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Research article

National trends of allergic diseases and pandemic–related factors among individuals with obesity in South Korea: A nationwide representative serial study, 2005–2021

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ABSTRACT

Background: Although obesity is known to be related to allergic diseases, few studies have investigated the prevalence of allergic diseases in individuals with obesity, especially during the COVID–19 pandemic. Thus, this study aimed to analyze national trends of allergic diseases among individuals with obesity and sociodemographic factors.

Methods: This study used data from the Korea National Health and Nutrition Examination Survey to examine the prevalence of allergic diseases among individuals with obesity in South Korea from 2005 to 2021. A nationally representative sample of 118,275 participants aged over 2 years or above was divided into six groups for analysis. This study used weighted multivariate regression analysis to examine the estimates of related factors. It assessed the weighted odds ratios or β–coefficients for these factors across different categories, including age, sex, region of residence, education level, household income, and body mass index for the entire population.

Results: All allergic diseases showed a general upward trend from 2005 to 2021, but each disease showed different prevalence trends when compared by age. Before the pandemic, those aged ≤39 years had an increasing trend for asthma and AD, but those aged ≥40 years had a decreasing

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trend. For asthma, β–coefficients were 0.629 (95 % CI, 0.299 to 0.958) for 19–39 years, −0.245 (−0.450 to −0.040) for 40–59 years, and −0.668 (−1.024 to −0.313) for ≥60 years. For AD, β–coefficients were 2.514 (1.258–3.769) in those aged 2–18 years, 0.630 (0.173–1.086) in those aged 19–39 years, −0.458 (−0.648 to −0.268) in those aged 40–59 years, and −0.253 (−0.454 to −0.052) in those aged ≥60 years. However, for both asthma and AD, there were no significant changes in prevalence during the pandemic. In the case of AR, trends were different from those of asthma and AD. Before the pandemic, AR showed an increasing trend in those aged ≤39 years and those aged ≥40 years: β–coefficients were 3.067 (2.344–3.790) in 19–39 years, 2.051 (1.609–2.493) in 40–59 years, and 1.173 (0.820–1.526) in ≥60 years. During the pandemic, there was an increasing trend only among those aged 40–59, with no significant changes in other age groups: β–coefficients were 1.438 (0.065–2.811) in 40–59 years.

Conclusions: From 2005 to 2021, all allergic diseases (asthma, AD, and AR) increased overall, but with different age-related trends. No significant link was found between COVID–19 and allergic diseases, possibly due to preventive measures like mask-wearing and social distancing. Anxiety about accessing healthcare during the pandemic likely contributed to a decline in allergy diagnoses, highlighting the need for comprehensive strategies to manage and prevent allergic diseases.

1. Introduction

The prevalence of obesity and allergic diseases such as asthma, atopic dermatitis (AD), and allergic rhinitis (AR) is increasing in modern society [1–4]. Factors such as urbanization, lifestyle changes, and dietary habits primarily contribute to this trend [5,6]. Urbanization has led to increased consumption of high–calorie and convenient foods while reducing opportunities for physical activity [7]. These allergic diseases are associated with increased health problems [8]. Previous research indicates that obesity is associated with allergic diseases, which reduces the quality of life for individuals and increases the overall disease burden [9]. Moreover, it imposes a substantial strain on healthcare resources and social infrastructure [10].

The COVID-19 pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS–CoV–2) had a unique influence on health and disease patterns [11]. The pandemic has highlighted the complex interactions between factors related to allergic diseases [12–16]. Previous studies examining trends in allergic diseases have mostly focused on adolescents, and these studies have demonstrated an increase in allergic disease prevalence among adolescents before the pandemic, followed by a decrease during the pandemic [17–22]. However, there is a deficiency of comprehensive study that examines long-term trends in the prevalence of allergic diseases among individuals with obesity, including all age groups before and during the COVID-19 pandemic [23]. Therefore, this study aimed to investigate the long-term trends in the prevalence of allergic diseases in individuals with obesity. This study differentiated between the pre-pandemic period (2005–2019) and during the pandemic period (2020–2021), aiming to comprehensively assess the impact of new environmental changes on health status. Ultimately, statistical analyses were conducted over a 17-year period, including the COVID-19 pandemic [24–26], considering sociodemographic factors such as sex, age, region, and socioeconomic status. Through this analysis, we aimed to illustrate the association between obesity and allergic diseases and contribute to the effective management and prevention of these conditions by informing policy formulation.

2. Materials and methods

2.1. Patient selection and data collection

Our study used data from the Korea National Health and Nutrition Examination Survey (KNHANES) conducted by the Korea Disease Control and Prevention Agency (KDCA) from 2005 to 2021 [27,28]. The KNHANES utilized the latest population and housing census data during its sampling design to establish a comprehensive sampling frame, ensuring the random selection of a representative sample from the population aged 1 year or above residing in South Korea [29,30]. The dataset included age, sex, region of residence, body mass index (BMI), education level, household income, and history of allergic diseases, including asthma, AD, and AR.

A nationally representative sample of 118,275 participants aged ≥2 years was selected to compare the prevalence of allergic diseases before and during the COVID-19 pandemic. The survey was conducted over 17 years, with the following number of participants in each year group: 2005–2009: 29,831; 2010–2012: 23,372; 2013–2016: 28,927; 2017–2019: 22,683; 2020: 6917; and 2021: 6545. The categorization by year aligns with the sampling design principles of KNHANES, where 2020 and 2021 were specifically allocated for a deeper examination of the effects of the COVID-19 pandemic. Criteria for obesity were determined based on the BMI categories, including overweight and obese groups. The research protocol was approved by both the Institutional Review Board of Kyung Hee University (KHUH 2022–06–042) and the KDCA. Trained interviewers visited selected households to conduct interviews with household representatives and obtained written informed consent from all participants prior to their participation [31]. Additionally, KNHANES provides public access to its data, which is a valuable resource for a diverse range of epidemiological inquiries.

2.2. Ascertainment of allergic diseases

This study aimed to ascertain the prevalence of allergic diseases, including asthma, AD, and AR, over 17 years, from 2005 to 2021. We conducted a comprehensive survey using a large sample size to achieve this objective. In the survey conducted by KNHANES regarding the diagnosis of allergic diseases, participants were asked whether they had ever been diagnosed with each allergic disease in their lifetime by a doctor. Based on these responses, the presence or absence of allergic diseases was determined. Additionally, data collection was conducted based on responses regarding potential risk factors for the onset of allergic diseases, including age, sex, and socioeconomic status [29,32].

2.3. Covariates

The covariates considered in this study included age groups (2–18, 19–39, 40–59, and ≥60 years), sex, region of residence (urban and rural), BMI group (underweight, normal weight, overweight, and obese), educational level (elementary school or lower, middle school, high school, and college or higher education), and household income (lowest, second, third, and highest quartiles). Region of residence was categorized into urban and rural areas based on survey responses of participants. Household income was stratified into 4 quartiles according to the standard income quartiles of the sample household and population data provided by KNHANES. BMI categories were classified according to the Asian–Pacific guidelines into four groups: underweight (<18.5 kg/m^2), normal weight (18.5–22.9 kg/m^2), overweight (23.0–24.9 kg/m^2), and obese (≥25.0 kg/m^2) [33,34].

2.4. Statistical analyses

The results of our study are presented through the examination of survey–reported data expressed as proportions or percentages. Weighted multivariate regression model analyses were conducted with weighted odds ratios (ORs) and 95 % confidence intervals (CIs) to analyze and compare the estimates of each related factor before and during the COVID–19 pandemic [35,36]. The prevalence of allergic diseases was calculated by analyzing data from the KNHANES from 2005 to 2021 and stratifying the data by year. A weighted complex sampling analysis was used to ensure accurate estimation. Binomial or linear logistic regression models were utilized to calculate the ORs with 95 % CIs or β–coefficients with 95 % CIs. Stratification analysis was conducted to ensure an accurate estimation, considering age, sex, region of residence, BMI, education level, and household income in all regression models. Furthermore, the ratio of ORs was calculated to estimate the interaction term of each risk factor and identify groups more vulnerable to allergic diseases for each variable. This study aimed to compare annual changes before and during the pandemic to evaluate the impact of the COVID-19 pandemic on the prevalence of allergic diseases. The SAS software (version 9.4; SAS Institute, Cary, NC, USA) was used for statistical analyses with a two–sided test. $P \leq 0.05$ was considered statistically significant [37–39].

3. Results

Our study aimed to investigate the changes in the prevalence of allergic diseases among individuals with obesity from 2005 to 2021 by utilizing data from KNHANES. To accomplish this, we included a total of 118,275 participants for analysis after excluding 33,987 individuals with missing household income, BMI, and weight data from the total sample of 152,262 survey respondents from 2005 to 2021 (Fig. 1). The demographic characteristics of the participants are summarized as follows: age (2–18 years, 18.36 % [95 % CI, 18.04–18.68]; 19–39 years, 30.87 % [30.40–31.35]; 40–59 years, 32.42 % [32.06–32.78]; and ≥60 years, 18.34 % [17.93–18.75]) and sex (male, 50.02 % [49.74–50.30]; female, 49.98 % [49.70–50.26]). Table 1 shows the baseline characteristics of the study population regarding weighted rates.

Fig. 2 shows the prevalence of asthma, AD, and AR in individuals with obesity compared to that of the overall population. All three

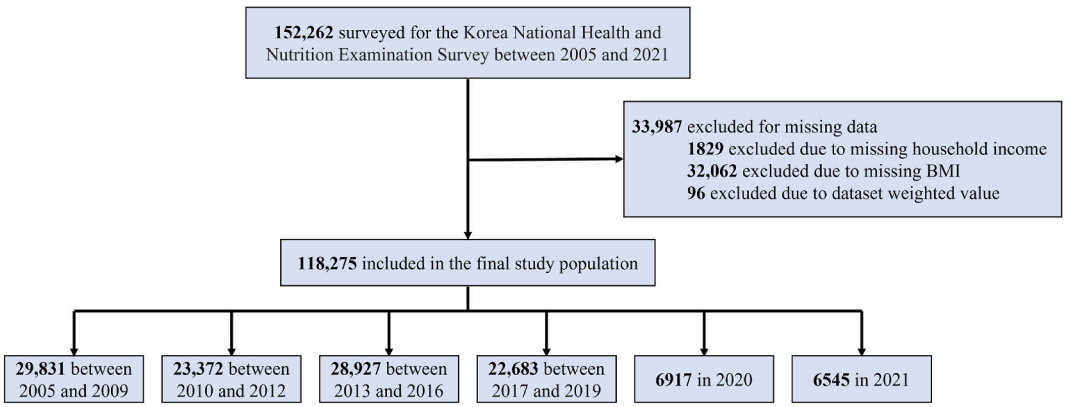

Fig. 1. Study population. BMI, body mass index.

Table 1
Weighted characteristics of Koreans based on data obtained from the KNHANES from 2005 to 2021 (n = 118,275).

	Total	2005–2009	2010–2012	2013–2016	2017–2019	2020	2021
Overall, n	118,275	29,831	23,372	28,927	22,683	6917	6545
Age (years), weighted % (95 % CI)							
2–18	18.36 (18.04–18.68)	22.46 (21.82–23.09)	19.90 (19.11–20.68)	17.63 (17.03–18.22)	16.11 (15.33–16.88)	14.93 (13.53–16.34)	14.47 (13.02–15.91)
19–39	30.87 (30.40–31.35)	32.84 (31.86–33.83)	31.95 (30.81–33.09)	30.69 (29.77–31.62)	29.50 (28.44–30.57)	29.00 (27.01–30.98)	28.41 (26.51–30.32)
40–59	32.42 (32.06–32.78)	30.20 (29.40–31.01)	31.97 (31.19–32.75)	33.33 (32.60–34.06)	33.42 (32.60–34.24)	33.32 (31.72–34.92)	32.98 (31.68–34.28)
≥60	18.34 (17.93–18.75)	14.50 (13.84–15.16)	16.19 (15.36–17.01)	18.35 (17.55–19.15)	20.97 (19.78–22.16)	22.75 (20.49–25.01)	24.14 (21.93–26.36)
Sex, weighted % (95 % CI)							
Male	50.02 (49.74–50.30)	49.61 (49.08–50.15)	50.11 (49.45–50.77)	50.03 (49.47–50.59)	50.16 (49.49–50.84)	50.39 (49.38–51.41)	50.17 (48.92–51.42)
Female	49.98 (49.70–50.26)	50.39 (49.85–50.92)	49.89 (49.23–50.55)	49.97 (49.41–50.53)	49.84 (49.16–50.51)	49.61 (48.59–50.62)	49.83 (48.58–51.08)
Region of residence, weighted % (95 % CI)							
Urban	82.73 (81.44–84.02)	80.91 (78.37–83.45)	80.41 (77.11–83.70)	82.95 (80.38–85.52)	85.06 (82.09–88.03)	85.29 (80.24–90.34)	84.49 (79.51–89.48)
Rural	17.27 (15.98–18.56)	19.09 (16.55–21.63)	19.59 (16.30–22.89)	17.05 (14.48–19.62)	14.94 (11.97–17.91)	14.71 (9.66–19.76)	15.51 (10.52–20.49)
BMI group[a], weighted % (95 % CI)							
Underweight	13.32 (13.05–13.58)	15.79 (15.23–16.35)	14.15 (13.58–14.71)	13.05 (12.51–13.58)	11.89 (11.27–12.51)	10.98 (9.86–12.09)	11.01 (9.89–12.13)
Normal weight	37.67 (37.32–38.02)	37.96 (37.31–38.60)	39.05 (38.18–39.92)	37.81 (37.14–38.49)	37.70 (36.94–38.46)	33.95 (32.49–35.41)	35.86 (34.31–37.40)
Overweight	19.98 (19.70–20.26)	20.09 (19.56–20.61)	19.60 (18.96–20.24)	20.14 (19.58–20.71)	19.86 (19.20–20.52)	20.79 (19.67–21.91)	19.62 (18.35–20.89)
Obese	29.03 (28.68–29.38)	26.17 (25.52–26.82)	27.20 (26.40–27.99)	29.00 (28.29–29.70)	30.54 (29.73–31.36)	34.29 (32.83–35.75)	33.52 (31.88–35.16)
Level of education, weighted % (95 % CI)							
Elementary school or lower education	12.40 (12.08–12.72)	17.30 (16.58–18.03)	13.85 (13.06–14.64)	11.47 (10.85–12.09)	9.94 (9.15–10.72)	7.80 (6.61–8.98)	8.89 (7.60–10.18)
Middle school	10.61 (10.39–10.84)	12.80 (12.31–13.29)	11.91 (11.39–12.43)	10.02 (9.61–10.44)	9.23 (8.72–9.75)	8.58 (7.66–9.50)	8.66 (7.78–9.54)
High school	26.55 (26.16–26.94)	28.89 (28.14–29.65)	27.82 (26.89–28.75)	25.30 (24.52–26.08)	25.20 (24.30–26.11)	25.34 (23.72–26.96)	26.02 (24.36–27.67)
College or higher education	36.63 (36.08–37.19)	30.41 (29.36–31.46)	33.39 (32.14–34.63)	36.26 (35.18–37.33)	41.98 (40.59–43.37)	43.45 (40.80–46.09)	43.76 (41.29–46.23)
Unknown	13.80 (13.49–14.10)	10.59 (10.11–11.07)	13.03 (12.42–13.64)	16.95 (16.26–17.64)	13.65 (12.89–14.41)	14.84 (13.41–16.26)	12.67 (11.41–13.93)
Household income, weighted % (95 % CI)							
Lowest quartile	14.94 (14.49–15.40)	15.80 (14.87–16.74)	15.77 (14.69–16.84)	14.95 (14.00–15.90)	14.46 (13.36–15.56)	13.43 (11.35–15.50)	12.84 (10.97–14.71)
Second quartile	25.47 (24.90–26.03)	25.41 (24.29–26.54)	28.06 (26.68–29.44)	25.01 (23.89–26.12)	25.08 (23.80–26.36)	23.02 (20.80–25.23)	23.59 (21.29–25.89)
Third quartile	29.73 (29.18–30.29)	29.51 (28.40–30.62)	29.27 (28.04–30.51)	30.16 (28.97–31.35)	29.30 (28.12–30.48)	30.23 (28.02–32.45)	30.92 (28.64–33.20)
Highest quartile	29.86 (29.10–30.61)	29.28 (27.68–30.87)	26.90 (25.43–28.37)	29.88 (28.30–31.46)	31.16 (29.39–32.94)	33.32 (29.92–36.72)	32.65 (28.86–36.44)

Abbreviations: BMI, body mass index; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.
[a]According to the Asian–Pacific guidelines, the BMI is divided into four groups: underweight (<18.5 kg/m^2), normal (18.5–22.9 kg/m^2), overweight (23.0–24.9 kg/m^2), and obese (≥25.0 kg/m^2).

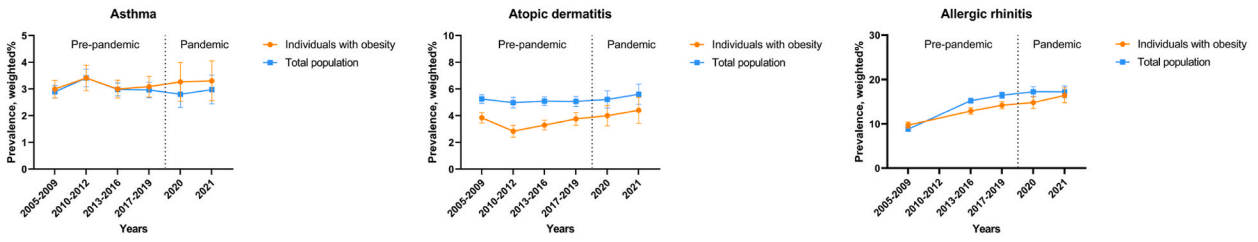

Fig. 2. Nationwide trends of allergic disease prevalence over 17 years among 118,275 Korean population and individuals with obesity, stratified by asthma, atopic dermatitis, and allergic rhinitis, 2005–2021.

Table 2
National trends in the prevalence of asthma, atopic dermatitis, and allergic rhinitis among individuals with obesity and difference of β–coefficients between before and during the COVID–19 pandemic (weighted % [95 % CI]) based on data obtained from the KNHANES.

Year	Before the pandemic				During the pandemic		Trends before the pandemic era, β (95 % CI)		Trends during the pandemic era, β (95 % CI)		β_{diff} between 2005–2019 and 2019–2021 (95 % CI)	
	2005–2009	2010–2012	2013–2016	2017–2019	2020	2021						
Asthma							β (95 % CI)	P-value	β (95 % CI)	P-value	β_{diff} (95 % CI)	P-value
Overall	3.00 (2.67–3.32)	3.41 (2.94–3.89)	3.00 (2.66–3.33)	3.09 (2.70–3.48)	3.27 (2.54–3.99)	3.31 (2.56–4.05)	−0.010 (−0.170 to 0.150)	0.899	0.103 (−0.323 to 0.529)	0.635	0.113 (−0.341 to 0.568)	0.625
Age group												
2–18	3.42 (2.12–4.71)	6.81 (4.47–9.14)	4.61 (2.95–6.26)	3.75 (1.91–5.59)	4.95 (1.67–8.24)	4.71 (0.00–9.53)	0.055 (−0.654 to 0.765)	0.879	0.432 (−2.242 to 3.107)	0.751	0.377 (−2.390 to 3.144)	0.789
19–39	1.92 (1.35–2.50)	3.03 (2.18–3.88)	3.02 (2.31–3.74)	4.05 (3.13–4.97)	4.25 (2.57–5.92)	3.12 (1.49–4.75)	**0.629 (0.299 to 0.958)**	**<0.001**	−0.508 (−1.468 to 0.452)	0.299	**−1.137 (–2.151 to –0.122)**	**0.028**
40–59	2.36 (1.90–2.81)	2.23 (1.64–2.83)	1.78 (1.37–2.19)	1.71 (1.27–2.15)	2.18 (1.16–3.19)	2.52 (1.52–3.52)	**−0.245 (–0.450 to –0.040)**	**0.019**	0.401 (−0.167 to 0.968)	0.167	**0.645 (0.042 to 1.249)**	**0.036**
≥60	6.04 (5.20–6.88)	5.36 (4.42–6.31)	4.71 (3.99–5.43)	4.03 (3.30–4.76)	3.51 (2.37–4.65)	4.30 (3.13–5.47)	**−0.668 (–1.024 to –0.313)**	**<0.001**	0.185 (−0.530 to 0.899)	0.612	**0.853 (0.055 to 1.651)**	**0.036**
Sex												
Male	2.31 (1.91–2.72)	2.95 (2.35–3.56)	2.24 (1.81–2.66)	2.93 (2.40–3.45)	3.43 (2.44–4.41)	2.76 (1.78–3.75)	0.096 (−0.111 to 0.303)	0.362	−0.122 (−0.697 to 0.453)	0.678	−0.218 (−0.829 to 0.393)	0.484
Female	3.85 (3.33–4.37)	3.99 (3.29–4.69)	4.01 (3.49–4.53)	3.33 (2.77–3.88)	3.03 (2.04–4.02)	4.12 (3.03–5.20)	−0.119 (−0.362 to 0.124)	0.337	0.436 (−0.189 to 1.062)	0.171	0.556 (−0.115 to 1.227)	0.105
Region of residence												
Urban	2.86 (2.49–3.24)	3.61 (3.04–4.18)	3.00 (2.62–3.38)	3.00 (2.59–3.42)	3.24 (2.43–4.05)	3.37 (2.52–4.23)	−0.006 (−0.186 to 0.174)	0.948	0.180 (−0.303 to 0.663)	0.464	0.186 (−0.329 to 0.702)	0.479
Rural	3.53 (2.90–4.17)	2.66 (1.94–3.39)	2.98 (2.31–3.66)	3.53 (2.53–4.53)	3.41 (1.91–4.90)	2.99 (1.67–4.30)	−0.027 (−0.378 to 0.325)	0.882	−0.281 (−1.114 to 0.552)	0.508	−0.254 (−1.158 to 0.649)	0.581
Education												
High school or lower education	3.48 (3.10–3.87)	3.80 (3.20–4.39)	3.61 (3.14–4.08)	3.07 (2.57–3.56)	3.99 (2.90–5.09)	3.68 (2.67–4.68)	−0.101 (−0.301 to 0.098)	0.319	0.270 (−0.299 to 0.839)	0.352	0.371 (−0.232 to 0.974)	0.228
College or higher education	1.99 (1.44–2.53)	2.79 (2.07–3.52)	2.75 (2.14–3.35)	3.35 (2.68–4.02)	3.09 (1.96–4.21)	3.34 (2.10–4.57)	**0.402 (0.128 to 0.677)**	**0.004**	0.012 (−0.712 to 0.735)	0.975	−0.391 (−1.165 to 0.383)	0.323
Household income												
Lowest and second quartile	3.85 (3.31–4.39)	4.01 (3.35–4.67)	3.33 (2.81–3.85)	3.33 (2.76–3.90)	4.15 (2.96–5.34)	3.77 (2.68–4.86)	−0.230 (−0.480 to 0.020)	0.072	0.190 (−0.434 to 0.815)	0.549	0.420 (−0.252 to 1.092)	0.221
Third and highest quartile	2.36 (1.97–2.76)	2.95 (2.30–3.61)	2.76 (2.31–3.22)	2.93 (2.43–3.44)	2.76 (1.92–3.60)	3.03 (2.00–4.05)	0.158 (−0.046 to 0.362)	0.128	0.064 (−0.526 to 0.654)	0.831	−0.094 (−0.718 to 0.530)	0.767
Atopic dermatitis												
Overall	3.84 (3.46–4.23)	2.84 (2.40–3.28)	3.30 (2.93–3.66)	3.76 (3.28–4.24)	4.00 (3.23–4.77)	4.40 (3.43–5.38)	−0.019 (−0.208 to 0.170)	0.842	0.328 (−0.228 to 0.883)	0.248	0.347 (−0.240 to 0.934)	0.247
Age group												

(*continued on next page*)

Table 2 (*continued*)

Atopic dermatitis												
Overall	3.84 (3.46–4.23)	2.84 (2.40–3.28)	3.30 (2.93–3.66)	3.76 (3.28–4.24)	4.00 (3.23–4.77)	4.40 (3.43–5.38)	−0.019 (−0.208 to 0.170)	0.842	0.328 (−0.228 to 0.883)	0.248	0.347 (−0.240 to 0.934)	0.247
2–18	9.34 (7.08–11.61)	9.43 (6.71–12.16)	14.74 (12.01–17.47)	15.94 (12.45–19.43)	13.49 (8.62–18.36)	17.10 (9.10–25.10)	**2.514 (1.258 to 3.769)**	**<0.001**	0.777 (−3.829 to 5.384)	0.741	−1.736 (−6.511 to 3.038)	0.476
19–39	5.17 (4.34–6.01)	4.95 (3.74–6.16)	5.67 (4.74–6.60)	7.29 (6.04–8.54)	7.97 (6.02–9.91)	9.53 (6.91–12.15)	**0.630 (0.173 to 1.086)**	**0.007**	1.150 (−0.348 to 2.648)	0.132	0.521 (−1.045 to 2.086)	0.515
40–59	2.66 (2.21–3.12)	1.32 (0.86–1.77)	1.13 (0.79–1.47)	1.37 (0.97–1.77)	1.94 (0.98–2.89)	1.52 (0.73–2.30)	**−0.458 (–0.648 to –0.268)**	**<0.001**	0.048 (−0.404 to 0.500)	0.835	**0.506 (0.015 to 0.996)**	**0.043**
≥60	2.24 (1.72–2.76)	0.86 (0.51–1.21)	1.40 (1.02–1.78)	1.23 (0.82–1.63)	1.01 (0.42–1.59)	0.75 (0.31–1.19)	**−0.253 (–0.454 to –0.052)**	**0.014**	−0.240 (−0.543 to 0.063)	0.121	0.013 (−0.351 to 0.377)	0.944
Sex												
Male	3.69 (3.14–4.25)	3.14 (2.47–3.81)	3.71 (3.16–4.25)	4.26 (3.57–4.95)	4.11 (3.06–5.16)	4.58 (3.24–5.93)	0.199 (−0.074 to 0.473)	0.153	0.186 (−0.585 to 0.958)	0.636	−0.013 (−0.831 to 0.805)	0.975
Female	4.03 (3.48–4.58)	2.46 (1.92–3.00)	2.75 (2.28–3.23)	3.06 (2.45–3.66)	3.84 (2.53–5.16)	4.13 (2.73–5.54)	**−0.322 (–0.575 to –0.068)**	**0.013**	0.524 (−0.264 to 1.311)	0.192	**0.846 (0.018 to 1.673)**	**0.045**
Region of residence												
Urban	4.05 (3.60–4.50)	3.06 (2.54–3.59)	3.43 (3.01–3.85)	4.05 (3.51–4.59)	4.34 (3.46–5.22)	4.55 (3.48–5.62)	−0.005 (−0.222 to 0.212)	0.961	0.250 (−0.363 to 0.863)	0.424	0.255 (−0.395 to 0.905)	0.442
Rural	3.02 (2.30–3.75)	1.97 (1.22–2.72)	2.71 (1.99–3.44)	2.29 (1.46–3.12)	2.15 (0.84–3.46)	3.68 (1.43–5.92)	−0.150 (−0.489 to 0.190)	0.388	0.752 (−0.510 to 2.013)	0.243	0.901 (−0.405 to 2.208)	0.176
Education												
High school or lower education	3.41 (2.98–3.84)	2.14 (1.70–2.58)	2.59 (2.19–2.99)	3.03 (2.49–3.56)	3.03 (2.12–3.94)	3.25 (2.13–4.37)	−0.147 (−0.355 to 0.062)	0.168	0.117 (−0.528 to 0.763)	0.722	0.264 (−0.414 to 0.942)	0.446
College or higher education	4.42 (3.66–5.19)	4.03 (3.06–5.00)	4.82 (4.00–5.63)	4.86 (4.04–5.68)	5.33 (3.95–6.72)	6.03 (4.31–7.74)	0.211 (−0.148 to 0.569)	0.249	0.590 (−0.387 to 1.568)	0.236	0.380 (−0.661 to 1.421)	0.475
Household income												
Lowest and second quartile	3.64 (3.10–4.17)	2.64 (1.97–3.31)	2.97 (2.44–3.49)	3.46 (2.83–4.09)	3.51 (2.31–4.70)	3.82 (2.55–5.08)	−0.067 (−0.327 to 0.193)	0.615	0.185 (−0.550 to 0.920)	0.621	0.252 (−0.528 to 1.031)	0.526
Third and highest quartile	4.00 (3.45–4.55)	2.99 (2.38–3.60)	3.54 (3.02–4.05)	3.96 (3.32–4.61)	4.29 (3.26–5.32)	4.76 (3.35–6.17)	0.008 (−0.254 to 0.271)	0.950	0.404 (−0.395 to 1.204)	0.321	0.396 (−0.446 to 1.237)	0.356
Allergic rhinitis												
Overall	9.73 (9.05–10.40)	N/A	12.89 (12.18–13.61)	14.19 (13.38–15.00)	14.81 (13.44–16.19)	16.42 (14.75–18.10)	**2.461 (2.131 to 2.790)**	**<0.001**	**1.146 (0.191 to 2.102)**	**0.019**	**−1.314 (–2.325 to –0.304)**	**0.011**
Age group												

(*continued on next page*)

Table 2 (*continued*)

Allergic rhinitis												
Overall	9.73 (9.05–10.40)	N/A	12.89 (12.18–13.61)	14.19 (13.38–15.00)	14.81 (13.44–16.19)	16.42 (14.75–18.10)	**2.461 (2.131 to 2.790)**	**<0.001**	**1.146 (0.191 to 2.102)**	**0.019**	**−1.314 (–2.325 to –0.304)**	**0.011**
2–18	N/A	N/A	23.45 (19.95–26.96)	26.17 (21.68–30.67)	26.00 (19.71–32.29)	30.48 (20.24–40.71)	2.717 (−2.969 to 8.404)	0.349	2.303 (−3.450 to 8.056)	0.432	−0.414 (−8.503 to 7.675)	0.920
19–39	15.70 (14.31–17.10)	N/A	18.80 (17.24–20.37)	21.28 (19.40–23.16)	20.36 (16.96–23.77)	23.05 (19.38–26.72)	**3.067 (2.344 to 3.790)**	**<0.001**	1.003 (−1.095 to 3.101)	0.348	−2.064 (−4.283 to 0.155)	0.068
40–59	8.95 (8.04–9.86)	N/A	11.19 (10.19–12.19)	12.62 (11.52–13.71)	14.83 (12.66–17.01)	15.57 (13.15–17.99)	**2.051 (1.609 to 2.493)**	**<0.001**	**1.438 (0.065 to 2.811)**	**0.040**	−0.613 (−2.055 to 0.829)	0.405
≥60	4.64 (3.87–5.41)	N/A	5.95 (5.18–6.72)	6.55 (5.71–7.39)	6.65 (5.23–8.08)	8.27 (6.50–10.04)	**1.173 (0.820 to 1.526)**	**<0.001**	0.918 (−0.097 to 1.934)	0.076	−0.254 (−1.329 to 0.821)	0.643
Sex												
Male	9.30 (8.40–10.20)	N/A	12.46 (11.47–13.46)	13.68 (12.60–14.76)	13.93 (12.22–15.65)	16.90 (14.70–19.09)	**2.427 (1.988 to 2.865)**	**<0.001**	**1.701 (0.438 to 2.963)**	**0.008**	−0.726 (−2.062 to 0.610)	0.287
Female	10.25 (9.33–11.17)	N/A	13.47 (12.52–14.41)	14.91 (13.75–16.08)	16.14 (14.00–18.27)	15.71 (13.67–17.75)	**2.524 (2.071 to 2.977)**	**<0.001**	0.353 (−0.851 to 1.557)	0.565	**−2.171 (–3.457 to –0.885)**	**0.001**
Region of residence												
Urban	10.24 (9.47–11.02)	N/A	13.61 (12.81–14.42)	14.60 (13.70–15.50)	15.20 (13.65–16.75)	17.65 (15.83–19.46)	**2.514 (2.139 to 2.888)**	**<0.001**	**1.581 (0.533 to 2.629)**	**0.003**	−0.933 (−2.046 to 0.180)	0.100
Rural	7.64 (6.21–9.07)	N/A	9.74 (8.24–11.24)	12.12 (10.08–14.16)	12.69 (9.28–16.10)	10.49 (7.23–13.74)	**2.066 (1.279 to 2.854)**	**<0.001**	−0.909 (−2.916 to 1.098)	0.374	**−2.975 (–5.131 to –0.820)**	**0.007**
Education												
High school or lower education	7.56 (6.85–8.26)	N/A	10.78 (9.94–11.62)	11.87 (10.83–12.90)	12.75 (11.05–14.45)	14.09 (11.80–16.39)	**2.082 (1.702 to 2.462)**	**<0.001**	1.126 (−0.144 to 2.395)	0.082	−0.957 (−2.282 to 0.368)	0.157
College or higher education	14.48 (13.01–15.96)	N/A	18.64 (17.26–20.01)	18.40 (17.00–19.79)	18.81 (16.56–21.05)	20.11 (17.54–22.68)	**3.033 (2.397 to 3.669)**	**<0.001**	0.890 (−0.638 to 2.418)	0.253	**−2.143 (–3.798 to –0.488)**	**0.011**
Household income												
Lowest and second quartile	8.25 (7.37–9.13)	N/A	11.48 (10.46–12.50)	12.56 (11.32–13.80)	11.53 (9.62–13.44)	12.65 (10.31–15.00)	**2.308 (1.844 to 2.773)**	**<0.001**	0.099 (−1.248 to 1.446)	0.885	**−2.209 (–3.634 to –0.785)**	**0.002**
Third and highest quartile	10.82 (9.90–11.75)	N/A	13.91 (12.94–14.89)	15.30 (14.22–16.38)	16.70 (14.78–18.62)	18.71 (16.48–20.93)	**2.541 (2.097 to 2.986)**	**<0.001**	**1.726 (0.440 to 3.013)**	**0.009**	−0.815 (−2.176 to 0.546)	0.241

Abbreviations: BMI, body mass index; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey.
The numbers in bold indicate significant differences ($p < 0.05$).

allergic diseases showed a general upward trend from 2005 to 2021. First, the weighted prevalence of asthma increased from 3.00 % (95 % CI, 2.67–3.32) in 2005–2009 to 3.09 % (2.70–3.48) in 2017–2019, 3.27 % (2.54–3.99) in 2020, and 3.31 % (2.56–4.05) in 2021. Second, the weighted prevalence of AD was 3.84 % (3.46–4.23) in 2005–2009, 3.76 % (3.28–4.24) in 2017–2019, and increased to 4.00 % (3.23–4.77) in 2020, and 4.40 % (3.43–5.38) in 2021. Third, the weighted prevalence of AR increased from 9.73 % (9.05–10.40) in 2005–2009 to 14.19 % (13.38–15.00) in 2017–2019, 14.81 % (13.44–16.19) in 2020, and 16.42 % (14.75–18.10) in 2021. The prevalence of allergic diseases in the total population, including individuals with obesity, is shown in Table S1.

Table 2 shows the prevalence of the three allergic diseases, including demographic factors, before and during the pandemic. For individuals with obesity, the three diseases showed similar upward trends over the entire study period; however, there were subtle differences between diseases when comparing the age groups. Before the pandemic, those aged ≤39 years had an increasing trend for asthma and AD, but those aged ≥40 years had a decreasing trend. For asthma, β–coefficients were 0.629 (95 % CI, 0.299 to 0.958) for 19–39 years, −0.245 (−0.450 to −0.040) for 40–59 years, and −0.668 (−1.024 to −0.313) for ≥60 years. For AD, β–coefficients were 2.514 (1.258–3.769) in those aged 2–18 years, 0.630 (0.173–1.086) in those aged 19–39 years, −0.458 (−0.648 to −0.268) in those aged 40–59 years, and −0.253 (−0.454 to −0.052) in those aged ≥60 years. However, for both asthma and AD, there were no significant changes in prevalence during the pandemic. In the case of AR, trends were different from those of asthma and AD. Before the pandemic, AR showed an increasing trend in those aged ≤39 years and those aged ≥40 years: β–coefficients were 3.067 (2.344–3.790) in 19–39 years, 2.051 (1.609–2.493) in 40–59 years, and 1.173 (0.820–1.526) in ≥60 years. During the pandemic, there was an increasing trend only among those aged 40–59, with no significant changes in other age groups: β–coefficients were 1.438 (0.065–2.811) in 40–59 years. The results of segmenting the overall period into specific intervals and comparing trends for each year are shown in Table S2.

Table 3 provides information on the change in each allergic disease with weighted OR (95 % CI) to assess the impact of the COVID–19 pandemic. After analyzing the data, we found that the overall prevalence of asthma, AD, and AR remained stable during the pandemic, indicating no significant changes in the prevalence of allergic diseases among individuals with obesity. When stratified by age group, sex, region of residence, education level, and household income, the prevalence of allergic diseases did not differ significantly among most subgroups. A significant increase in the prevalence of AR was observed in the urban population with an OR of 1.20 (95 % CI, 1.01–1.42), and a significant increase in the prevalence of asthma was noted in males with an OR of 1.26 (1.02–1.55). However, there were exceptions as in most cases, the differences were not statistically significant.

4. Discussion

4.1. Key findings

We analyzed the trends of allergic disease prevalence, including those of asthma, AD, and AR, before and during the COVID–19 pandemic using data from the KNHANES database, a nationally representative survey of over 118,275 South Koreans conducted from 2005 to 2021. The prevalence of all three allergic diseases showed an upward trend among individuals with obesity during the entire study period. However, age–specific differences were observed in the prevalence of each disease. Before the pandemic, the prevalence of asthma and AD showed a tendency of increase in those aged ≤39 years and decrease in those aged ≥40 years, but the prevalence of AR tended to increase in all age groups. During the pandemic, Asthma and AD showed no significant trend change across all ages, but AR showed an increasing trend among those aged 40–59 years. To investigate the impact of the COVID–19 pandemic, we compared the prevalence of before and during the pandemic and found no significant association.

4.2. Plausible underlying mechanisms

During the study period of 2005–2021, all three allergic diseases showed an upward trend. Previous studies have shown that various environmental pollutants, lifestyle changes, and genetic factors can positively impact the occurrence and prevalence of each allergic disease [40–42]. Therefore, this upward trend is likely attributed to various environmental factors.

We observed some differences when the three allergic diseases were compared by age. Before the pandemic, asthma and AD tended to increase in those aged ≤39 years and decrease in those aged ≥40 years, with no significant changes seen during the pandemic. The observed age-related trends are likely associated with hormonal shifts, lifestyle alternations, and immune system changes that commonly occur with aging [43–45]. However, AR showed an increasing trend regardless of age before the pandemic, and an increasing trend was shown among people aged 40–59 during the pandemic. This suggests that the etiology and pathogenesis are more complex compared to other allergic diseases [46,47].

To evaluate the impact of the COVID–19 pandemic, we compared the prevalence of allergic diseases before and during the pandemic and found no significant correlation. This suggests that several preventive measures during the pandemic, such as mask wearing and social distancing, reduced exposure to microorganisms or allergens, which might have affected the prevalence of allergic diseases [48]. Additionally, people were hesitant to seek medical attention during the pandemic out of fear of infection [49]. This reluctance reduced the frequency of allergic disease diagnoses compared to the period before the pandemic.

4.3. Clinical and policy implications

Previous studies have shown that obesity is a major metabolic disease that occurs with several allergic diseases [50,51]. Therefore, it is important to uncover the association between obesity and allergic diseases, prompting numerous studies in this area. The overall

Table 3
Changes in asthma, atopic dermatitis, and allergic rhinitis prevalence among individuals with obesity between before and during the COVID–19 pandemic (weighted % [95 % CI]) based on data obtained from the KNHANES.

	Asthma				Atopic dermatitis				Allergic rhinitis			
	2020 versus 2017–2019 (reference)		2021 versus 2020 (reference)		2020 versus 2017–2019 (reference)		2021 versus 2020 (reference)		2020 versus 2017–2019 (reference)		2021 versus 2020 (reference)	
	Weighted OR (95 % CI)	P–value	Weighted OR (95 % CI)	P–value	Weighted OR (95 % CI)	P–value	Weighted OR (95 % CI))	P–value	Weighted OR (95 % CI)	P–value	Weighted OR (95 % CI)	P–value
Overall	1.06 (0.82–1.37)	0.664	1.01 (0.74–1.39)	0.940	1.07 (0.84–1.36)	0.597	1.11 (0.82–1.50)	0.517	1.05 (0.92–1.20)	0.448	1.13 (0.96–1.33)	0.142
Age group												
2–18	1.34 (0.56–3.18)	0.510	0.95 (0.27–3.35)	0.934	0.82 (0.51–1.34)	0.431	1.32 (0.65–2.69)	0.439	0.99 (0.66–1.50)	0.966	1.25 (0.70–2.22)	0.450
19–39	1.05 (0.66–1.68)	0.832	0.73 (0.37–1.41)	0.345	1.10 (0.80–1.53)	0.562	1.22 (0.82–1.82)	0.336	0.95 (0.75–1.19)	0.639	1.17 (0.88–1.56)	0.279
40–59	1.28 (0.75–2.19)	0.371	1.16 (0.62–2.17)	0.638	1.42 (0.80–2.53)	0.232	0.78 (0.38–1.59)	0.494	1.21 (0.99–1.47)	0.061	1.06 (0.82–1.36)	0.654
≥60	0.87 (0.59–1.28)	0.470	1.24 (0.79–1.94)	0.357	0.82 (0.41–1.65)	0.574	0.74 (0.32–1.75)	0.496	1.02 (0.78–1.33)	0.901	1.26 (0.91–1.75)	0.156
Sex												
Male	1.18 (0.83–1.67)	0.357	0.80 (0.50–1.27)	0.346	0.96 (0.70–1.32)	0.817	1.12 (0.75–1.68)	0.576	1.02 (0.86–1.21)	0.807	**1.26 (1.02 to 1.55)**	**0.031**
Female	0.91 (0.62–1.32)	0.616	1.38 (0.89–2.12)	0.150	1.27 (0.84–1.91)	0.253	1.08 (0.66–1.77)	0.765	1.10 (0.91–1.32)	0.327	0.97 (0.77–1.21)	0.783
Region of residence												
Urban	1.08 (0.81–1.45)	0.595	1.04 (0.73–1.49)	0.823	1.07 (0.83–1.39)	0.580	1.05 (0.76–1.45)	0.755	1.05 (0.91–1.20)	0.507	**1.20 (1.01 to 1.42)**	**0.041**
Rural	0.96 (0.56–1.65)	0.894	0.87 (0.46–1.65)	0.675	0.94 (0.46–1.91)	0.863	1.74 (0.72–4.22)	0.222	1.05 (0.73–1.51)	0.776	0.81 (0.51–1.28)	0.363
Education												
High school or lower education	1.31 (0.95–1.82)	0.102	0.92 (0.62–1.36)	0.667	1.00 (0.70–1.44)	0.988	1.07 (0.67–1.73)	0.771	1.09 (0.90–1.31)	0.382	1.12 (0.88–1.43)	0.345
College or higher education	0.92 (0.60–1.41)	0.698	1.08 (0.64–1.83)	0.766	1.10 (0.80–1.52)	0.553	1.14 (0.76–1.70)	0.526	1.03 (0.87–1.22)	0.758	1.09 (0.88–1.35)	0.451
Household income												
Lowest and second quartile	1.26 (0.89–1.78)	0.193	0.91 (0.60–1.37)	0.637	1.01 (0.68–1.52)	0.947	1.09 (0.67–1.79)	0.726	0.91 (0.73–1.13)	0.390	1.11 (0.84–1.48)	0.463
Third and highest quartile	0.94 (0.66–1.34)	0.732	1.10 (0.70–1.74)	0.684	1.09 (0.80–1.47)	0.592	1.12 (0.75–1.66)	0.588	1.11 (0.95–1.30)	0.202	1.15 (0.94–1.40)	0.176

Abbreviations: BMI, body mass index; CI, confidence interval; KNHANES, Korea National Health and Nutrition Examination Survey; OR, odds ratio.
The numbers in bold indicate significant differences ($p < 0.05$).

increasing trend of allergic diseases in our study highlights the need to manage and prevent these diseases. Therefore, more effective prevention programs and environmental responses are needed, including reducing environmental pollution, encouraging healthy lifestyles, and developing personal and public health policies. Additionally, age–specific diagnosis and management policies are needed, as different patterns of allergic diseases are observed in different age groups. Specifically, in the case of AR, the disease prevalence tended to increase in the ≥40 years age group; therefore, age–related factors must be assessed to adjust management practices and develop better treatment options. Finally, understanding the prevalence of allergic diseases in pandemic situations such as COVID–19 warrants further research to help assess the health impact of another pandemic and develop response strategies.

4.4. Strengths and limitations

Several limitations of this study lie in the inherent characteristics of the KNHANES database. First, although we aimed to analyze the correlation between allergic diseases and childhood obesity, we lacked data on infants and children aged 0–2 years, which prevented us from gaining important insights into the prevalence and trends in this age group. Second, data for ages 2–18 in the 2005–2009 period and full demographic data in the 2010–2012 period were missing for AR, which may have affected the results of the analysis. Third, because this study was based on self–reported data, recall and social biases may have influenced our findings [29,52]. Fourth, the KHANES dataset is missing clinical test information for allergic diseases, so our analysis is based on doctor diagnoses of lifetime prevalence for each allergic disease. It may limit our ability to quantitatively assess the severity of allergic diseases. Fifth, because the BMI distribution of the Korean population used in this study is different from the standards of WHO, the BMI classification in this study was divided into four groups based on guidelines tailored to the Asia Pacific region. Depending on regional population characteristics, BMI classification according to the Asia Pacific guidelines has lower criteria for overweight and obesity categories compared to the WHO classification [53]. This may limit the applicability of the association between obesity and the prevalence of allergic diseases in other regions. Finally, in this study, the initial number of study population was 152,262, but due to excluding participants with missing values in household income, BMI, and weight values, the final number of study population was 118,275. Although this may cause bias in the results, this can be overcome because the dataset used is representative of the Korean population and a large sample size was used even after excluding missing values [14,54].

Despite these limitations, one of the most significant strengths of our study is that we used large nationally representative data over 17 years to monitor trends of allergic diseases in conjunction with obesity. We also carefully analyzed changes across different demographic groups before and during the COVID–19 pandemic, which adds academic value to our findings; the long–term nature of our study makes our results more meaningful. This approach provides a basis for developing individualized policies for managing and preventing allergic diseases, considering age, sex, level of education, household income, and region of residence.

5. Conclusion

We identified overall increasing trend in the prevalence of allergic diseases (asthma, AD, and AR) from 2005 to 2021. When compared by age, each allergic disease showed different prevalence trends. Before the pandemic, the prevalence of asthma and AD tended to increase in those aged ≤39 years and decrease in those aged ≥40 years, but the prevalence of AR tended to increase in all age groups. During the pandemic, asthma and AD showed no significant trend change across all ages, but AR showed an increasing trend among those aged 40–59 years. These differences in disease prevalence by age highlight the importance of personalized diagnosis and management. No significant association was observed between COVID–19 and allergic diseases, suggesting that preventive measures, such as wearing masks and social distancing, affected the prevalence due to reduced exposure to allergens or microbes. Anxiety about accessing healthcare during the pandemic contributed to the decline in allergy diagnoses. These findings highlight the urgent need for comprehensive strategies to manage and prevent allergic diseases, including reduction of environmental pollution, promoting healthy lifestyles, and tailoring public health policies.

Data availability statement

The data are available upon request. Study protocol and statistical code: Available from DKY (yonkkang@gmail.com). Dataset: Available from the Korea Disease Control Agency (KDCA) through a data use agreement.

Ethical statement

The Kyung Hee University (KHUH 2022–06–042) and the Korea Disease Control and Prevention Agency approved the study protocol. Written informed consent was obtained from all participants at enrollment.

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CRediT authorship contribution statement

Yejun Son: Writing – original draft, Data curation, Conceptualization. **Jaeyu Park:** Investigation, Data curation, Conceptualization. **Yujin Choi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Data curation, Conceptualization. **Hyejun Kim:** Validation, Project administration. **Jiseung Kang:** Validation, Supervision. **Lee Smith:** Validation, Supervision. **Kyung Sik Yoon:** Supervision. **Selin Woo:** Writing – review & editing, Supervision, Conceptualization. **Dong Keon Yon:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e29921.

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