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Disaster-Related Factors and Occult Hematuria in Fukushima: The Fukushima Health Management Survey

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Abstract

Background

The Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident caused widespread psychological distress and lifestyle changes. Understanding how disaster-related factors influence renal health may help identify at-risk populations and guide post-disaster health management. This study aimed to examine the association between urinary occult blood and disaster-related factors among residents affected by the Great East Japan Earthquake.

Methods

This cross-sectional study analyzed data from the 2011 Comprehensive Health Check and Mental Health and Lifestyle Survey. In total, 30,637 residents from the evacuation area of Fukushima Prefecture who completed both surveys were included. Disaster-related exposures, including evacuation experience, psychological distress, and post-traumatic stress disorder symptoms, as well as lifestyle and metabolic factors were analyzed. The primary outcome was occult hematuria detected through urinalysis. Multivariate logistic regression was performed to assess associations between disaster-related factors and occult hematuria, with adjustments for potential confounders.

Results

In Model 1, which included psychological distress, occult hematuria was positively associated with age (odds ratio [OR]: 1.02; 95% confidence interval [CI]: 1.01–1.02), female sex (OR: 2.57; 95% CI: 2.23–2.96), leanness (OR: 1.32; 95% CI: 1.08–1.61), evacuation experience (OR: 1.35; 95% CI: 1.22–1.49), hyperuricemia (OR: 1.32; 95% CI: 1.03–1.70), physical inactivity (OR: 1.22; 95% CI: 1.01–1.48), current smoking (OR: 1.51; 95% CI: 1.25–1.83), and former drinking (OR: 1.87; 95% CI: 1.32–2.65). In sex-stratified analyses, the associations remained significant for men for age, leanness, hyperuricemia, current smoking, and former drinking. Similarly, the associations remained significant for women for age, leanness, evacuation experience, physical inactivity, current smoking, and former drinking. Similar results were observed in Model 2, which incorporated post-traumatic stress disorder symptoms.

Conclusions

Disaster-related psychological and lifestyle factors were considerably associated with occult hematuria among Fukushima residents. Stressors related to post-disaster living conditions may contribute to renal microvascular changes and the onset of occult hematuria.

BACKGROUND

On March 11, 2011, the Great East Japan Earthquake (GEJE), a magnitude 9.0 event, struck off the Pacific coast of Japan's Tohoku region. Massive tremors and tsunamis across eastern Japan resulted in 18,425 deaths or missing persons in 12 prefectures, mainly in Tohoku. The tsunami damaged the Fukushima Daiichi Nuclear Power Plant (NPP) on the east coast of Fukushima Prefecture, causing a nuclear accident. Radiation released from the accident forced many residents in the surrounding areas to evacuate. More than 160,000 evacuees experienced considerable lifestyle disruptions after the accident.

Health problems often increase following natural or human-made disasters. Epidemiological studies report higher incidences of psychiatric disorders, including depression and post-traumatic stress disorder (PTSD), as well as cardiovascular diseases (CVDs), such as hypertension and myocardial infarction, after major disasters.[1–5] The duration and extent of these effects vary by disaster type. For example, although the GEJE caused the highest immediate mortality in Miyagi and Iwate Prefectures, Fukushima Prefecture experienced more than twice the number of disaster-related deaths over the following 10 years (2,319 vs. 929 in Miyagi and 470 in Iwate).[6] This disparity likely reflects the NPP accident and resulting larger long-term evacuee population in Fukushima.

After the GEJE and NPP accident, 23,982 residents of Fukushima remained evacuated for over 10 years, compared with 1,532 residents of Miyagi and 817 of Iwate. Evacuation drastically altered lifestyles, including dietary and exercise habits.

Although the link between urinary occult blood and stress is not fully understood, autonomic nervous system dysregulation has been identified as a potential cause of idiopathic renal bleeding, a contributor to hematuria.[7] Studies have also shown associations between PTSD symptoms after disasters and both mental health disturbances and CVDs,[8] likely related to heightened sympathetic activity and inflammatory changes. Therefore, evacuation may influence the presence of blood in urine through physical and mental stress. In the current study, we examined the relationship between evacuation experience following the GEJE and urinary occult blood, along with associated risk factors. The results may inform health management strategies for evacuees in future disasters in Japan and elsewhere.

METHODS

Study Design

The Fukushima Health Management Survey (FHMS) is a cohort study designed to investigate the long-term effects of low-dose radiation exposure on the health of individuals registered as residents of evacuation zones in Fukushima Prefecture at the time of the accident at the Fukushima Daiichi NPP, owned by the Tokyo Electric Power Company, on March 11, 2011.[1–3] This study used data from the Comprehensive Health Check (CHC) and the Mental Health and Lifestyle Survey (MHLS) questionnaires (general use) conducted in fiscal year (FY) 2011, with valid responses obtained from 73,432 individuals (response rate: 40.7%). Although the CHC included all age groups, this analysis focused on participants

aged ≥ 40 years. Of the 72,867 individuals who underwent the CHC in FY 2011, 39,515 participants aged 40–90 years as of April 1, 2011, were initially selected. The exclusion criteria included 756 women who were menstruating or had unknown menstrual status; 8,062 individuals with abnormal renal function (estimated glomerular filtration rate < 60 mL/min/1.73 m^2 or proteinuria ≥ +), a history of chronic kidney disease, dialysis, or other kidney diseases; and 60 individuals with missing urine occult blood test results. Ultimately, 30,637 participants (17,301 men, 13,336 women) were included in the analysis.

Definition

Urine Occult Blood

Urine occult blood was defined on the basis of urine dipstick test results from the CHC data. A result was considered “positive” if the test showed (+) or higher.

Polycythemia

According to Sakai et al., polycythemia was defined as having at least one of the following values above the reference range[6]:

- Red blood cell count: men > 5.79 × 10^6/μL, women > 5.49 × 10^6/μL
- Hemoglobin: men > 17.9 g/dL, women > 15.9 g/dL
- Hematocrit: men > 54.9%, women > 47.9%

Lifestyle Diseases

Obesity was defined as a body mass index (BMI) of ≥ 25 kg/m², underweight as BMI < 18.5 kg/m², and normal weight as BMI = 18.5–25 kg/m².

According to the Japan Atherosclerosis Society guidelines, dyslipidemia was defined as any of the following:

- High-density lipoprotein cholesterol (HDL-chol) < 40 mg/dL
- Low-density lipoprotein cholesterol ≥ 140 mg/dL
- Fasting triglyceride (TG) ≥ 150 mg/dL
- Casual TG ≥ 150 mg/dL
- Non-HDL-chol ≥ 170 mg/dL
- Use of cholesterol-lowering drugs.[5]

“Hypertension” was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure (DBP) ≥ 90 mmHg, or use of antihypertensive medication.

“Diabetes” was defined as fasting blood glucose (FBS) ≥ 126 mg/dL, casual blood glucose (BS) ≥ 200 mg/dL, hemoglobin A1c (HbA1c) (National Glycohemoglobin Standardization Program) ≥ 6.5%, or use of hypoglycemic medication.

Hyperuricemia was defined as a uric acid level > 7.0 mg/dL.

Smoking Habits

Smoking status was assessed using the MHLS smoking questionnaire and categorized into three groups: never smokers, former smokers, and current smokers.

Exercise Habits

Exercise habits were evaluated using the MHLS exercise questionnaire and classified into four categories: almost every day, 2–4 times a week, about once a week, or almost never.

Drinking Habits

Drinking habits were determined from a questionnaire on alcohol consumption. Participants were classified as rarely drinkers (less than once a month), former drinkers, light drinkers (ethanol intake < 44.0 g/day), or heavy drinkers (ethanol intake ≥ 44.0 g/day).

Insomnia Symptoms

Insomnia symptoms were assessed using the Japanese version of the Athens Insomnia Scale (AIS), a validated tool for evaluating insomnia symptoms among FHMS participants.[9–11] The AIS consists of eight items—sleep induction, nighttime awakenings, early morning awakenings, sleep duration, sleep quality, daytime well-being, functioning, and sleepiness—with total scores ranging from 0 to 8. In accordance with previous studies, total scores were divided into quartiles (Q1–Q4) from the lowest to highest for analysis.

Disaster-Related Factors

Participants residing in “full-scale evacuation zones” (Tomioka Town, Hirono Town, Naraha Town, Kawauchi Village, Katsurao Village, Iitate Village, Okuma Town, Futaba Town, and Namie Town) at the time of the earthquake were defined as having evacuation experience. For those in “partial evacuation zones” (Tamura City, Minamisoma City, Date City, and Kawamata Town), the evacuation experience was determined from FHMS residence data at the time of the disaster. Anxiety regarding the acute and long-term effects of radiation was assessed using a four-point scale (1 = extremely low to 4 = extremely high).

Scores of 3 or 4 were classified as “anxiety” for analysis.[12] In addition, the death of close relatives owing to the disaster was included as a disaster-related factor.

Psychological Distress and PTSD Symptoms

Overall mental health status was assessed using the Kessler 6-item Psychological Distress Scale (K6), validated in Japanese populations by Furukawa et al. and Sakurai et al. Based on prior research, a total K6 score of ≥ 13 indicated “psychological distress.” PTSD symptoms were evaluated using the Post-traumatic Stress Disorder Checklist (PCL), with the Japanese version demonstrating reliability and validity in the MHLS. A total PCL score ≥ 44 indicates “PTSD symptoms.”[13–20]

Statistical Analysis

All analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Continuous variables are presented as mean ± standard deviation, and categorical variables as number (%). Participants were divided into two groups on the basis of the presence or absence of occult blood in urine samples.

Differences in each factor between groups were assessed using an unpaired t-test for continuous variables and chi-squared tests for categorical variables. Multivariate logistic regression was used to calculate age- and sex-adjusted odds ratios (ORs) with 95% confidence intervals (CIs) to identify factors associated with occult hematuria. Missing values were handled by including them as dummy variables in the regression models. To account for potential sex differences, interaction terms between sex and each variable were tested in a multivariate-adjusted model. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

Table 1 presents the physical characteristics of the participants. Among the 30,637 participants, 1,704 (5.6%) tested positive for urinary occult blood. The positive group had significantly higher age and HDL-chol levels, as well as higher proportions of women and lean individuals. Conversely, BMI, uric acid, red blood cell, hemoglobin, hematocrit, FBS, BS, HbA1c, DBP, TG, and non-HDL-chol levels were significantly lower. The prevalence of overweight, hyperuricemia, polycythemia, diabetes, and hypertension was also significantly lower; by contrast, dyslipidemia showed a nonsignificant tendency to be lower.

Table 1
Physical characteristics of the study participants

N	Occult blood (-)	Occult blood (+)	p value
	28933	1704	
Age (year), Mean (SD)	60 (10.9)	61.3 (11.0)	< 0.0001
Sex, N (%)			
Male	12510 (43.2)	425 (24.9)	< 0.0001
Female	16423 (56.8)	1279 (75.1)	
BMI (kg/m^2), Mean (SD)	23.8 (3.5)	23 (3.5)	< 0.0001
BMI, N (%)			
Normal	17977 (62.2)	1163 (68.3)	< 0.0001
Lean	1243 (4.3)	121 (7.1)	
Overweight	9690 (33.5)	419 (24.6)	
Uric acid (mg/dL), Mean (SD)	4.9 (1.3)	4.7 (1.2)	< 0.0001
Hyper uric acid, N (%)			
No	27117 (93.8)	1626 (95.5)	0.004
Yes	1805 (6.2)	77 (4.5)	
RBC (×10^6/μL), Mean (SD)	4.7 (0.4)	4.5 (0.4)	< 0.0001
Hemoglobin (g/dL), Mean (SD)	14.3 (1.5)	13.7 (1.5)	
Hematocrit (%), Mean (SD)	42.9 (3.9)	41.5 (3.8)	
Polycythemia, N (%)			
No	28417 (98.3)	1680 (98.6)	0.234
Yes	502 (1.7)	23 (1.4)	
FBS (mg/dL), Mean (SD)	102 (22.9)	97.9 (17.3)	< 0.0001
BS (mg/dL), Mean (SD)	109.6 (42.2)	102.7 (30.4)	0.002

Data are presented as the mean (standard deviation[SD]) or number (frequency [%]). Differences between the hematuria (-) and hematuria (+) groups were analyzed using the unpaired t-test or chi-squared test. A $p < 0.05$ was considered statistically significant. BMI, Body mass index; RBC, Red blood cell; FBS, Fasting blood sugar; BS, Blood sugar; HbA1c (NGSP), Hemoglobin A1c (National Glycohemoglobin Standardization Program); BP, Blood pressure; HDL, High-density lipoprotein; LDL, Low-density lipoprotein.

N	Occult blood (-)	Occult blood (+)	p value
	28933	1704	
HbA1c (NGSP) (%), Mean (SD)	5.5 (0.8)	5.4 (0.5)	< 0.0001
Diabetes, N (%)			
No	25655 (88.7)	1593 (93.5)	< 0.0001
Yes	3266 (11.3)	111 (6.5)	
Systolic BP (mmHg), Mean (SD)	130.9 (16.2)	130.5 (17.1)	0.285
Diastolic BP (mmHg), Mean (SD)	78.9 (10.3)	77.7 (10.8)	< 0.0001
Hypertension, N (%)			
No	14729 (50.9)	914 (53.7)	0.025
Yes	14186 (49.1)	787 (46.3)	
HDL-cholesterol (mg/dL), Mean (SD)	60.5 (15.4)	62.5 (15.7)	< 0.0001
LDL-cholesterol (mg/dL), Mean (SD)	127.7 (32.6)	126.4 (32.2)	0.109
Triglyceride (mg/dL), Mean (SD)	115.8 (83.8)	108.2 (90.0)	< 0.0001
NON-HDL-cholesterol (mg/dL), Mean (SD)	150.0 (36.5)	147.5 (35.5)	0.006
Hyperlipidemia, N (%)			
No	12401 (42.9)	767 (45.0)	0.084
Yes	16522 (57.1)	937 (55.0)	

Data are presented as the mean (standard deviation[SD]) or number (frequency [%]). Differences between the hematuria (-) and hematuria (+) groups were analyzed using the unpaired t-test or chi-squared test. A $p < 0.05$ was considered statistically significant. BMI, Body mass index; RBC, Red blood cell; FBS, Fasting blood sugar; BS, Blood sugar; HbA1c (NGSP), Hemoglobin A1c (National Glycohemoglobin Standardization Program); BP, Blood pressure; HDL, High-density lipoprotein; LDL, Low-density lipoprotein.

Table 2 compares lifestyle habits and disaster-related factors between the occult blood–positive and negative groups. The positive group showed significantly higher proportions of evacuation experiences, anxiety regarding acute radiation effects, and PTSD symptoms. There was also a trend toward higher anxiety regarding long-term radiation effects. Smoking habits, drinking habits, and insomnia were significantly associated with the presence of urinary occult blood.

Table 2
Comparison of lifestyle habits and disaster-related factors between the urine occult blood–positive and –negative groups

N	Occult blood (-)	Occult blood (+)	p value
	28933	1704	
Evacuation experience, N (%)			
No	13938 (48.4)	698 (41.1)	< 0.0001
Yes	14861 (51.6)	999 (58.9)	
Exercise, N (%)			
Every day	3202 (16.7)	167 (14.9)	0.411
2–4 days/week	4508 (23.6)	269 (24.0)	
once a week	2832 (14.8)	164 (14.6)	
Almost never	8582 (44.9)	521 (46.5)	
Smoking habits, N (%)			
Never smoker	11449 (60.4)	766 (68.3)	< 0.0001
Former smoker	4493 (23.7)	173 (15.4)	
Current smoker	3021 (15.9)	182 (16.2)	
Drinking habits, N (%)			
Rarely drinker	9448 (49.3)	638 (56.6)	< 0.0001
Former drinker	489 (2.5)	40 (3.5)	
Light drinker (ethanol intake < 44.0 g/day)	7383 (38.5)	371 (32.9)	
Heavy drinker (ethanol intake ≥ 44.0 g/day)	1859 (9.7)	79 (7.0)	
Insomnia, N (%)			
Q1	2441 (18.1)	125 (16.7)	0.001
Q2	3764 (27.9)	172 (23.0)	
Q3	4583 (34.0)	264 (35.2)	
Q4	2698 (20.0)	188 (25.1)	

Data are presented as numbers (frequency [%]). Differences between the hematuria (-) and hematuria (+) groups were analyzed using the chi-squared test. A p-value < 0.05 was considered statistically significant. PTSD, Post-traumatic stress disorder.

N	Occult blood (-)	Occult blood (+)	p value
	28933	1704	
Experience of losing a loved one, N (%)			
No	15041 (78.7)	883 (78.6)	0.984
Yes	4082 (21.3)	240 (21.4)	
Anxiety about acute radiation effects, N (%)			
No	15786 (85.6)	890 (83.3)	0.037
Yes	2645 (14.4)	178 (16.7)	
Anxiety about chronic radiation effects, N (%)			
No	9578 (51.7)	517 (48.8)	0.061
Yes	8935 (48.3)	543 (51.2)	
Psychological distress, N (%)			
No	15612 (85.4)	902 (84.3)	0.327
Yes	2671 (14.6)	168 (15.7)	
PTSD symptoms, N (%)			
No	14551 (78.2)	804 (73.6)	< 0.0001
Yes	4060 (21.8)	289 (26.4)	

Data are presented as numbers (frequency [%]). Differences between the hematuria (-) and hematuria (+) groups were analyzed using the chi-squared test. A p-value < 0.05 was considered statistically significant. PTSD, Post-traumatic stress disorder.

Table 3 shows the results of age- and sex-adjusted and multivariate logistic regression analyses examining factors associated with urinary occult blood. Owing to potential multicollinearity, psychological distress and PTSD symptoms were analyzed in separate models. In the age- and sex-adjusted model, age, female sex, leanness, evacuation experience, physical inactivity, current smoking, and former drinking were significantly and positively associated with urinary occult blood. Hyperuricemia and heavy drinking showed positive but nonsignificant associations. By contrast, overweight status was significantly negatively associated. In Model 1 (including psychological distress as an independent variable), significant positive association were found for age (OR: 1.02; 95% CI: 1.01–1.02), female sex (2.57, 2.23–2.96), leanness (1.32, 1.08–1.61), evacuation experience (1.35, 1.22–1.49), hyperuricemia (1.32, 1.03–1.70), physical inactivity (1.22, 1.01–1.48), current smoking (1.51, 1.25–1.83), and former

drinking (1.87, 1.32–2.65). Overweight status (0.68, 0.61–0.77) was significantly negatively associated. Interaction testing showed a significant effect of age (p = 0.002) but not other sex-based interactions.

Among men, significant positive associations were observed for age (1.03, 1.02–1.04), leanness (1.67, 1.03–2.71), hyperuricemia (1.36, 1.03–1.79), current smoking (1.70, 1.22–2.37), and former drinking (2.04, 1.26–3.31), whereas overweight status (0.76, 0.61–0.94) was negatively associated. Among women, age (1.01, 1.01–1.02), leanness (1.25, 1.02–1.04), evacuation experience (1.42, 1.26–1.60), physical inactivity (1.29, 1.03–1.62), current smoking (1.45, 1.12–1.87), and heavy drinking (1.69, 1.06–2.70) were significantly positively associated. Exercise 2–4 days per week (1.23, 0.96–1.57) showed a nonsignificant positive trend, whereas overweight status (0.66, 0.58–0.76) and insomnia (Q2) (0.72, 0.54–0.95) were significantly negatively associated. Similar patterns were observed in Model 2, which included PTSD symptoms.

Table 4 shows the sensitivity analysis assessing the influence of lifestyle-related diseases (diabetes, hypertension, and dyslipidemia) on the relationship between evacuation experience and urinary occult blood. The results, ORs, and 95% CIs remained largely unchanged, indicating that the association between evacuation experience and urinary occult blood was robust.

Table 4
Sensitivity analysis examining the influence of lifestyle-related diseases on the association between evacuation experience and urinary occult blood

	All	
	Multivariate OR (95% CI)	p value
Model 1a	1.35 (1.22–1.50)	< 0.0001
Model 2b	1.35 (1.22–1.49)	
Model 3c	1.35 (1.22–1.49)	
Model 4d	1.34 (1.21–1.48)	
Model 5e	1.34 (1.21–1.48)	
Model 6f	1.34 (1.21–1.48)	

[a] Adjusted for age, sex, BMI, evacuation, hyperuricemia, hyperuric acid, exercise, smoking, drinking, insomnia, loss in the family, anxiety about acute radiation effects, anxiety about chronic radiation effects, psychological distress, and diabetes.

[b] Adjusted for age, sex, BMI, evacuation, hyperuricemia, hyperuric acid, exercise, smoking, drinking, insomnia, loss in the family, anxiety about acute radiation effects, anxiety about chronic radiation effects, psychological distress, and hypertension.

[c] Adjusted for age, sex, BMI, evacuation, hyperuricemia, hyperuric acid, exercise, smoking, drinking, insomnia, loss in the family, anxiety about acute radiation effects, anxiety about chronic radiation effects, psychological distress, and hyperlipidemia.

[d] Adjusted for age, sex, BMI, evacuation, hyperuricemia, hyperuric acid, exercise, smoking, drinking, insomnia, loss in the family, anxiety about acute radiation effects, anxiety about chronic radiation effects, PTSD symptoms, and diabetes.

[e] Adjusted for age, sex, BMI, evacuation, hyperuricemia, hyperuric acid, exercise, smoking, drinking, insomnia, loss in the family, anxiety about acute radiation effects, anxiety about chronic radiation effects, PTSD symptoms, and hypertension.

f Adjusted for age, sex, BMI, evacuation, hyperuricemia, hyperuric acid, exercise, smoking, drinking, insomnia, loss in the family, anxiety about acute radiation effects, anxiety about chronic radiation effects, PTSD symptoms, and hyperlipidemia.

Logistic regression models used a significance threshold of $p < 0.05$.

OR, odds ratio; CI, confidence interval; Ref., reference; BMI, Body mass index; PTSD, Post-traumatic stress disorder.

DISCUSSION

Table 2 compares lifestyle habits and disaster-related factors between the urine occult blood–positive and –negative groups. The urine occult blood–positive group showed a significantly higher proportion of participants with evacuation experience. Evacuation may indirectly cause occult hematuria. Additionally,

factors associated with evacuation, such as physical inactivity, smoking, and past alcohol consumption, can increase stress and promote weight gain,[21,22] possibly contributing to hypertension and renal damage, elevating the likelihood of occult hematuria. Aging is associated with an increase in physical abnormalities that can cause occult hematuria,[23] explaining its prevalence among older individuals.[24] Women and individuals with low BMI are also more likely to exhibit occult hematuria,[25] consistent with known epidemiological patterns.

The relationship between evacuation-related stress and urinary stones also warrants discussion. Individuals prone to urinary stones often experience elevated stress levels. Psychological stress has been linked to the onset and exacerbation of conditions such as hypertension, diabetes, and metabolic syndrome.[26] Stress has also been associated with hyperuricemia, a known risk factor for urinary stones.[26]

Uric acid is produced during purine metabolism,[27] and its levels tend to increase because of overeating, excessive drinking, and lack of exercise. Elevated uric acid not only contributes to stone formation but may also lead to other metabolic and vascular disorders.

Xanthine oxidoreductase (XOR), an enzyme responsible for uric acid synthesis, also generates oxidative stress, which has been implicated in aging and other related diseases.[28] In animal studies, stress similar to that experienced during evacuation induced chronic inflammation in visceral fat, leading to increased XOR activity, oxidative stress, and arteriosclerosis.

Individuals under severe stress, such as those affected by natural disasters, should prioritize stress reduction to help prevent urinary stones and reduce the risk of metabolic syndrome, hypertension, and diabetes.

Although urinary stones may present with severe symptoms, they can also be asymptomatic and detectable only through imaging studies. Urinary tract infections, such as cystitis, may also cause occult hematuria and could be influenced by evacuation conditions. In a study of 97 patients with voiding dysfunction who performed intermittent self-catheterization, 17 (17%) were evacuees, and 4 (6%) developed cystitis following the GEJE.[29] Difficulties using Western-style toilets during evacuation were noted as contributing factors. These observations suggest that poor sanitation and restricted facilities during evacuation may increase susceptibility to urinary tract infections.

Consistent with the results of multivariate analyses including both K6 and PCL, age and low BMI emerged as considerable risk factors for hematuria.[25] Current smoking may contribute to renal damage by elevating blood pressure[24] and is also a known risk factor for urothelial tumors. Other potential causes of occult hematuria, such as hypertension, or diabetes-related kidney disease and nephritis, are often present and accompanied by proteinuria; therefore, they were excluded from this discussion. Congenital anomalies and renal vascular disorders, while potential causes, are unlikely to be related to evacuation. Common causes of hematuria or occult hematuria include urinary stones, infections, and

malignancies. Urinary stones are more likely to occur in individuals with hyperuricemia, regardless of the stone composition. Multivariate analysis using the K6 model indicated that hyperuricemia was also associated with other stone types, such as calcium oxalate stones.[26]

In the age- and sex-adjusted univariate regression analysis, trauma-related symptoms (measured by PCL) were associated with hematuria. For instance, conditions such as white-coat hypertension,[21] a stress-related elevation in blood pressure,[22] may cause transient renal injury and subsequent hematuria. This finding supports the hypothesis that stress contributes to the development of hematuria.[21]

Sex-specific differences also deserve attention. Among women, evacuation experience and lack of exercise were particularly relevant. Women may be more sensitive to the effects of stress,[30] which can increase blood pressure and predispose them to kidney injury. In men, hyperuricemia, a known risk factor for urinary stones,[31] was more prevalent and may explain the observed sex differences.

Although the interaction analysis indicated a significant effect of age, there were no significant sex-based differences in the association between evacuation experience and occult hematuria. Therefore, the study conclusions were drawn from the entire population, and sex-stratified results should be interpreted as reference values.

Sensitivity analysis further showed that lifestyle-related diseases, including diabetes, hypertension, and dyslipidemia, did not significantly affect hematuria occurrence. A prior study on asymptomatic microscopic hematuria in 236 patients aged 40 years or older (105 men, 131 women)[32] identified the following etiologies: bacterial cystitis (28 cases), urinary tract stones (25 cases), renal cysts (14 cases), urethral caruncle (13 cases), follicular cystitis (7 cases), bladder tumors (5 cases), and chronic glomerulonephritis (4 cases). Conditions likely to be stress-related include bacterial cystitis, urolithiasis, and bladder tumors. Psychological stress may suppress immune function, increasing susceptibility to infection. Animal studies have shown that stress induces mitochondrial dysfunction in urothelial cells,[33] leading to epithelial degeneration. This suggests that chronic stress causes cellular injury via sympathetic activation and mitochondrial dysfunction, contributing to chronic inflammation and development of urinary stones and cystitis—two major causes of microscopic hematuria. Risk factors for urothelial carcinoma, which occurs in approximately 0.5% of individuals who test positive for urinary occult blood in Japan, include male sex, age > 40 years, history of smoking, exposure to harmful substances, history of urological disease, urinary irritation symptoms, urinary tract infection, and frequent use of painkillers. Individuals who meet these criteria are considered at high risk for urothelial carcinoma and require careful evaluation. Several reports have suggested a potential association between stress and malignant tumors, including urothelial tumors.

Although no major studies have directly examined the link between psychological stress and urinary tract malignancies, particularly urothelial carcinoma, some literature indicates that stress may increase the overall risk of malignant tumors. One cohort study investigated the association between perceived stress and urinary tract tumors.[34]

Although hematuria is more prevalent among individuals with PCL, it is essential to distinguish asymptomatic cases from treatable conditions. For example, urinary tract infections typically present with symptoms and can be diagnosed by detecting bacteria or white blood cells in the urinary sediment in milder cases.[35,36] Chronic kidney disease can be identified through proteinuria or by estimating the glomerular filtration rate using blood tests; the presence of casts or dysmorphic red blood cells on urinalysis also suggests kidney damage.[37]

This study has a few limitations. First, some residents might have poor mental health status and could not answer the survey. Studies have indicated that mental health status might affect the survey response rate, and this factor might have occurred in our study. Second, a high level of psychological distress might have affected the subjective health status of the study participants. A high frequency of poor subjective health could be a consequence of high psychological distress, which could have led to the over-adjustment of ORs in this study. Finally, there was insufficient information regarding pre-disaster factors, such as personality traits, social adaptation, traumatic experiences, and other mental health problems.

CONCLUSIONS

Disaster-related psychological and lifestyle factors were significantly associated with occult hematuria among residents of the Fukushima evacuation zone. These findings highlight the importance of incorporating renal health monitoring into post-disaster health management, specifically for evacuees and individuals experiencing prolonged lifestyle disruptions or psychological distress. Timely medical evaluation for hematuria and minimally invasive secondary screening methods may facilitate early detection and reduce the need for hospital visits in disaster-affected settings. Further longitudinal studies are needed to clarify causal pathways, examine the long-term renal effects of chronic stress and determine whether improvements in living conditions or mental health interventions reduce hematuria risk. Future research should also explore the underlying biological mechanisms to better understand how disaster-related stressors contribute to renal microvascular changes.

Abbreviations

AIS Athens Insomnia Scale

BMI body mass index

CVDs cardiovascular diseases

BS casual blood glucose

CHC Comprehensive Health Check

CIs confidence intervals

DBP diastolic blood pressure

FBS fasting blood glucose

FY fiscal year

FHMS Fukushima Health Management Survey

GEJE Great East Japan Earthquake

HbA1c hemoglobin A1c

HDL-chol High-density lipoprotein cholesterol

K6 Kessler 6-item Psychological Distress Scale

MHLS Mental Health and Lifestyle Survey

NPP Nuclear Power Plant

ORs odds ratios

PTSD post-traumatic stress disorder

PCL Post-traumatic Stress Disorder Checklist

TG triglyceride

XOR Xanthine oxidoreductase

Declarations

Ethics approval and consent to participate: This study was approved by the ethics committee of Fukushima Medical University (approval numbers: 1319, 29064, and 2020239) and performed in accordance with the guidelines of the Council for International Organizations of Medical Science and the principles of the Declaration of Helsinki. Informed consent was obtained from all participants and the community representatives.

Consent for publication:

Not applicable

Availability of data and materials: The datasets analyzed during the current study are not publicly available because the Fukushima Health Management Survey is governed by the privacy policy of the Fukushima Prefecture Government. However, the data are available from the corresponding author upon reasonable request.

Competing interests: The authors declare no conflicts of interest.

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Authors' contributions:

Contributions

SO, FH, TO, HN, SS, KO, and MN designed the study, FH performed statistical analysis. All authors interpreted the data. SO and FH drafted the manuscript. FH, MS, AS, JJK, IM, HO, and SY critically revised the manuscript. SO, as guarantor of the study, accept full responsibility for the results of this study, had access to the data, and controlled the decision to publish. All authors read and approved the final manuscript.

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Table 3

Table 3 is available in the Supplementary Files section.

Figures

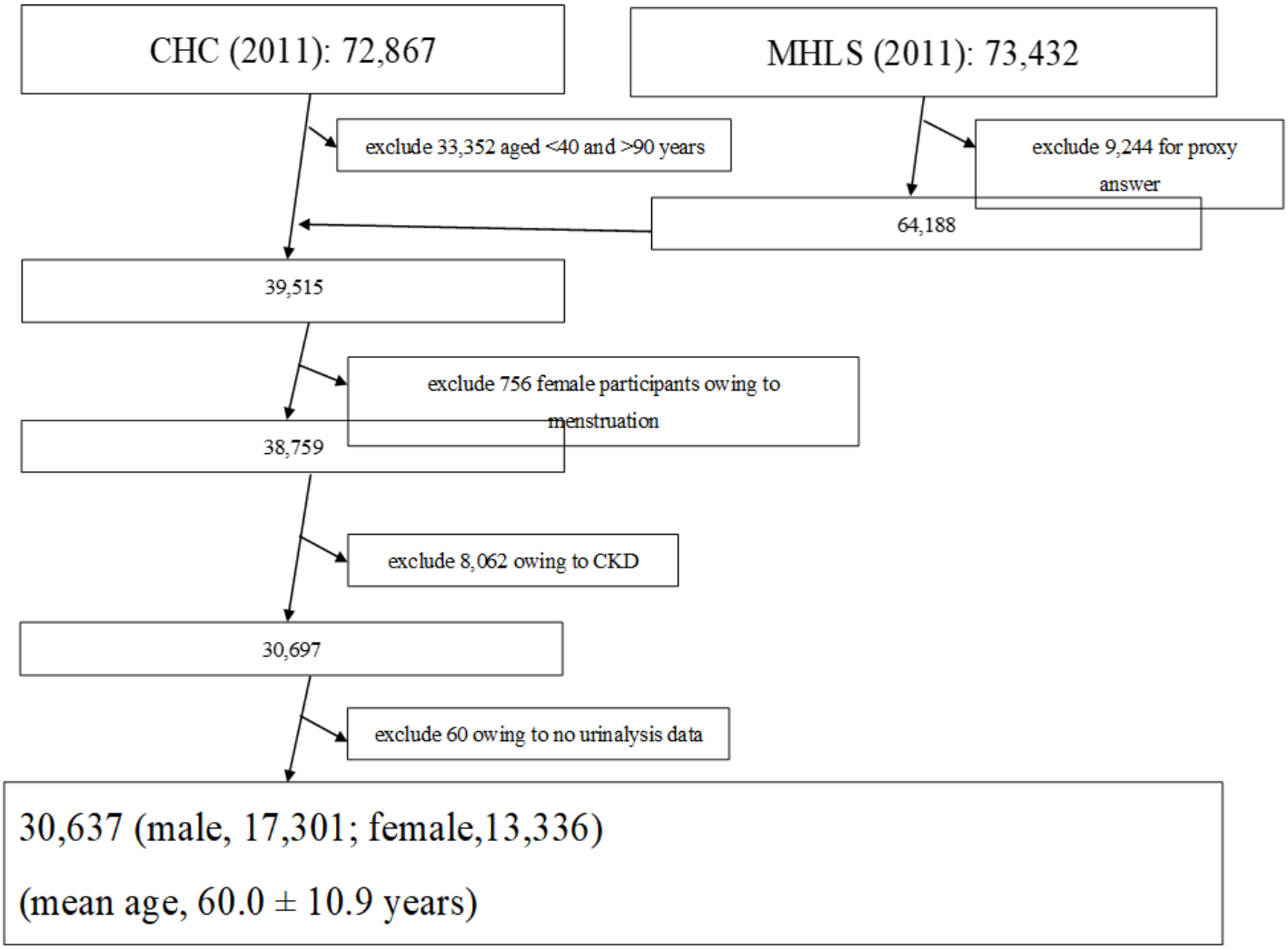


Figure 1

Study design. Of 72,867 individuals who visited the CHC in FY 2011, 39,515 participants aged 40–90 years as of April 1, 2011, were selected. We excluded 756 women who were menstruating or whose menstrual status was unknown; 8,062 individuals with abnormal renal function (eGFR < 60 or proteinuria), a history of chronic kidney disease, dialysis, or other kidney diseases; and 60 individuals

with missing urine occult blood test results. In total, 30,637 individuals (17,301 men and 13,336 women) were ultimately included in the analysis.

CKD, chronic kidney disease; CHC, Comprehensive Health Check; FY, fiscal year; eGFR, estimated glomerular filtration rate; MHLS, Mental Health and Lifestyle Survey

Supplementary Files

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- Table3.docx