ht level increased in 2011–2012, and all of these levels were lower in 2013–2014 than in 2011–2012; however, both Hb level and Ht level were still significantly higher than baseline ($p < 0.0001$, respectively). For non-evacuee women, RBC and Ht level significantly decreased in both 2011–2012 and 2013–2014 ($p < 0.0001$, respectively), Hb level significantly increased in 2011–2012 ($p < 0.0001$) but decreased in 2013–2014 compared to 2011–2012. For evacuee women, RBC significantly increased in 2011–2012 ($p < 0.0001$), but significantly decreased in 2013–2014 ($p < 0.0001$), Hb level significantly increased in 2011–2012 and showed the similar level in 2013–2014 compared to 2011–2012, while Ht level significantly increased in both 2011–2012 and 2013–2014 ($p < 0.0001$, respectively).

Table 2
Changes in RBC, Hb level, and Ht level according to evacuation status.

		Men non-Evacuees N = 997	Evacuees N = 2372	p[a]	Women non-Evacuees N = 1372	Evacuees N = 2992	p[a]
RBC (avarage)	(2008–2010: baseline)	466.1	472.9		435.0	439.7	
	(2011–2012: after the GEJE)	463.9	480.6		432.2	443.0	
	(2013–2014: after the GEJE)	451.0	473.2		423.0	437.5	
Δ1	(2011–2012)–Baseline	−2.2	7.7	<0.0001	−2.8	3.3	<0.0001
	p	0.0133	<0.0001		<0.0001	<0.0001	
Δ2	(2013–2014)–Baseline	−15.1	0.3	<0.0001	−12.0	−2.2	<0.0001
	p	<0.0001	0.636		<0.0001	<0.0001	
Hb (average) (g/dL)	(2008–2010: baseline)	14.55	14.78		13.04	13.20	
	(2011–2012: after the GEJE)	14.63	15.11		13.13	13.42	
	(2013–2014: after the GEJE)	14.41	15.00		13.08	13.43	
Δ1	(2011–2012)–Baseline	0.08	0.33	<0.0001	0.09	0.22	<0.0001
	p	0.0034	<0.0001		<0.0001	<0.0001	
Δ2	(2013–2014)–Baseline	−0.13	0.23	<0.0001	0.04	0.23	<0.0001
	p	0.0001	<.00001		0.1592	<0.0001	
Ht (average) (%)	(2008–2010: baseline)	43.82	44.37		39.99	40.48	
	(2011–2012: after the GEJE)	43.65	44.89		39.91	40.78	
	(2013–2014: after the GEJE)	42.94	44.80		39.63	40.87	
Δ1	(2011–2012)–Baseline	−0.17	0.53	<0.0001	−0.08	0.30	<0.0001
	p	0.0352	0.1623		<0.0001	<0.0001	
Δ2	(2013–2014)–Baseline	−0.88	0.43	<0.0001	−0.36	0.39	<0.0001
	p	<0.0001	<0.0001		<0.0001	<0.0001	

p values were calculated by Student *t*-test.
RBC, red blood cell count: Hb, hemoglobin; Ht. hematocrit.
[a] Age-adjusted *p* value for comparing changes in the evacuee group to changes in the non-evacuee group before and after the earthquake.

Furthermore, age-adjusted *p* values comparing changes in RBC, Hb level, and Ht level in the evacuee group to those in the non-evacuee group between baseline and 2011–2012 or between baseline and 2013–2014 were significant ($p < 0.0001$) for both men and women (Table 2). Of note, although RBC, Hb level and Ht level in 2011–2012 were higher among evacuees compared with non-evacuees in both men and women, all levels in 2013–2014 were lower than in 2011–2012; however, among evacuees, Hb level and Ht level remained higher than baseline in both men and women.

3.3. Influence of the evacuation on changes of Hb level in relation to smoking, overweight/obesity, weight gain, and hypertension

Since Hb level is a representative index of polycythemia and serves as one of major criteria in PV (Thiele et al., 2008), we analyzed age-adjusted *p* values to compare changes in Hb level among evacuees with those among non-evacuees between before and after the earthquake (Table 3). In men, the evacuation significantly increased Hb level regardless of smoking status, BMI, increase in BMI or hypertension in both 2011–2012 and 2013–2014. The evacuation had a more significant influence on non-smokers and those with a BMI < 25 kg/m^2 and a <1 kg/m^2 increase in BMI in 2011–2012. In women, the evacuation significantly increased Hb level among non-smokers in both 2011–2012 and 2013–2014 ($p < 0.0001$, respectively). Furthermore, the evacuation increased Hb level regardless of overweight/obesity or hypertension in both 2011–2012 and 2013–2014, and the increase in Hb level was significantly higher in those with a BMI < 25 kg/m^2 and a <1 kg/m^2 increase in BMI in 2011–2012 ($p < 0.001$, respectively). These results revealed that life as an evacuee leads to increase in Hb level.

Table 3
Influence of the evacuation on changes of Hb in relation to smoking, overweight/obesity, weight gain, and hypertension.

			Changes in Hb (g/dL) (2011–2012)–before			Changes in Hb (g/dL) (2013–2014)–before		
Sex	Factors	n	non-Evacuees	Evacuees	p[a]	non-Evacuees	Evacuees	p[a]
Men	Smoking (−)	2629	0.09	0.35	<0.0001	−0.11	0.23	<0.0001
	Smoking (+)	720	0.07	0.28	0.032	−0.20	0.20	<0.0001
	BMI < 25 kg/m2	2308	0.08	0.37	<0.0001	−0.12	0.29	<0.0001
	BMI ≧ 25 kg/m2	1041	0.09	0.27	0.027	−0.17	0.10	<0.001
	Change in BMI < 1 kg/m2	2166	0.06	0.24	<0.0001	−0.17	0.03	<0.0001
	Change in BMI ≧ 1 kg/m2	1183	0.21	0.46	0.010	0.07	0.49	<0.0001
	Hypertension (−)	1422	0.09	0.38	<0.0001	−0.08	0.30	<0.0001
	Hypertension (+)	1927	0.08	0.30	<0.0001	−0.17	0.17	<0.0001
Women	Smoking (−)	4204	0.10	0.22	<0.0001	0.03	0.09	<0.0001
	Smoking (+)	160	−0.004	0.07	0.821	0.24	0.11	0.171
	BMI < 25 kg/m^2	3035	0.10	0.23	<0.001	0.07	0.25	<0.0001
	BMI ≧ 25 kg/m^2	1329	0.07	0.19	0.035	−0.04	0.18	<0.0001
	Change in BMI < 1 kg/m^2	2994	0.09	0.18	<0.001	0.02	0.14	<0.0001
	Change in BMI ≧ 1 kg/m^2	1370	0.13	0.27	0.034	0.10	0.38	<0.0001
	Hypertension (−)	2066	0.12	0.25	0.005	0.11	0.32	<0.0001
	Hypertension (+)	2298	0.07	0.18	0.003	−0.03	0.15	<0.0001

p values were calculated by Student *t*-test.
BMI, body math index; Hb, hemoglobin.
[a] Age-adjusted *p* value for comparing changes in the evacuee group to changes in the non-evacuee group before and after the earthquake.

3.4. Influence of the evacuation on prevalence of polycythemia in relation to smoking, overweight/obesity, and hypertension

The prevalence of polycythemia before the disaster (baseline), in 2011–2012, and in 2013–2014, was 0.94%, 1.02%, and 0.77% for non-evacuees ($p = 0.86$ and $p = 0.56$) and 0.88%, 1.42%, and 1.68% for evacuees ($p < 0.0001$ and $p < 0.0001$), respectively. The prevalence of polycythemia was virtually unchanged after stratifying by overweight/obesity, smoking status or hypertension (Table 4). Among the obese, the prevalence of polycythemia before the disaster, in 2011–2012, and in 2013–2014 was 1.35%, 1.65%, and 0.9% for non-evacuees ($p = 0.79$ and $p = 0.51$) and 1.47%, and 2.23%, and 2.17% for evacuees ($p < 0.05$ and $p = 0.09$), and among the non-obese was 0.77%, 0.77%, and 0.71% for non-evacuees ($p = 1$ and $p = 1$) and 0.6%, 1.04%, and 1.45% for evacuees ($p = 0.01$ and $p < 0.0001$), respectively. Among smokers, the prevalence of polycythemia before the disaster, in 2011–2012, and in 2013–2014 was 1.29%, 1.29%, and 1.29% for non-evacuees ($p = 1$ and $p = 1$) and 1.85%, 3.09%, and 2.78% for evacuees ($p = 0.13$ and $p = 0.24$), and among non-smokers was 0.9%, 0.99%, and 0.71% for non-evacuees ($p = 0.86$ and $p = 0.54$) and 0.74%, 1.19%, and 1.53% for evacuees ($p < 0.005$ and $p < 0.0001$), respectively. Among the hypertensive, the prevalence of polycythemia before the disaster, in 2011–2012, and in 2013–2014 was 1.13%, 1.06%, and 0.76% for non-evacuees ($p = 1$ and $p = 0.3$) and 1.17%, 1.65%, and 1.76% for evacuees ($p = 0.06$ and $p = 0.03$), and among the non-hypertensive was 0.68%, 0.97%, and 0.55% for non-evacuees ($p = 0.55$ and $p = 1$) and 0.53%, 1.14%, and 1.58% for evacuees ($p < 0.01$ and $p < 0.0001$), respectively.

4. Discussion

In this analysis of 3 to 4 years after the GEJE, the prevalence of polycythemia was significantly higher among evacuees than non-evacuees, similar to our analysis of 1–2 years after the GEJE (Sakai et al., 2014), regardless of the presence or absence of obesity, smoking, and hypertension. Of note, the evacuation significantly increased the prevalence of polycythemia especially in non-smokers and individuals without obesity or hypertension. We suggest that the evacuation is an independent factor for polycythemia.

It is unclear why evacuation after the GEJE led to an increase in the prevalence of polycythemia. The increased incidence of cardiovascular events following the Hanshin-Awaji Earthquake was reported be associated with the elevated Ht (Kario & Matsuo, 1995). It is reasonable to assume that an increase in the concentration of red blood cells, a situation in which Ht level is also increased, will lead to thrombosis. In practice, an increase in the concentration of red blood cells from the movement or shift of plasma from the vascular compartment into interstitial spaces is believed to be a cause of polycythemia rather than an increase in red blood cell production in the bone marrow as in stress-induced polycythemia (Emery et al., 1974; Patterson et al., 1998; de Boer et al., 2007; Austin et al., 2011). In contrast to PV, polycythemia in which only red blood cells increase has been referred to as relative polycythemia (Lawrence and Berlin, 1952) or stress polycythemia (Dameshek, 1953). In a former study of 18 patients (16 men, two women), eight patients were obese, nine were hypertensive, and those patients had been subjected to undue nervous stress and strain, which were thought to be related to relative polycythemia.

We believe that the cause of the increase in the prevalence of polycythemia among evacuees of the GEJE is psychological stress due to experiencing an unprecedented disaster and being forced to evacuate their homes. Determining the mechanism by which psychological stress induces polycythemia would be useful in preventing the onset of polycythemia and its related disease. Several studies have analyzed changes in Hb level and Ht level, blood pressure, and heart rate activity in conjunction with acute psychological stress induced by performing mental arithmetic for a short time (Austin et al., 2011; Jern et al., 1989, 1991; Patterson et al., 1998; Ring et al., 2008). According to these studies, Hb and Ht levels increased transiently along with blood pressure and heart rate. Subsequently, the increase in blood pressure makes plasma move to the outside of blood vessels and produces a high concentration of red blood cells. Therefore, those studies proved experimentally that mental stress could be a cause of polycythemia. However, it is difficult to say that the psychological stress induced by prolonged evacuation after the GEJE would cause the same results as acute mental stress tests. On the other hand, if psychological stress is repeated during prolonged evacuation, it is possible that Hb and Ht levels would increase gradually to cause polycythemia. The increase in Ht level due to a mental stress test correlated with systolic blood pressure, and average increases in plasma noradrenaline and adrenaline were also detected (Jern et al., 1991). This also suggests that increases in Hb and Ht levels due to psychological stress produce a risk of cardiovascular occlusive disease especially in individuals with hypertension, as was reported in victims of the Hanshin-Awaji Earthquake (Kario and Matsuo, 1995). In addition to having an influence during the acute phase of disaster, Ht was the only significant predictor for long-term (30-year) associations with coronary heart disease regardless of gender, smoking, or age (Pizzi et al., 2010). Therefore, persistent polycythemia could be a critical finding to predict cardiovascular disease.

We previously reported an increase in hypertension (Ohira et al., 2014), diabetes mellitus (Satoh et al., 2015), atrial fibrillation (Suzuki et al., 2015), hypo-high-density lipoprotein cholesterolemia (Satoh et al., 2016), and obesity (Ohira et al., 2016a, b) after the GEJE. Furthermore, we revealed a high prevalence of polycythemia among evacuees

Table 4
Influence of the evacuation on prevalence of polycythemia in relation to smoking, overweight/obesity, and hypertension.

				Prevalence of polycythemia, n (%)				
n				Baseline	2011–2012	p^a	2013–2014	p^a
Total		non-Evacuees	2349	22(0.94)	24 (1.02)	0.86	18 (0.77)	0.56
		Evacuees	5364	47(0.88)	76 (1.42)	<0.0001	90 (1.68)	<0.0001
Overweight/Obesity	(+)	non-Evacuees	666	9(1.35)	11 (1.65)	0.79	6 (0.9)	0.51
	(+)	Evacuees	1704	25(1.47)	38 (2.23)	<0.05	37 (2.17)	0.09
	(−)	non-Evacuees	1683	13(0.77)	13 (0.77)	1	12 (0.71)	1
	(−)	Evacuees	3660	22(0.6)	38 (1.04)	0.01	53 (1.45)	<0.0001
Smoking	(+)	non-Evacuees	233	3(1.29)	3 (1.29)	1	3 (1.29)	1
	(+)	Evacuees	647	12(1.85)	20 (3.09)	0.13	18 (2.78)	0.24
	(−)	non-Evacuees	2116	19(0.9)	21 (0.99)	0.86	15 (0.71)	0.54
	(−)	Evacuees	4717	35(0.74)	56 (1.19)	<0.005	72 (1.53)	<0.0001
Hypertension	(+)	non-Evacuees	1322	15(1.13)	14 (1.06)	1	10 (0.76)	0.3
	(+)	Evacuees	2903	34(1.17)	48 (1.65)	0.06	51 (1.76)	0.03
	(−)	non-Evacuees	1027	7(0.68)	10 (0.97)	0.55	8 (0.78)	1
	(−)	Evacuees	2461	13(0.53)	28 (1.14)	<0.01	39 (1.58)	<0.0001

[a] McNemar's test was used to compare changes in the prevalence of polycythemia between evacuees and non-evacuees before (baseline) and after (2011–2012 and 2013–2014) the earthquake.

in our previous and current investigations. These results show that individuals in the disaster area may have an increased risk of high plasma viscosity and cardiovascular disease in the future.

The strengths of the present study were the inclusion of a relatively large number of residents from the evacuation zone, as well as the assessment of RBC, Hb level, and Ht level before and after the disaster, which allowed longitudinal analyses of the association between evacuation and risk of polycythemia. On the other hand, the potential limitations of this study warrant consideration. First, although significant increases in body weight and BMI were observed among both evacuees and non-evacuees, aging may have affected the results. Second, the study did not evaluate socioeconomic factors other than evacuation. Other environmental or socioeconomic factors, such as changes in living condition and job status, may have influenced the association between evacuation and risk of polycythemia in the present study. In the mental health and lifestyle survey by the FHMS, 54% of survey respondents changed their job status and 21% lost their job (Yabe et al., 2014; Suzuki et al., 2015). Whether such changes in job status among the evacuees affects the prevalence of polycythemia has yet to be determined. Therefore, it is possible that changes in the job status of the evacuees may affect their Hb or Ht levels. Finally, because the target population aged 40–74 years in the present study was comprised of people insured by National Health Insurance (mainly for farmers, fisherpersons, the self-employed, and retired employees), the authors did not include people insured by social insurance (mainly for employees) in the analysis. This may modify the results, although 56% of the census population aged 40–90 years in the target communities was enrolled in National Health Insurance.

5. Conclusion

The current study revealed that the prolonged evacuation after the GEJE is a cause of polycythemia even 3 to 4 years after the disaster and the regular health management of evacuees is very important in preventing the onset of lifestyle-related diseases.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

AS, HN and TO designed the study and contributed to writing the manuscript. HN and TO also performed data collection and statistical analysis. MH, AO, HS, YK, HS, AT, YS, HS, YH, GK, KO, SH, and SY contributed to planning the health screening program. HT, HO, and MA contributed to the scientific review. All authors read and approved the final manuscript.

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Appendix A. The Fukushima Health Management Survey Group

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