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Long-term risk of allergic disorders following Kawasaki disease: a population-based cohort study

Jae-Hee Seol[1,2], Lucy Youngmin Eun[2*] and Ji-Ho Lee[3*]

Abstract

Background Kawasaki disease (KD) is an acute systemic vasculitis primarily affecting children under five years old. While its etiology remains unclear, immune dysregulation has been implicated, suggesting a potential link between KD and allergic diseases. Previous epidemiological studies have reported inconsistent findings regarding this association across different countries. This study aims to investigate the association between KD and allergic diseases in Korea.

Methods A nationwide population-based cohort study was conducted utilizing data from the Korean National Health Insurance database. KD cases were defined as admissions with a primary diagnosis of KD plus treatment records for immunoglobulin or aspirin. The control group had no KD diagnosis. Between 2008 and 2015, 41,806 KD cases were matched 1:4 with 163,548 controls using propensity score matching. The incidence and prevalence of asthma, rhinitis, atopic dermatitis, and urticaria from 2017 to 2021 were analyzed using hazard ratios (HRs) and odds ratios (ORs).

Results Mean age was 2.63 ± 1.84 years for KD patients and 2.64 ± 1.85 years for controls ($P = 0.119$). The proportion of females was 42.20% in the KD group and 42.60% in the control group ($P = 0.145$). KD patients showed significantly higher risks for developing rhinitis (HR 1.045, 95%CI 1.013–1.078) and urticaria (HR 1.139, 95%CI 1.085–1.197). However, no significant association was found in the incidence of asthma or atopic dermatitis. KD diagnosis at age 5 or older was associated with decreased risk of all allergic disorders. The prevalence of all allergic disorders studied was significantly higher in the KD group, with the strongest associations observed for rhinitis (OR 1.178, 95%CI 1.151–1.205) and urticaria (OR 1.192, 95%CI 1.155–1.230). Gender and urban living also influenced the prevalence of allergic disorders. A sensitivity analysis conducted to account for the COVID-19 pandemic showed consistent results, confirming the association between KD and increased risk and prevalence of allergic disorders.

Conclusions This study demonstrates a significant association between Kawasaki disease and increased risk of allergic disorders, particularly rhinitis and urticaria. These findings suggest potential shared pathogenesis between the two conditions and highlight the need for long-term monitoring of allergic conditions in KD patients.

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Clinical trial number Not applicable.

Keywords Kawasaki disease, Allergy, Asthma, Epidemiology

Background

Kawasaki disease (KD) is an acute systemic vasculitis disorder first described by Tomisaku Kawasaki in 1961 in Japan, primarily affecting children under five years old. It is the leading cause of severe cardiac complications, particularly coronary artery aneurysms [1]. KD has unique pathological characteristics, but its exact cause remains unknown. It is believed to result from multifactorial interactions involving pathogens, environmental triggers, immune mediated vasculitis, and genetic susceptibility [2–4]. This complex interplay of factors likely explains the variability in clinical manifestations and outcomes observed in patients with KD.

Emerging evidence suggests that KD involves immune dysregulation, as studies have reported abnormalities in immune responses. Notably, increased levels of type 2 T-helper cell (Th2) cytokines such as IL-4 and IL-5, along with elevated eosinophil counts, have been observed in KD patients. Additionally, the involvement of matrix metalloproteinases (MMPs) suggests potential parallels in immune mechanisms between KD and allergic diseases [5–7]. These findings have led to hypotheses and epidemiological studies exploring the association between KD and allergic diseases.

Cohort studies conducted in Southeast Asia, the United States, Canada, and Australia have reported an increased likelihood of allergic diseases, including asthma, allergic rhinitis, and atopic dermatitis, in KD patients [8–12]. These findings provide epidemiological evidence supporting the association between KD and allergic diseases. Given this context, the purpose of this study was to investigate the association between KD and allergic diseases in Korea. To achieve this, we conducted a population-based matched case-control study using data from the Korean National Health Insurance Service (NHIS). Through this large-scale, population-based analysis, we aim to clarify the relationship between KD and allergic diseases and contribute to understanding their shared pathophysiology.

Methods

Data source

The National Health Information Database (NHID) in South Korea is a comprehensive public health database managed by the NHIS [13]. It covers over 50 million people and includes data from 2002 on health care utilization, health screening, socio-demographic variables, and mortality. NHID comprises several interconnected databases: eligibility, national health screening, health care utilization, long-term care insurance, and health care provider. These databases contain detailed information on insurance contributions, demographics, health behaviors, medical treatments, prescriptions, and health care institutions. The NHID uses deidentified join keys to link these databases while maintaining privacy. Researchers have utilized this resource to study various diseases, health conditions, risk factors, and health policy impacts. Access to NHID is available through a formal application process, requiring ethics approval and review by the NHIS committee.

Study design and population

Subjects assigned the KD diagnostic code (M303) at least once as a main or sub-diagnosis between January 2002 and December 2021 (KD cases) were initially identified. To enhance diagnostic accuracy and exclude suspected but unconfirmed cases, we included only those who were hospitalized with KD as the main diagnosis and received treatment with intravenous immunoglobulin (IVIG) or aspirin. In Korea, KD treatment generally follows the American Heart Association guidelines, with IVIG as standard first-line therapy and adjunctive aspirin commonly used. Aspirin monotherapy may be administered when IVIG is delayed or not indicated. Subsequently, we narrowed the KD subjects to those with birth years between 2008 and 2015 (Fig. 1). The control group was identified using 1:4 propensity score matching, with adjustment for year of birth, sex, and urbanicity. This approach ensured a balanced comparison between KD cases and controls, minimizing potential confounding factors.

Study outcomes

This study included 4 allergic disorders, such as asthma, allergic rhinitis, atopic dermatitis, and urticaria. Allergic disorders were identified with corresponding ICD-10 diagnostic codes: asthma (J45–J46), allergic rhinitis (J303–J304), atopic dermatitis (L208–L209), and urticaria (L501, L508, and L509). The total represented cases with any allergic disorders. We restricted the subjects with allergic disorders to those who had been treated with them as the main diagnosis at least twice, ensuring a more accurate identification of true allergic cases. The observational period during which we assessed the incidence and prevalence of allergic disorders was 2017 to 2021 (Fig. 1). The incident case was defined as a new diagnosis of allergic disorders for observational period. The prevalent case was the total number of subjects who had been treated for allergic disorders during observational period. The incidence and prevalence rates were

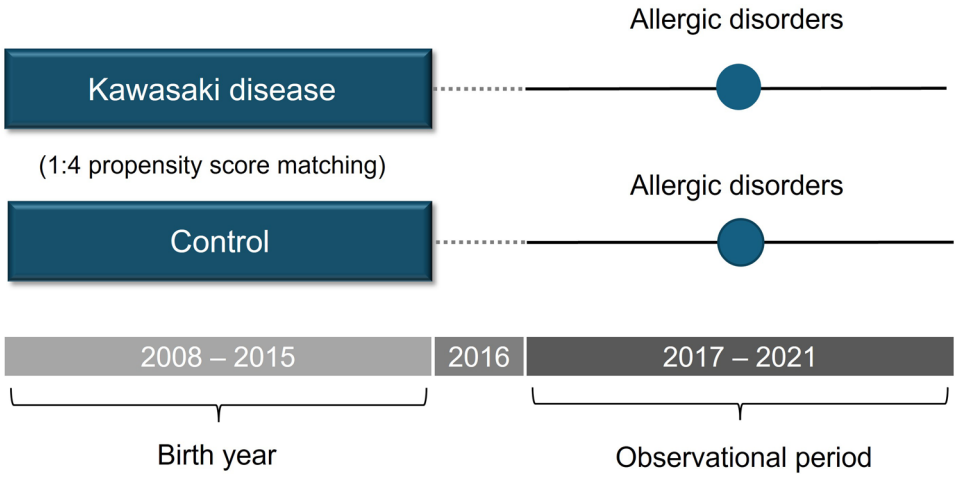

Fig. 1 Summary of study design

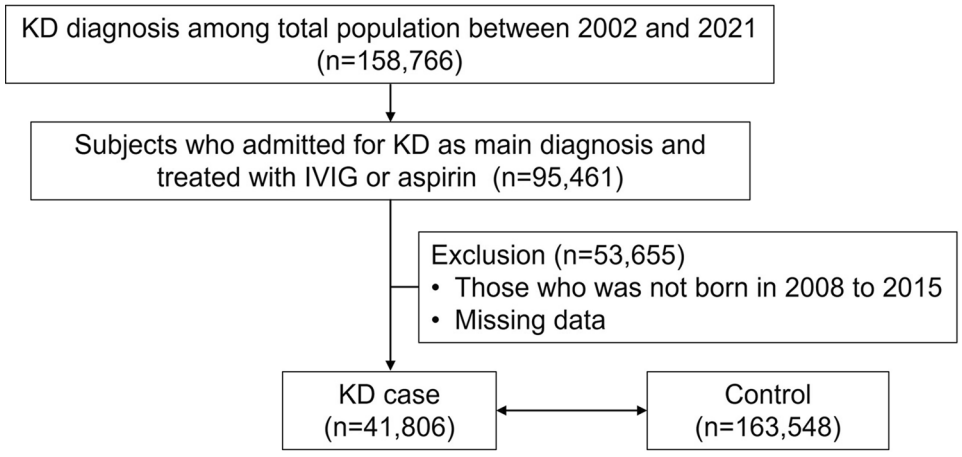

Fig. 2 Patient selection flow. KD, Kawasaki disease; IVIG, intravenous immunoglobulin

calculated by dividing the number of incident and prevalent cases by the total number of KD subjects and controls, respectively.

Statistical analysis

The baseline characteristics of the KD cases and controls were compared using the Mann–Whitney U test for continuous variables and the chi-square test for categorical variables. KD cases and controls were identified using propensity score matching with a caliper width of 0.2 and the Greedy matching method. The incidence of allergic disorders was compared using a Cox proportional hazard model and described as hazard ratios (HRs) with 95% confidence intervals (CIs). The prevalence of allergic disorders was assessed using a logistic regression model and described as odds ratios (ORs) with 95% CIs. In a multivariable analysis of HR and OR, all variables including age, sex, and urbanicity were adjusted. In the sensitivity analysis, the observational period was restricted to 2017 to 2019 to assess whether study results were consistent regardless of the COVID-19 pandemic (2020–2021). An additional sensitivity analysis was performed to investigate whether the season of KD diagnosis influenced the incidence and prevalence of allergic disorders within the KD group. Based on the month of diagnostic date, KD cases were categorized into four seasonal groups: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). The Cochran-Armitage trend test was used to assess the association between the season of KD diagnosis and allergic disorders. All statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). A *P* value of less than 0.05 was considered statistically significant.

Results

Demographics of study participants

From the Korean population of approximately 50 million, 158,766 subjects with a diagnostic history of KD between 2002 and 2021 were initially identified (Fig. 2). To ensure accurate identification of relevant KD patients,

Table 1 Baseline characteristics of the study subjects

Variables	KD cases (*n* = 41,806)	Controls (*n* = 163,548)	*P*
Age			
Mean (years)	2.63 ± 1.84	2.64 ± 1.85	0.119
≤ 2 years	22,038 (52.71)	85,869 (52.50)	0.176
3–4 years	13,376 (32.00)	52,068 (31.84)	
≥ 5 years	6,392 (15.29)	25,611 (15.66)	
Sex (female)	17,643 (42.20)	69,667 (42.60)	0.145
Urbanicity			0.073
Urban	28,054 (67.11)	108,991 (66.64)	
Non-urban	13,752 (32.89)	54,557 (33.36)	

Represented as mean ± SD or n (%). KD, Kawasaki disease

the cohort was restricted to those admitted with KD as the main diagnosis and who received treatment for KD (*n* = 95,461). The final KD cohort consisted of 41,806 subjects born between 2008 and 2015, with 163,548 matched controls identified using a 1:4 ratio. The distribution of KD cases and controls by year of birth was as follows: 5,116 and 19,981 in 2008; 5,005 and 19,593 in 2009; 5,347 and 21,287 in 2010; 5,601 and 22,123 in 2011; 5,917 and 23,668 in 2012; 5,157 and 20,628 in 2013; 4,943 and 17,388 in 2014; and 4,720 and 18,880 in 2015.

Table 1 presents the baseline characteristics of the study subjects. The mean age was 2.63 ± 1.84 years for KD patients and 2.64 ± 1.85 years for controls (*P* = 0.119). The proportion of females was 42.20% in the KD group and 42.60% in the control group (*P* = 0.145). Urban residents constituted 67.11% of the KD group and 66.64% of the control group (*P* = 0.073).

Incidence of allergic disorders

The risk of developing asthma in patients with KD was not statistically significant (HR 1.041, 95%CI 0.991–1.094, *P* = 0.111) (Fig. 3). Patients with KD showed a slightly increased risk of developing allergic rhinitis (HR 1.045, 95%CI 1.013–1.078, *P* = 0.006). No statistically significant association was found between KD and the development of atopic dermatitis (HR 1.049, 95%CI 0.989–1.113, *P* = 0.114). However, patients with KD demonstrated a significantly higher risk of developing urticaria (HR 1.139, 95%CI 1.085–1.197, *P* < 0.001). When all allergic diseases were considered as a single outcome, the KD group exhibited a significantly higher risk of developing any allergic disease during the follow-up period compared to controls (HR 1.054, 95%CI 1.029–1.079, *P* < 0.001).

Patients diagnosed with KD at 5 years or older showed decreased risk of all allergic disorders: asthma (HR 0.693, 95%CI 0.650–0.740, *P* < 0.001), allergic rhinitis (HR 0.688, 95%CI 0.660–0.716, *P* < 0.001), atopic dermatitis

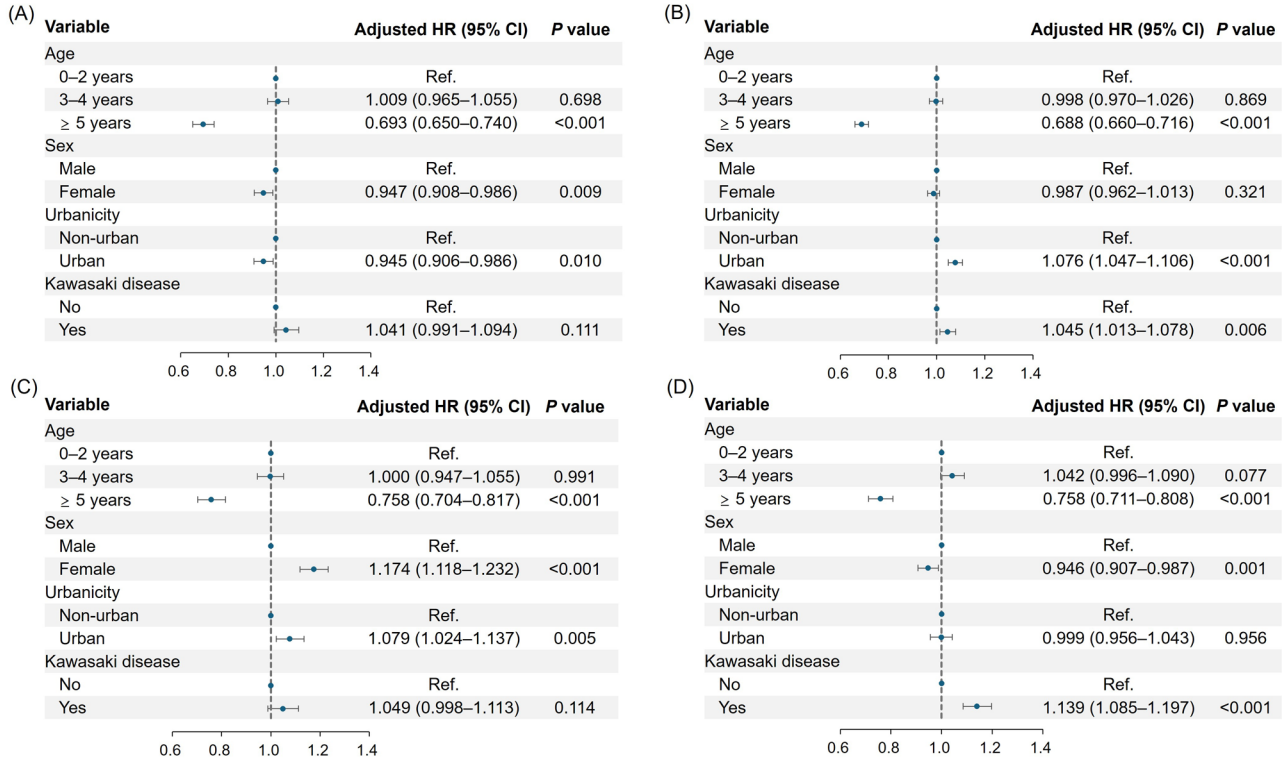

Fig. 3 Hazard ratio of asthma (**A**), allergic rhinitis (**B**), and atopic dermatitis (**C**), and urticaria (**D**) according to the demographics and Kawasaki disease. CI, confidence interval; HR, hazard ratio

(HR 0.758, 95%CI 0.704–0.817, $P<0.001$), and urticaria (HR 0.758, 95%CI 0.711–0.808, $P<0.001$). Female sex was associated with lower risk of developing asthma (HR 0.947, 95%CI 0.908–0.986, $P=0.009$) and urticaria (HR 0.946, 95%CI 0.907–0.987, $P=0.001$), but higher risk of atopic dermatitis (HR 1.174, 95%CI 1.118–1.232, $P<0.001$). Urban residents demonstrated a higher risk of developing allergic rhinitis (HR 1.076, 95%CI 1.047–1.106, $P<0.001$) and atopic dermatitis (HR 1.079, 95%CI 1.024–1.137, $P=0.005$), whereas urban living was associated with lower risk of asthma (HR 0.945, 95%CI 0.906–0.986, $P=0.010$). Detailed incidence results were presented in Table 2.

Prevalence of allergic disorders

Asthma was more prevalent in patients with KD compared to those without KD (OR 1.041, 95%CI 1.011–1.072, $P=0.007$) (Fig. 4). Other allergic disorders were also more prevalent in patients with KD: allergic rhinitis (OR 1.178, 95%CI 1.151–1.205, $P<0.001$), atopic dermatitis (OR 1.076, 95%CI 1.043–1.110, $P<0.001$), and urticaria (OR 1.192, 95%CI 1.155–1.230, $P<0.001$). The KD group showed statistically significant increase in the prevalence of any allergic disorders (OR 1.182, 95%CI 1.154–1.210, $P<0.001$).

Patients diagnosed with KD at 5 years or older showed decreased prevalence of asthma (OR 0.915, 95%CI 0.883–0.947, $P<0.001$), allergic rhinitis (OR 0.907, 95%CI 0.884–0.931, $P<0.001$), and urticaria (OR 0.923, 95%CI 0.888–0.959, $P<0.001$). Female sex was associated with lower prevalence of asthma (OR 0.835, 95%CI 0.815–0.856, $P<0.001$), allergic rhinitis (OR 0.841, 95%CI 0.826–0.857, $P<0.001$), and urticaria (OR 0.930, 95%CI 0.906–0.956, $P<0.001$). Urban residents demonstrated decreased risk of asthma (OR 0.851, 95%CI 0.830–0.873, $P<0.001$), whereas urban living was associated with higher risk of atopic dermatitis (OR 1.095, 95%CI 1.066–1.125, $P<0.001$). Detailed prevalence results were presented in Table 3.

Sensitivity analysis

A sensitivity analysis showed consistent results regardless of COVID-19 pandemic (Fig. 5). KD was associated with increased risk of allergic rhinitis (HR 1.045, 95%CI 1.011–1.080, $P=0.010$), urticaria (HR 1.135, 95%CI 1.076–1.198, $P<0.001$), and total (HR 1.052, 95%CI 1.027–1.079, $P<0.001$). Allergic disorders were more prevalent in patients with KD compared to those without KD: asthma (OR 1.039, 95%CI 1.008–1.071, $P=0.013$), allergic rhinitis (OR 1.160, 95%CI 1.135–1.186, $P<0.001$), atopic dermatitis (OR 1.066, 95%CI 1.030–1.104, $P<0.001$), urticaria (OR 1.194, 95%CI 1.154–1.235, $P<0.001$), and total (OR 1.182, 95%CI 1.154–1.210, $P<0.001$). An additional sensitivity analysis did not reveal any association between the diagnostic season of KD and either the incidence (Supplementary Table 1) or prevalence of allergic diseases (Supplementary Table 2).

Discussion

The present study documents an association between KD and allergic diseases. Previous research has reported elevated odds ratio of allergic diseases among KD patients in regions such as Southeast Asia (Taiwan and Japan), the United States, and Australia [8, 9, 14, 15]. However, conflicting findings have also been observed within the same regions, with some studies reporting no significant association between KD and asthma [16, 17]. These variations may arise from methodological differences,

Table 2 Comparison of the incidence of allergic diseases and association with Kawasaki disease

Allergy	KD	Incidence of allergy (n, %)	Univariable analysis		Multivariable analysis	
			HR (95% CI)	*P*	HR (95% CI)	*P*
Asthma	No	7,402 (4.53)	reference		reference	
	Yes	1,966 (4.70)	1.043 (0.993–1.096)	0.096	1.041 (0.991–1.094)	0.111
Allergic Rhinitis	No	18,750 (11.46)	reference		reference	
	Yes	4,995 (11.95)	1.047 (1.015–1.080)	0.004	1.045 (1.013–1.078)	0.006
Atopic dermatitis	No	5,129 (3.14)	reference		reference	
	Yes	1,381 (3.30)	1.050 (0.990–1.115)	0.105	1.049 (0.989–1.113)	0.114
Urticaria	No	7,002 (4.28)	reference		reference	
	Yes	2,028 (4.85)	1.141 (1.086–1.199)	< 0.001	1.139 (1.085–1.197)	< 0.001
Total	No	33,138 (20.26)	reference		reference	
	Yes	8,882 (21.25)	1.055 (1.031–1.080)	< 0.001	1.054 (1.029–1.079)	< 0.001

HR, hazard ratio; KD, Kawasaki disease

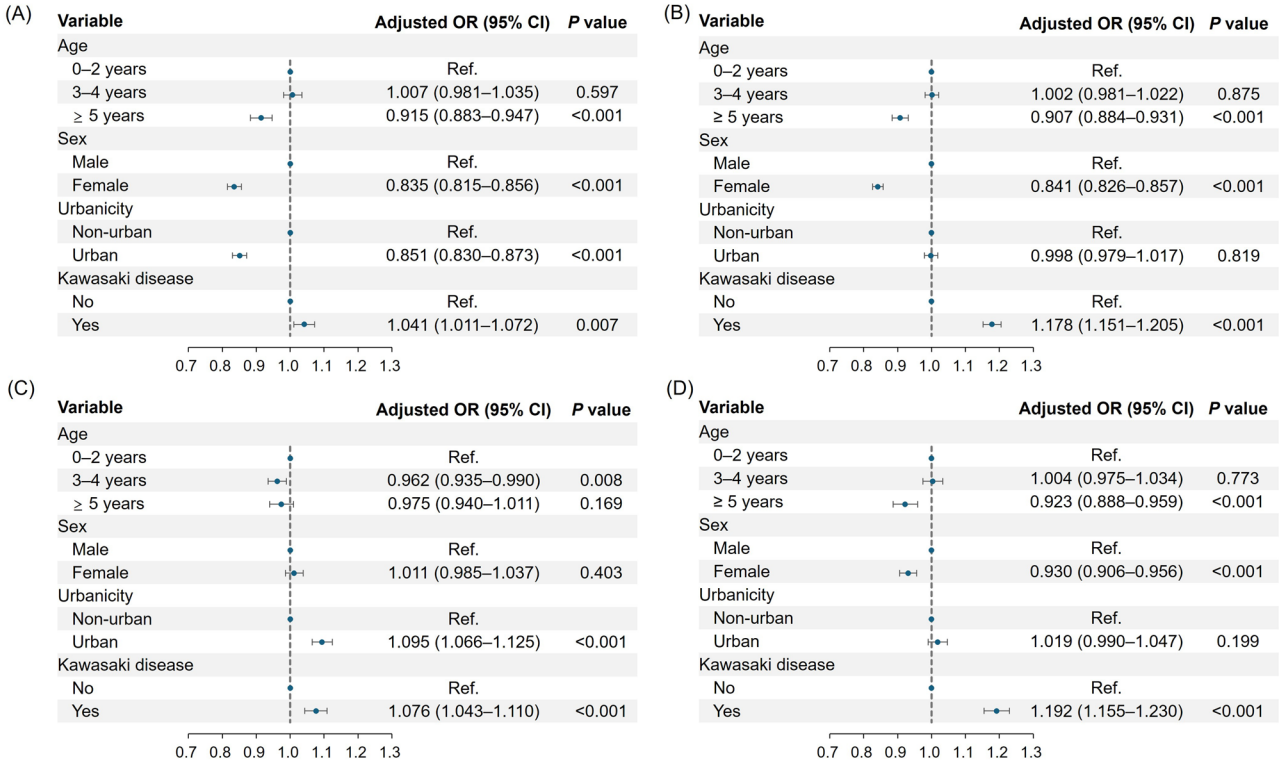

Fig. 4 Odds ratio of asthma (**A**), allergic rhinitis (**B**), and atopic dermatitis (**C**), and urticaria (**D**) according to the demographics and Kawasaki disease. CI, confidence interval; OR, odds ratio

Table 3 Comparison of the prevalence of allergic diseases and association with Kawasaki disease

Allergy	KD	Prevalence of allergy (n, %)	Univariable analysis		Multivariable analysis	
			OR (95% CI)	*P*	OR (95% CI)	*P*
Asthma	No	25,160 (15.38)	reference		reference	
	Yes	6,656 (15.92)	1.042 (1.012–1.073)	0.006	1.041 (1.011–1.072)	0.007
Allergic Rhinitis	No	103,769 (63.45)	reference		reference	
	Yes	28,081 (67.17)	1.179 (1.152–1.206)	< 0.001	1.178 (1.151–1.205)	< 0.001
Atopic dermatitis	No	21,849 (13.36)	reference		reference	
	Yes	5,951 (14.23)	1.076 (1.044–1.110)	< 0.001	1.076 (1.043–1.110)	< 0.001
Urticaria	No	19,493 (11.92)	reference		reference	
	Yes	5,810 (13.90)	1.193 (1.156–1.231)	< 0.001	1.192 (1.155–1.230)	< 0.001
Total	No	109,218 (66.78)	reference		reference	
	Yes	29,427 (70.39)	1.183 (1.155–1.210)	< 0.001	1.182 (1.154–1.210)	< 0.001

OR, odds ratio; KD, Kawasaki disease

environmental factors such as air quality, levels of industrialization, hygiene practices, and pathogen exposure, as well as genetic diversity across populations.

Recent epidemiological studies in Korea have reported a delayed increase in the incidence of allergic diseases among KD patients compared to controls, but these studies were limited by small sample sizes and a follow-up period of up to six years [18]. Our study analyzed a larger cohort of KD patients over an extended follow-up period ranging from 2 to 13 years. To address the initial instability of data in the NHIS database, we established a window period and enrolled patients diagnosed with KD between 2008 and 2015, analyzing the incidence and prevalence of allergic diseases from 2017 to 2021. Additionally, our

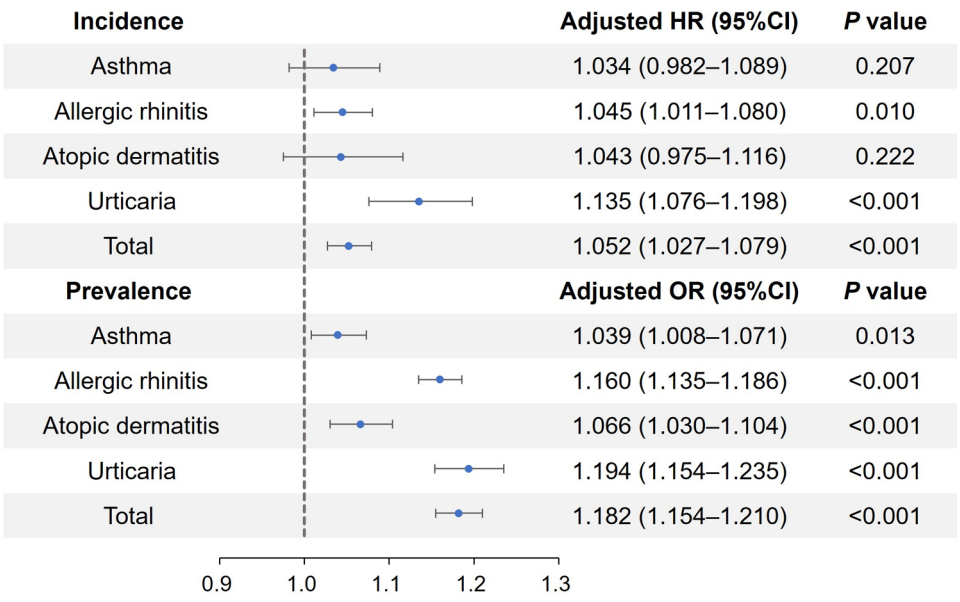

Fig. 5 Sensitivity analysis of incidence and prevalence of allergic disorders according to Kawasaki disease. CI, confidence interval; HR, hazard ratio; OR, odds ratio

study is distinguished by its use of not only ICD codes but also treatment records, including aspirin and IVIG, to enhance diagnostic accuracy and minimize potential misclassification.

Our analysis of overall allergic outcome—defined as the presence of any allergic disease (asthma, allergic rhinitis, atopic dermatitis, or chronic urticaria)—revealed a modest but statistically significant increase in both incidence and prevalence among KD patients compared to controls. This approach may better reflect the overall allergic burden and is consistent with previous hypotheses suggesting shared immunologic mechanisms between KD and allergic conditions [9, 19, 20]. Although the effect sizes were modest, their statistical significance and potential clinical relevance should not be overlooked. Even small effect sizes can translate into substantial impacts at the population level, particularly given the widespread prevalence of KD and the chronic nature of allergic diseases. The consistency of our findings across multiple statistical approaches, including sensitivity analyses, further supports their robustness. In disease-specific analyses, allergic rhinitis and chronic urticaria showed significantly increased hazard ratios, whereas asthma and atopic dermatitis did not. This may be due to the follow-up period in our study, which spanned 2 to 13 years after KD diagnosis. Since asthma incidence often increases after school age [21], further long-term follow-up may be necessary for a more comprehensive risk assessment. Regarding prevalence, however, Kawasaki disease was significantly associated with all four allergic conditions—namely, asthma, allergic rhinitis, atopic dermatitis, and chronic urticaria—indicating a broader relationship across allergic disease categories.

Analyses by age, gender, and residential area provided additional insights. For most allergic diseases, exception of atopic dermatitis, the odds ratio decreased as the age at KD diagnosis increased. This pattern may reflect the immaturity of the immune system in younger children. Children under two years of age are known to exhibit a Th2-skewed immune response, which gradually becomes balanced with age [22, 23]. This Th2-dominant immune state may partially explain the higher risk of allergic diseases in patients diagnosed with KD at an earlier age. A previous study by Aschbacher et al. demonstrated that the immune system is especially plastic and vulnerable to environmental stressors in early life, especially before the age of five. During this period, immunological imprinting may contribute to long-term inflammatory or allergic tendencies [24]. This supports the notion that KD occurring after the age of five may have a diminished impact on immune programming, as the immune system has matured beyond its most vulnerable phase. As a result, the long-term risk of allergic outcomes may be lower in this subgroup. In the case of atopic dermatitis, differences in disease mechanisms and skin barrier function may contribute to this distinct pattern [19].

Gender differences were also notable, with male KD patients showing higher odds ratio for asthma, allergic rhinitis, and chronic urticaria whereas females showed higher HR and OR for atopic dermatitis. These findings may reflect hormonal influences on allergic responses as well as sex-specific gene expression patterns of KD, or differences in bronchial development between genders

[25, 26]. Additionally, environmental factors appeared to play a role. KD patients living in urban areas had a lower risk of asthma but a higher risk of allergic rhinitis and atopic dermatitis compared to those in rural areas. Environmental exposures in urban settings may influence the immune system of KD patients, triggering allergic immune responses [27–29].

Although no studies have directly examined how KD-induced inflammation might drive immune remodeling leading to the development of allergic diseases, previous research has highlighted common immunological and genetic factors between KD and allergic diseases, suggesting the possibility of shared pathophysiological mechanisms. For instance, MMPs have been implicated in the regulation of cytokine secretion, including TGF-β, TNF-α, and IL-1 [7, 30]. Furthermore, imbalances in Th1/Th2 cell activity and altered ratios of Th17 cells to regulatory T cells (Treg) have been associated with both KD and allergic diseases [5, 6, 31–33]. Genetic factors involved in immune responses have also been shown to influence KD development [34]. Notably, genetic studies have identified overlapping susceptibility genes, such as IL-1β, IL-10, IL-4, and HLA, that are associated with both KD and allergic diseases [19, 35–40].

KD is a complex disorder with an unclear pathophysiology, and the precise mechanisms by which KD influences the development of allergic diseases remain unclear. However, the findings of this study provide valuable insights into the mechanisms underlying KD. Analyses of subject demographics revealed factors influencing KD development and its relationship with allergic diseases, contributing to a better understanding of their interplay.

Given the chronic nature of allergic diseases, long-term immune monitoring is essential for KD patients. Future research should focus on integrating molecular, genetic, and environmental data to further elucidate the shared mechanisms between KD and allergic diseases. A more comprehensive analysis of these interactions will not only enhance clinical management strategies but also provide insights into the long-term health outcomes for KD patients. In addition, we were not provided with detailed information regarding IVIG and aspirin treatment. As a result, we were unable to analyze whether treatment modalities influenced the study outcomes. Further research is warranted to investigate the impact of treatment on the risk of allergic diseases.

While our study provides valuable evidence linking KD and allergic diseases, several limitations must be acknowledged. First, the diagnosis of allergic diseases relied solely on ICD codes, which made it impossible to verify diagnostic criteria and may have led to the exclusion of certain patients due to varying levels of healthcare accessibility. Second, the data was sourced from the NHIS database, which began in 2002, limiting the inclusion of cases diagnosed before this period and constraining the ability to conduct longer-term follow-up studies. Third, the lack of detailed personal information, such as family history, lifestyle factors, and environmental exposures, restricted our ability to account for potential confounding variables. Fourth, while we included treatment records to enhance diagnostic accuracy, due to the limitations of the available data, we were unable to compare the effects of different treatment modalities, such as IVIG or aspirin, on the development of allergic diseases. Another important limitation is that the diagnosis of allergic diseases depends on healthcare utilization, and cases with mild symptoms or limited healthcare access may not have been captured, potentially leading to underestimation of incidence or prevalence.

Conclusion

Our nationwide population-based study demonstrated a significant association between KD and an increased risk of allergic diseases, suggesting that KD may be a risk factor for subsequent allergic conditions. Younger age at KD diagnosis was associated with a higher risk of allergic outcomes, while male patients and those residing in urban areas were identified as high-risk groups for asthma. These findings suggest the potential benefit of targeted monitoring in vulnerable subgroups. The observed association may reflect shared immunological mechanisms or the possibility that KD acts as a trigger for long-term immune remodeling. These findings highlight the importance of long-term observation and the need for further research into the molecular and immunological pathways linking KD and allergic diseases. Such research will be crucial for improving risk stratification and guiding future preventive strategies.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-025-05724-3.

Supplementary Material 1

Author contributions

Conceptualization: JH Seol. Methodology: JH Lee. Validation: LY Eun. Formal analysis: JH Seol, JH Lee. Investigation: JH Lee. Data curation: JH Lee. Writing-original draft: JH Seol, JH Lee. Writing-review & editing: LY Eun. Visualization: JH Lee. Supervision: Seol JH, LY Eun. All authors contributed to the article and approved the submitted version.

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Data availability

The data that support the findings of this study were obtained from the National Health Insurance Service (NHIS) of Korea under strict confidentiality agreements. Due to privacy regulations and data sharing policies of the NHIS, these data cannot be shared publicly. Researchers interested in accessing the data can request access directly from the NHIS (https://nhiss.nhis.or.kr).

Declarations

Ethics approval and consent to participate
This study was approved by the Institutional Review Board of Wonju Severance Christian Hospital (CR322347) and adhered to the principles of the Declaration of Helsinki. Given the retrospective design of the study utilizing fully anonymized claims data provided by the National Health Insurance Service (NHIS) under strict privacy regulations, obtaining informed consent from participants, including minors under the age of 16, was not feasible. As such, the requirement for informed consent was waived by the Institutional Review Board in accordance with national regulations and institutional guidelines.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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