

## ORIGINAL ARTICLE

Atopic Dermatitis, Urticaria and Skin Disease

# Atopic dermatitis: Correlation of distinct risk factors with age of onset in adulthood compared to childhood

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**Abstract**

**Background:** Atopic dermatitis (AD) has long been regarded as a primarily pediatric disease. However, there is growing evidence for a high rate of adult-onset AD. We aimed to characterize factors associated with adult-onset versus childhood-onset AD and controls.

**Methods:** We analyzed cross-sectional data of the CK-CARE-ProRaD cohorts Bonn, Augsburg, Davos, Zürich of 736 adult patients stratified by age of AD onset (childhood-onset <18 years: 76.4% (subsets: 0 to 2; ≥2 to 6; ≥7 to 11; ≥12 to 18); adult-onset

**Abbreviations:** AC, allergic conjunctivitis; AD, atopic dermatitis; AR, allergic rhinitis; BCS, British birth cohort studies; BMI, body mass index; BSA, body surface area; CAIC, corrected Akaike information criterion; DD, differential diagnosis; DLQI, dermatology life quality index; EASI, eczema area and severity index; EH, eczema herpeticum; ETS, environmental tobacco smoke; FA, food allergy; FAMD, factor analysis of mixed data; HSV, herpes simplex virus; LR, logistic regression; MLGB, machine-learning gradient boosting; MLR, multinomial logistic regression; OR, odds ratio; PA, physical activity; ProRaD, prospective longitudinal study investigating the remission phase in patients with atopic dermatitis and other allergy-associated diseases; SCORAD, scoring atopic dermatitis; T2, type 2; tIgE, total serum immunoglobulin E.

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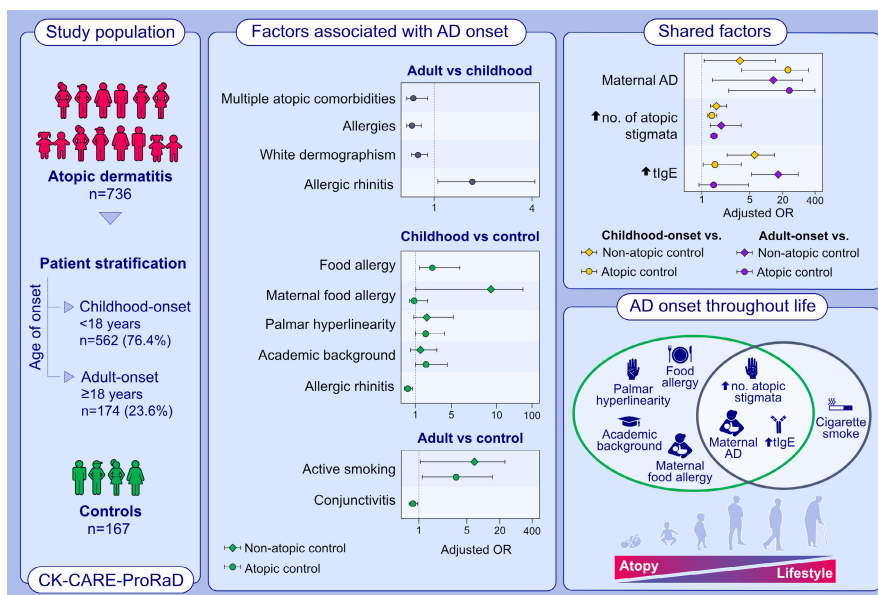
≥18 years: 23.6% (subsets: ≥18 to 40; ≥41 to 60; ≥61) and 167 controls (91 atopic, 76 non-atopic)).

**Results:** We identified active smoking to be associated with adult-onset AD versus controls (adjusted Odds Ratio (aOR)=5.54 [95% Confidence Interval: 1.06–29.01] vs. controls<sup>non-atopic</sup>, aOR=4.03 [1.20–13.45] vs. controls<sup>atopic</sup>). Conjunctivitis showed a negative association versus controls<sup>atopic</sup> (aOR=0.36 [0.14–0.91]). Food allergy (aOR=2.93 [1.44–5.96]), maternal food allergy (aOR=9.43 [1.10–80.95]), palmar hyperlinearity (aOR=2.11 [1.05–4.25]), and academic background (aOR=2.14 [1.00–4.54]) increased the odds of childhood-onset AD versus controls<sup>atopic</sup>. Shared AD-associated factors were maternal AD (4–34x), increased IgE (2–20x), atopic stigmata (2–3x) with varying effect sizes depending on AD onset and control group. Patients with adult-compared to childhood-onset had doubled odds of allergic rhinitis (aOR=2.15 [1.12–4.13]), but reduced odds to feature multiple (3–4) atopic comorbidities (aOR=0.34 [0.14–0.84]). Adult-onset AD, particularly onset ≥61 years, grouped mainly in clusters with low contributions of personal and familial atopy and high frequencies of physical inactivity, childhood-onset AD, particularly infant-onset, mainly in “high-atopic”-clusters.

**Conclusions:** The identified associated factors suggest partly varying endo- and exogenous mechanisms underlying adult-onset versus childhood-onset AD. Our findings might contribute to better assessment of the individual risk to develop AD throughout life and encourage prevention by non-smoking and physical activity as modifiable lifestyle factors.

#### KEYWORDS

adult-onset, associated factor, atopic dermatitis, childhood-onset, phenotype



#### GRAPHICAL ABSTRACT

Adult compared to childhood-onset AD was associated with allergic rhinitis, but reduced odds of multiple atopic comorbidities, allergies, and white dermographism. Compared to controls, adult-onset was associated with active smoking, childhood-onset with food allergy, maternal food allergy, palmar hyperlinearity and both with maternal AD, increased tIgE, higher number of atopic stigmata. Our data point towards partly varying endo- and exogeneous mechanisms underlying adult- and childhood-onset with the highest impact of atopy on onset in early life while lifestyle factors gain importance within adult-onset.

Abbreviations: AD, atopic dermatitis; Ig, immunoglobulin; no., number; OR, odds ratio; tIgE, total serum IgE

## 1 | INTRODUCTION

Atopic dermatitis (AD) is the most common chronic inflammatory skin disease with a high impact on patients' and relatives' quality of life, productivity at work and burden on the healthcare system with an increasing cumulative lifetime prevalence of 15%–28% in developed countries.<sup>1,2</sup> Main factors of the complex pathophysiology are an altered skin barrier, modified immune system, skin microbiome dysbiosis, all influenced by gene–gene and gene–environment interactions.<sup>1,3–7</sup>

There is a wide range of (endo) phenotypes and disease trajectories.<sup>1,4,6,8–30</sup> While early birth cohort studies have suggested a clearance of AD in >50% of affected children, there is growing evidence for AD being a lifelong disease with variable phenotypic expression, high rate of adult-onset or relapsing AD after long asymptomatic intervals with different influencing factors such as age, disease-onset, ethnicity, and others.<sup>1,2,4,9,12–15,18,19,23,24,30–32</sup>

A meta-analysis conducted in 2018 reported a pooled proportion of 26.1% of patients with AD onset  $\geq 16$  years across different countries in Europe (24.0%), Asia (21.4%), the United States (53.0%), and other regions (24.3%),<sup>12</sup> a recent longitudinal study of two British birth cohort studies (BCS) adult-onset  $\geq 23$  years in 40%–43%.<sup>2</sup> A higher frequency of hand and/or head–neck-dermatitis<sup>12,15</sup> and atopic stigmata<sup>9,15</sup> in adult-compared to childhood-onset AD has been reported by some, but not all<sup>33</sup> studies. Overall, there is growing, but varying and still limited information on adult-onset AD, especially in late adulthood.<sup>15</sup>

Therefore, we sought to characterize factors associated with adult-onset versus childhood-onset AD and controls.

## 2 | METHODS

### 2.1 | Study design and participants

We analyzed cross-sectional baseline data of 903 adults enrolled in the ProRAD<sup>8,34</sup> study at Bonn, Augsburg, Davos, Zürich between 11/2016 and 01/2021 after written informed consent: 736 AD patients according to Hanifin and Rajka and 167 controls without AD (76 non-atopic and 91 atopic controls (no AD, but allergic rhinitis (AR) and/or asthma and/or food allergy (FA), and/or allergic conjunctivitis (AC) and/or allergies (self-reported)). AD patients were stratified by age of AD onset in adulthood  $\geq 18$  years ( $n=174$ ) and childhood <18 years ( $n=562$ ) with further stratification in onset at (i) 0 to <2 years (infancy), (ii)  $\geq 2$  to <7, (iii)  $\geq 7$  to <12, (iv)  $\geq 12$  to <18 years (adolescence), (v) early- ( $\geq 18$  and <41 years), (vi) middle- ( $\geq 41$  and <61 years), and (vii) late- ( $\geq 61$  years) adulthood. Participants' characteristics are presented in Table 1 and Table S1. All study methods followed the Declaration of Helsinki and were approved by the respective local ethics committees. Further details are outlined in Methods S1.

### 2.2 | Statistical analysis

The associations of AD onset with clinical and epidemiological factors were analyzed using binary logistic regression (LR) with outcomes (1) adult-versus childhood-onset AD (2); adult-onset AD versus (2.1) controls<sup>non-atopic</sup>; (2.2) controls<sup>atopic</sup> (3); childhood-onset AD versus (3.1) controls<sup>non-atopic</sup>; (3.2) controls<sup>atopic</sup>; and multinomial LR (MLR) with outcomes (4) strata of childhood- and adult-onset AD versus (4.1) controls<sup>non-atopic</sup>; (4.2) controls<sup>atopic</sup> (5); strata of adult-onset versus childhood-onset AD (6); strata of childhood-onset AD versus adult-onset AD (7); adolescence versus early-adulthood; and (8) strata of onset at age (i)  $\geq 2$  to <7, (ii)  $\geq 7$  to <12; (iii)  $\geq 12$  to <18; (iv)  $\geq 18$  to <41; (v)  $\geq 41$  to <61; and (vi)  $\geq 61$  years versus onset in infancy (covariates see Figures 1–3, Tables 1–3 and Table S1). MLR models of the AD subgroups were adjusted for sex and age, localization of eczema additionally for severity, binary LR models for all covariates. Effect sizes are given in terms of univariate and adjusted odds ratios ((a)OR) with 95% confidence intervals (CI). Additionally, we performed factor analyses of mixed data (FAMD) of (i) all subjects: AD and controls and (ii) only AD patients, followed by hierarchical clustering using Ward's criterion.<sup>35,36</sup> All *p*-values are two-sided with a significance level of 5%. Statistical analysis was conducted using R version 3.5.3<sup>37</sup> and SPSS version 27.0. Further details such as add-on packages,<sup>35,38–47</sup> data pre-processing,<sup>8,48,49</sup> and variable selection<sup>8,50,51</sup> are provided in Methods S2.

## 3 | RESULTS

### 3.1 | Distribution of age of AD onset

Disease onset in adulthood  $\geq 18$  years was reported by 23.6% of our patients ( $n=174$ ) with 12.8% in early- ( $\geq 18$  and <41 years), 6.2% middle- ( $\geq 41$  and <61 years) and 4.6% late adulthood ( $\geq 61$  years). Childhood-onset was reported in 76.4% ( $n=562$ ), with 44.2% in infancy (0 to <2 years), mainly in the first 6 months of life (32.6%) and 11.6% between 7 and 24 months, 19.3% between age 2 and 6 years, 6.2% between age 7 and 11 years, and 6.7% in adolescence ( $\geq 12$  to <18 years; Table 1, Figure 1 and Figure S1).

### 3.2 | Family history

Familial atopy is a known risk factor (RF) for AD<sup>1,6</sup> but the impact on AD onset in diverse life periods less clear. In our cohort, maternal AD was the most important associated factor for both childhood- and adult-onset AD compared to controls without AD and increased the odds of AD up to 34-fold (childhood-onset: aOR=4.36, 95% CI [1.18–16.17] vs. controls<sup>non-atopic</sup>, aOR=32.97 [4.03–269.68] vs. controls<sup>atopic</sup>; Figure 2), adult-onset AD: aOR=15.79 [1.81–137.74] versus controls<sup>non-atopic</sup>, aOR=34.15

TABLE 1 Characteristics of patients with atopic dermatitis stratified by age at AD onset.

Factor	Age at onset of AD (years)									
	0 to 18	≥18	0 to <2	≥2 to <7	≥7 to <12	≥12 to <18	≥18 to <41	≥41 to <61	≥61	
<b>Biomarkers</b>	n = 562/736	n = 174	n = 325	n = 142	n = 46	n = 49	n = 94	n = 46	n = 34	
tIgE [IU/mL], [Median, Q1–Q3]	76.4% 544.1	23.6% 477.5	44.17% 749.0	19.3% 280.5	11.5% 406.3	6.2% 764.8	12.8% 477.5	6.2% 769.5	4.6% 443.5	73.1–1418.2
Increased tIgE [n, %]	436	128	257	104	38	37	72	32	24	2843.5
Eosinophils [G/L], [Median, Q1–Q3]	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.2–0.6
Eosinophilia >0.5 G/L [n, %]	86	28	53	18	7	8	9	9	10	294
<b>Comorbidities</b>	n	n	n	n	n	n	n	n	n	%
Asthma	287	47	184	60	17	26	29	13	5	14.7
Allergic rhinitis	428	100	262	102	29	35	69	22	9	26.5
Food allergy	330	56	227	67	14	22	38	12	6	17.6
Conjunctivitis	350	79	212	86	24	28	55	16	8	23.5
<b>No. of atopic com.</b>										
0	68	48	30	19	12	7	14	17	17	50.0
1	70	34	30	25	7	8	17	7	10	29.4
2	98	44	50	31	7	10	28	13	3	8.8
3	175	32	105	40	17	13	22	6	4	11.8
4	151	16	110	27	3	11	13	3	0	0.0
3–4	326	48	215	67	20	24	35	67	20	43.5
Self-reported allergies	487	106	295	120	36	36	68	28	10	29.4
Cardiovascular diseases	59	42	37	10	5	7	9	12	21	61.8
Alopecia areata	35	15	23	6	2	4	11	3	1	2.9
<b>Atopic stigmata</b>	n	n	n	n	n	n	n	n	n	%
No. of atopic stigmata (Median, Q1–Q3)	7	5	7	6	5	6	6	5	4	3.0–7.0
Hertoghe's sign	244	78	149	56	19	20	44	19	15	44.1
Facial pallor/erythema	302	95	194	64	21	23	56	21	18	52.9

TABLE 1 (Continued)

Factor	Age at onset of AD (years)																	
	0 to 18	≥18	0 to <2	≥2 to <7	≥7 to <12	≥12 to <18	≥18 to <41	≥41 to <61	≥61									
Dirty neck	127	22.6	83	25.5	28	19.7	7	15.2	9	18.4	15	16.0	13	28.3	10	29.4		
White dermographism	344	61.2	210	64.6	75	52.8	23	50.0	36	73.5	43	45.7	19	41.3	13	38.2		
Periorbital darkening	352	62.6	92	52.9	220	67.7	83	58.5	19	41.3	30	61.2	53	56.4	25	54.3	14	41.2
Dennie-Morgan fold	320	56.9	66	37.9	199	61.2	77	54.2	22	47.8	22	44.9	42	44.7	14	30.4	10	29.4
Anterior neck fold	242	43.1	59	33.9	153	47.1	55	38.7	20	43.5	14	28.6	32	34.0	18	39.1	9	26.5
Ear rhagades	176	31.3	37	21.3	122	37.5	33	23.2	9	19.6	12	24.5	20	21.3	14	30.4	3	8.8
Keratosis pilaris	179	31.9	41	23.6	112	34.5	39	27.5	11	23.9	17	34.7	26	27.7	7	15.2	8	23.5
Nipple eczema	59	10.5	7	4.0	38	11.7	12	8.5	4	8.7	5	10.2	6	6.4	1	2.2	0	-
Cheilitis sicca	266	47.3	63	36.2	161	49.5	74	52.1	13	28.3	18	36.7	36	38.3	18	39.1	9	26.5
Perleche	170	30.2	35	20.1	110	33.8	36	25.4	12	26.1	12	24.5	20	21.3	9	19.6	6	17.6
Pityriasis alba	98	17.4	18	10.3	63	19.4	19	13.4	11	23.9	5	10.2	8	8.5	6	13.0	4	11.8
Palmar hyperlinearity	372	66.2	108	62.1	222	68.3	88	62.0	26	56.5	36	73.5	57	60.6	29	63.0	22	64.7
Xerosis cutis	499	88.8	161	92.5	299	92.0	119	83.8	38	82.6	43	87.8	87	92.6	42	91.3	32	94.1
Active smoking	124	22.1	45	25.9	65	20.0	39	27.5	8	17.4	12	24.5	32	34.0	12	26.1	1	2.9
Daily smoking	72	12.8	30	17.2	40	12.3	17	12.0	6	13.0	9	18.4	19	20.2	10	21.7	1	2.9
Never-smokers	318	56.6	76	43.7	191	58.8	75	52.8	29	63.0	23	46.9	41	43.6	22	47.8	13	38.2
Occasional smokers	52	9.3	15	8.6	25	7.7	22	15.5	2	4.3	3	6.1	13	13.8	2	4.3	0	-
Former smokers	120	21.4	53	30.5	69	21.2	28	19.7	9	19.6	14	28.6	21	22.3	12	26.1	20	58.8
Passive smoking	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Never	190	33.8	49	28.2	105	32.3	50	35.2	18	39.1	17	34.7	24	25.5	15	32.6	10	29.4
Occasional	160	28.5	36	20.7	99	30.5	37	26.1	11	23.9	13	26.5	23	24.5	9	19.6	4	11.8
Daily	104	18.5	45	25.9	60	18.5	26	18.3	10	21.7	8	16.3	26	27.7	13	28.3	6	17.6
Former	108	19.2	44	25.3	61	18.8	29	20.4	7	15.2	11	22.4	21	22.3	9	19.6	14	41.2
Lifestyle, other	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Never-doing-sports	81	14.4	53	30.5	51	15.7	16	11.3	5	10.9	9	18.4	24	25.5	14	30.4	15	44.1
Household-size ≥ 4 persons	139	24.7	30	17.2	80	24.6	42	29.6	9	19.6	8	16.3	18	19.1	10	21.7	2	5.9
Only child	67	11.9	25	14.4	38	11.7	15	10.6	6	13.0	8	16.3	13	13.8	6	13.0	6	17.6
Cat exposure	345	61.4	103	59.2	192	59.1	92	64.8	29	63.0	32	65.3	60	63.8	24	52.2	19	55.9

(Continues)

TABLE 1 (Continued)

Factor	Age at onset of AD (years)																	
	0 to <18	≥18	0 to <2	≥2 to <7	≥7 to <12	≥12 to <18	≥18 to <41	≥41 to <61	≥61									
Dog exposure	337	60.0	107	61.5	188	57.8	85	59.9	29	63.0	35	71.4	54	57.4	31	67.4	22	64.7
Mould exposition	292	52.0	61	35.1	175	53.8	71	50.0	18	39.1	28	57.1	43	45.7	15	32.6	3	8.8
Rural living	200	35.6	70	40.2	117	36.0	49	34.5	19	41.3	15	30.6	31	33.0	20	43.5	19	55.9
No. inhabitants	50,000	11,139–313,958	28,638	5024–299,145	46963	10,500–300,000	59,865	9000–318,000	65,405	16,072–321,500	47,000	14,731–320,820	36,763	5000–300,000	32,114	17,359–79,250	205,000	3375–130,000
Body mass index [Median, Q1–Q3]	23.8	21.5–27.1	24.8	22.7–28.4	23.5	21.5–26.8	23.9	21.0–28.0	24.3	22.1–28.3	24.2	21.8–26.9	24.7	22.4–27.6	24.6	22.2–28.6	26.6	24.0–28.9
Obesity (BMI≥30)	80	14.2	28	16.1	41	12.6	24	16.9	8	17.4	7	14.3	12	12.8	8	17.4	8	23.5
Academic patient &/or parents	434	77.2	94	54.0	253	77.8	114	80.3	37	80.4	30	61.2	58	61.7	21	45.7	15	44.1
Patient academic	384	68.3	83	47.7	219	67.4	102	71.8	34	73.9	29	59.2	50	53.2	18	39.1	15	44.1
Mother academic	213	37.9	36	20.7	157	48.3	63	44.4	22	47.8	13	26.5	36	38.3	10	21.7	10	29.4
Father academic	255	45.4	56	32.2	122	37.5	56	39.4	24	52.2	11	22.4	24	25.5	6	13.0	6	17.6
Perinatal factors	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Cesarean section (refvag)	71	12.6	9	5.2	49	15.1	14	9.9	5	10.9	3	6.1	7	7.4	1	2.2	1	2.9
Birth weight (median, Q1–Q3)	3.330	3.045–3.600	3.500	3.100–3.700	3300	3000–3625	3400	3100–3710	3400	3180–3600	3200	2975–3525	3500	3175–3660	3450	3050–3600	3925	3562–4400
Preterm birth (<37 week)	29	5.2	8	4.6	19	5.8	5	3.5	1	2.2	4	8.2	6	6.4	2	4.3	0	0.0
Breastfeeding	429	76.3	140	80.5	243	74.8	112	78.9	40	87.0	34	69.4	66	70.2	40	87.0	34	100.0
Breastfeeding >4 months <sup>a</sup>	191	73.5	23	69.7	117	73.1	45	70.3	18	81.8	11	78.6	17	70.8	3	60.0	3	75.0
Proneness to infections	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Herpes simplex	272	48.4	76	43.7	162	49.8	63	44.4	18	39.1	29	59.2	39	41.5	19	41.3	18	52.9
Eczema herpeticum	67	11.9	7	4.0	46	14.2	12	8.5	3	6.5	6	12.2	4	4.3	3	6.5	0	-
Verrucae	347	61.7	73	42.0	193	59.4	88	62.0	30	65.2	36	73.5	40	42.6	21	45.7	12	35.3
Bacterial	242	43.1	54	31.0	162	49.8	50	35.2	11	23.9	19	38.8	32	34.0	13	28.3	9	26.5
Family history	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Positive family history for allergies	356	63.3	57	32.8	216	66.5	96	67.6	24	52.2	20	40.8	43	45.7	9	19.6	5	14.7
No parental atopy	172	30.6	92	52.9	216	66.5	96	67.6	13	28.3	22	44.9	37	39.4	31	67.4	24	70.6



**TABLE 1** (Continued)

Factor	Age at onset of AD (years)																	
	0 to <2	≥2 to <7	≥7 to <12	≥12 to <18	≥18 to <41	≥41 to <61	≥61											
1 parent atopic	280	49.8	70	40.2	89	27.4	48	33.8	26	56.5	23	46.9	48	51.1	12	26.1	10	29.4
Both parents atopic	110	19.6	12	6.9	164	50.5	67	47.2	7	15.2	4	8.2	9	9.6	3	6.5	0	-
<b>Maternal atopy</b>	<b>301</b>	<b>53.6</b>	<b>57</b>	<b>32.8</b>	<b>72</b>	<b>22.2</b>	<b>27</b>	<b>19.0</b>	<b>22</b>	<b>47.8</b>	<b>21</b>	<b>42.9</b>	<b>41</b>	<b>43.6</b>	<b>11</b>	<b>23.9</b>	<b>5</b>	<b>14.7</b>
Maternal AD	151	26.9	34	19.5	92	28.3	31	21.8	15	32.6	13	26.5	25	26.6	6	13.0	3	8.8
Maternal asthma	98	17.4	18	10.3	60	18.5	24	16.9	8	17.4	6	12.2	10	10.6	5	10.9	3	8.8
Maternal allergic rhinitis	192	34.2	35	20.1	114	35.1	52	36.6	13	28.3	13	26.5	27	28.7	7	15.2	1	2.9
Maternal food allergy	137	24.4	15	8.6	94	28.9	29	20.4	7	15.2	7	14.3	14	14.9	1	2.2	0	-
<b>Paternal atopy</b>	<b>199</b>	<b>35.4</b>	<b>37</b>	<b>21.3</b>	<b>119</b>	<b>36.6</b>	<b>52</b>	<b>36.6</b>	<b>18</b>	<b>39.1</b>	<b>10</b>	<b>20.4</b>	<b>25</b>	<b>26.6</b>	<b>7</b>	<b>15.2</b>	<b>5</b>	<b>14.7</b>
Paternal AD	80	14.2	15	8.6	50	15.4	21	14.8	7	15.2	2	4.1	10	10.6	2	4.3	3	8.8
Paternal asthma	56	10.0	16	9.2	29	8.9	16	11.3	7	15.2	4	8.2	12	12.8	3	6.5	1	2.9
Paternal allergic rhinitis	126	22.4	16	9.2	74	22.8	34	23.9	10	21.7	8	16.3	13	13.8	2	4.3	1	2.9
Paternal food allergy	45	8.0	7	4.0	29	8.9	13	9.2	2	4.3	1	2.0	6	6.4	0	-	1	2.9
<b>Basic demographics</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>
Female (ref male)	342	60.9	85	48.9	199	61.2	92	64.8	25	54.3	26	53.1	49	52.1	25	54.3	11	32.4
Age (median, Q1–Q3)	35.1	26.4–49.4	56.5	44.0–64.9	33.7	25.3–48.8	36.0	27.1–48.3	37.5	28.8–52.1	40.2	30.1–54.1	49.2	36.7–58.9	55.7	50.7–62.5	75.0	67.1–79.3
<b>AD Course</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>
Active AD	525	93.4	172	98.9	312	96.0	124	87.3	44	95.7	45	91.8	93	98.9	46	100.0	33	97.1
AD in remission	37	6.6	2	1.1	13	4.0	18	12.7	2	4.3	4	8.2	1	1.1	0	0.0	1	2.9
Seasonal flare	211	37.5	52	29.9	118	36.3	58	40.8	19	41.3	16	32.7	37	39.4	9	19.6	6	17.6
AD course	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3	Med	Q1–Q3
AD onset [years]	1.0	0.2–4.0	40.0	27.0–58.8	0.2	0.1–0.6	3.0	2.3–5.0	8.0	7.0–10.0	14.0	13.0–16.0	28.0	22.0–35.0	50.5	47.0–57.8	70.0	64.2–76.0
EASI	5.8	1.8–14.9	8.4	3.0–21.8	7.6	2.4–17.4	3.9	1.3–8.6	3.3	1.2–12.3	5.0	1.0–12.8	7.8	1.9–22.3	7.8	2.9–20.6	12.5	6.2–21.9
BSA	15.5	4.0–35.9	22.2	5.6–49.3	21.0	6.1–41.5	8.0	2.0–24.2	10.0	2.1–28.2	13.5	3.5–32.0	20.8	4.1–50.4	19.0	5.1–40.8	34.0	13.6–50.1
oSCORAD	30.3	17.9–42.5	34.8	21.4–47.2	33.5	20.5–44.9	25.5	14.6–38.8	23.0	14.5–38.1	25.7	14.2–41.2	32.7	21.3–44.6	30.9	19.4–44.7	40.1	31.1–51.5
SCORAD	36.0	22.0–51.8	42.0	25.8–56.7	39.9	24.9–54.2	32.0	18.0–47.0	29.1	18.7–49.1	30.2	16.4–49.4	40.8	22.6–56.1	36.7	25.0–51.5	47.0	39.4–62.9
DLQI	7.0	2.2–14.8	9.0	3.0–16.0	8.0	4.0–16.0	6.0	1.0–11.0	7.0	3.0–12.8	6.0	2.0–13.0	9.5	3.0–17.0	8.0	4.2–17.5	9.0	3.0–14.8
Pruritus	4.0	2.0–7.0	5.0	2.0–7.0	4.0	2.0–6.0	4.0	1.0–7.0	4.0	2.0–6.8	3.0	1.0–6.0	4.0	1.2–7.0	5.0	2.0–6.8	5.0	3.2–8.0

(Continues)

TABLE 1 (Continued)

Factor	Age at onset of AD (years)																	
	0 to 18		≥18		0 to <2		≥2 to <7		≥7 to <12		≥12 to <18		≥18 to <41		≥41 to <61		≥61	
Distribution of eczema	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Head neck	431	76.7	135	77.6	269	82.8	97	68.3	29	63.0	36	73.5	71	75.5	37	80.4	27	79.4
Trunk	372	66.2	133	76.4	236	72.6	77	54.2	26	56.5	33	67.3	65	69.1	37	80.4	31	91.2
Arms	469	83.5	151	86.8	285	87.7	108	76.1	36	78.3	40	81.6	82	87.2	40	87.0	29	85.3
Legs	384	68.3	127	73.0	240	73.8	83	58.5	28	60.9	33	67.3	65	69.1	36	78.3	26	76.5
Hand eczema	355	63.2	113	64.9	218	67.1	79	55.6	25	54.3	33	67.3	61	64.9	29	63.0	23	67.6
Hands dorsal	302	53.7	101	58.0	187	57.5	69	48.6	18	39.1	28	57.1	53	56.4	27	58.7	21	61.8
Palmae	215	38.3	76	43.7	136	41.8	45	31.7	14	30.4	20	40.8	42	44.7	19	41.3	15	44.1

Note: Blue font: adult-onset, black font: childhood-onset AD. Atopic comorbidities = allergic conjunctivitis, allergic rhinitis (AR), asthma, Food allergy (FA), BSA = body surface area, DLQI = Dermatology Life Quality Index, EASI = Eczema Area and Severity Index, tlgE: increased total serum immunoglobulinE levels, age-dependent cut-off points: age 12–15 y: 200 IU/mL, age ≥16 y: 100 IU/mL, IQR = interquartile range (Q1–Q3), NA = not applicable (outcome variable), (o)SCORAD = (objective) SCORing Atopic Dermatitis.

<sup>a</sup> No imputation because of ≥30% missing values. Effect sizes of the characteristics associated with different subgroups of AD stratified by AD onset are given in Figures 1–3, Tables 2 and 3 and Figures S2–S14.

[3.15–370.28] versus controls<sup>atopic</sup> (Figure 3 and Figures S2–S6, Table 2 and Table S2). Additionally, maternal FA increased the odds of childhood-onset AD compared to controls<sup>non-atopic</sup> (aOR = 9.43 [1.10–80.95]; Figure 2). Stratification revealed associations across all ages of childhood up to early-adult-onset AD with the strongest association in infancy-onset AD (aOR = 29.54 [4.04–215.87]; Figure S5, Table 2). We found no association of maternal AD or maternal FA with mode of delivery and breastfeeding as important factors contributing to immune interactions between children and mothers (Table S3). Paternal AD was associated with AD with onset in up to age 6, but with onset at later age only in univariate analyses (Table 2 and Table S2).

### 3.3 | Lifestyle factors

We investigated modifiable factors to assess their potential for AD prevention in different windows of life. Active smoking was the main lifestyle factor associated with adult-onset AD (aOR = 5.54 [1.06–29.01] vs. controls<sup>non-atopic</sup>, aOR = 4.03 [1.20–13.45] vs. controls<sup>atopic</sup>; Figure 3). Daily passive exposure to environmental tobacco smoke (ETS) showed associations with childhood- and adult-onset AD in univariate analyses (Figures 2 and 3, Table S2) and MLR of subgroups (Table 2, Figures S2–S6).

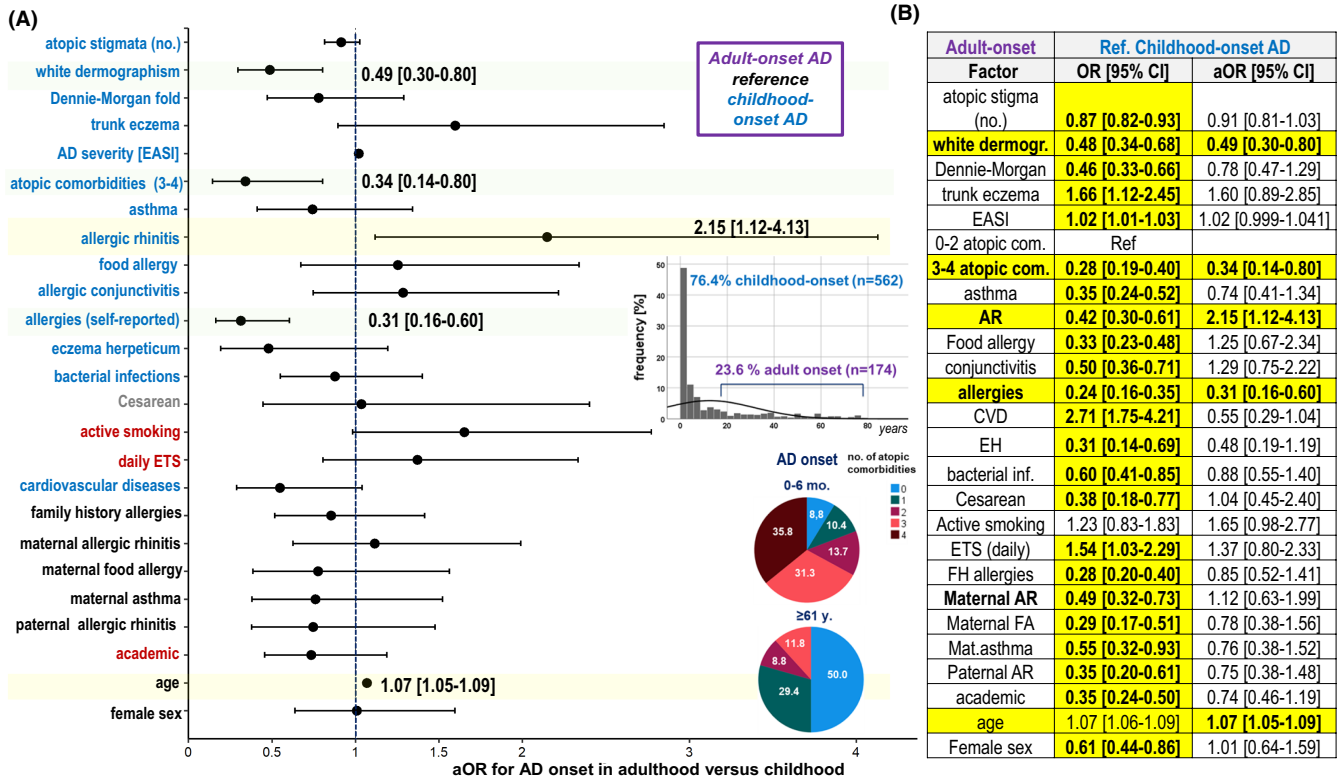
Within AD, active smoking tended to increase the odds of adult-compared to childhood-onset AD overall (aOR = 1.65 [0.98–2.77]; Figure 1). Subgroup analysis revealed that active smoking (aOR = 2.08 [1.27–3.40]) and daily ETS (aOR = 1.68 [1.00–2.81]) increased the odds of AD onset in early-adulthood versus childhood (Figure S7) and halved the odds of infancy-onset versus adult-onset (Figure S8).

Never-doing sports compared to physical activity (PA) was associated with disease-onset in early- (aOR = 2.72 [1.13–6.55]), middle- (aOR = 3.61 [1.33–9.95]), and late-adulthood (aOR = 7.74 [2.17–27.63]) versus controls<sup>non-atopic</sup> (Table 2, Figures S2 and S3). Within AD, patients with onset in middle- (aOR = 2.19 [1.03–4.65]) and late- (aOR = 4.43 [1.48–13.23]) adulthood had higher odds of physical inactivity than adults with infancy-onset (Table 3, Figures S9 and S10).

A higher educational level of patients' and/or their parents doubled the odds of childhood-onset AD compared to controls<sup>atopic</sup> (aOR = 2.14 [1.00–4.54], Figure 2) and reduced the odds of AD with onset in middle- (aOR = 0.41 [0.21–0.79]) and late (aOR = 0.33 [0.12–0.86]) adulthood versus childhood (Figure S7), particularly versus infancy onset (Table 3; Figure S9). Analysis of a potential relationship between these factors revealed a higher frequency of smoking and of physical inactivity in subjects without compared to those with an academic background (Table S4).

A household size of at least four persons approximately halved the odds of AD onset before age 2 years (Figure S6) and between 7 and 40 years (Figure S4) compared to controls<sup>atopic</sup> (Table 2). Childhood- and adult-onset AD overall showed the same trend in univariate analyses (Figures 2 and 3). There was a small positive





**FIGURE 1** Frequency and factors associated with adult-onset atopic dermatitis (AD) compared to childhood-onset AD. Allergic rhinitis was associated with adult-onset AD, multiple atopic comorbidities, allergies, and white dermographism with childhood-onset AD. Forest plot (A) and Table (B) of associations of clinical and epidemiological factors with adult-onset AD (n = 174) versus childhood-onset AD (n = 562) obtained from a binary logistic regression model. Effect sizes are presented as adjusted odds ratios (aOR) with 95% confidence intervals (CI). Bold and yellow boxes: p-values < .05. Embedded in panel (A), the frequencies of age at onset of AD in child and adulthood are depicted in a histogram and number of atopic comorbidities [% of patients] depending on AD onset in pie charts (onset < 6 months: n = 240; ≥61 years: n = 34). Academic was defined as education at least A-level up to university degree of patients' and their parents. Allergies were self-reported. AR, allergic rhinitis; CVD, cardiovascular diseases; EASI, Eczema Area and Severity Index; EH, Eczema herpeticum; ETS, environmental tobacco smoke/passive smoking; FA, food allergy; FH, family history; no., number.

association between the patients' age at visit and adult-onset AD both versus controls and childhood-onset AD (Figures 2 and 3).

### 3.4 | Phenotype and atopic stigmata

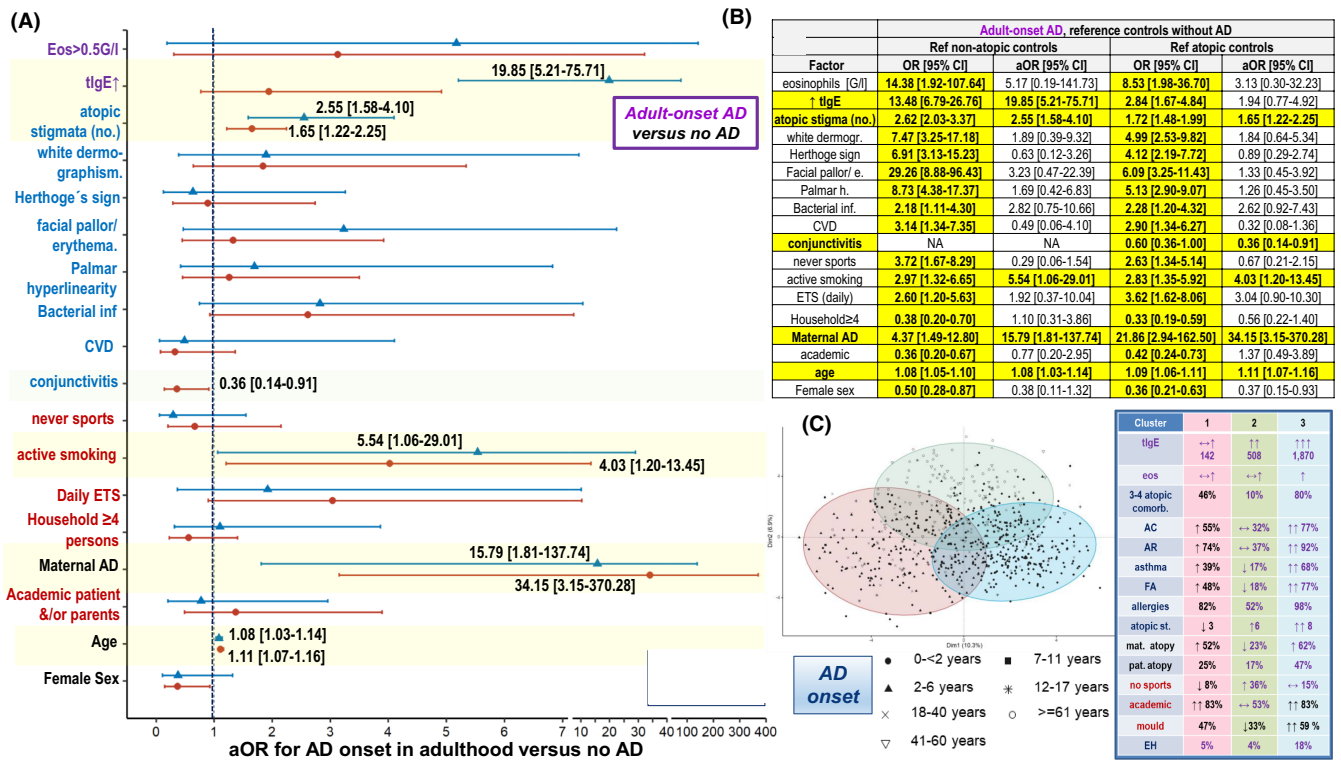
We sought to investigate whether the phenotype of subjects is helpful in assessing the odds of AD with different ages of manifestation. Atopic stigmata are phenotypic traits described more frequently in patients with atopic comorbidities compared to the general population.<sup>52,53</sup> Patients with childhood-onset AD exhibited a median number of seven atopic stigmata, adult-onset-AD five, controls<sup>non-atopic</sup> two and controls<sup>non-atopic</sup> one (Table 1). Each additional atopic stigma approximately doubled the odds of AD compared to controls (Figures 2 and 3) with highest odds in infancy-onset (Table 2). All atopic stigmata were more frequent in both adult-onset and childhood-onset AD compared to controls with higher frequencies in atopic controls (Table 1) and associated factors in univariate LR (Table S2), most of them also in MLR (Table 2). Palmar hyperlinearity doubled the odds of childhood-onset AD versus controls<sup>atopic</sup> (aOR = 2.11 [1.05–4.25], Figure 2).

Infancy-onset AD featured slightly increased odds of a higher number of atopic stigmata compared to later onsets (Table 3, Figures S8 and S11). Patients with childhood-onset overall exhibited a higher frequency of white dermographism, Dennie–Morgan fold, ear rhagades, pityriasis alba, perleche, cheilitis sicca, keratosis pilaris, nipple eczema, periorbital darkening, and anterior neck fold than those with adult-onset (Table 1 and Table S2). White dermographism was the stigma with the largest differences between groups, halved the odds of adult-compared to childhood-onset AD overall (Figure 1) with decreasing odds in later phases of adulthood (Figure S7).

### 3.5 | Severity and distribution of eczema

Adult-onset AD tended to be slightly more severe than childhood-onset (Figure 3), particularly versus onset between 2 and 12 years (Figure S8). Compared to infancy-onset, we found lower odds of (i) head–neck eczema in AD for onset between age 2 and 11 years as well as for early-adult-onset, and of (ii) trunk eczema with onset age ≥2–6 years in MLR adjusted for severity, sex, and age (Table 3,





**FIGURE 3** Main factors associated with adult-onset atopic dermatitis (AD) compared to controls without AD and with clusters of AD patients. (A, B) Active smoking, maternal AD, increased total IgE, and atopic stigmata were main factors associated with adult-onset AD ( $n=174$ ) compared to controls ( $n=167$ ) without AD ( $n=76$  non-atopic (blue lines),  $n=91$  atopic (red lines)) obtained from a binary logistic regression model. Forest plot (A) and Table (B) of effect sizes presented as (adjusted) Odds Ratios (aOR) with 95% Confidence intervals (CI). Bold and yellow boxes:  $p$ -values  $< .05$ . Violet: biomarker, blue: visible phenotype, atopic stigmata and comorbidities, red: modifiable factors, black: unswayable factors. (C) Generation of three clusters of AD patients (AD ( $n=736$ , childhood-onset:  $n=562$ , adult-onset:  $n=174$ )), with hierarchical clustering using Ward's criterion of the 42 most important principal component of a factor analysis of mixed data (FAMD). Cluster 1:  $n=288$ , Cluster 2:  $n=196$ , Cluster 3:  $n=312$ . % refers to the number of patients with the respective trait within the respective cluster (e.g., AC in 46% of cluster 1 ( $n=104/288$ )). Contribution of covariates are given in Table S7, exact numbers and other details of all clinical traits associated with the respective clusters in Table S8. AC, allergic conjunctivitis, academic defined as education at least A-level up to university degree of the patient and/or parents. AR, allergic rhinitis; atopic st., median number of atopic stigmata; CVD, cardiovascular diseases; eos, eosinophils [G/L]; Eos  $> 0.5$  G/L, eosinophilia; comorb., comorbidities; EH, eczema herpeticum; ETS, environmental tobacco smoke/passive smoking; FA, food allergy; mat, maternal; pat., paternal; household, household size ( $\geq 4$  persons); HSV, herpes simplex infection; mold, mold exposition; palmar h., palmar hyperlinearity; skin inf., proneness to skin infections (eczema herpeticum, other herpes simplex, bacterial and mycotic infections); tlgE, median total-serum IgE [IU/mL]; white derm., white dermographism; no., number; tlgE†, age-dependent increased total serum IgE.

conjunctivitis only with infancy-onset (Figure S8). Adolescent-onset AD featured higher odds of asthma, herpes simplex virus, and verucae than early-adulthood-onset AD (Tables S5 and S6).

Adult compared to childhood-onset AD overall featured doubled odds of AR (aOR = 2.15 [1.12–4.13]), but threefold-reduced odds of multiple (3–4) atopic comorbidities at once (aOR = 0.34 [0.14–0.80]) and allergies (aOR = 0.31 [0.16–0.60]; Figure 1). The odds of AD with 3–4 atopic comorbidities were highest with infancy onset (aOR = 5.38 [3.44–8.44] vs. adult onset, Figure S8), decreased with later manifestation (Figures S8 and S13, Table 3) and were 10-fold reduced for late-adult-onset-AD compared to childhood-onset (early-adult: aOR = 0.40 [0.25–0.63], middle-adult: aOR = 0.16 [0.07–0.35], and late-adult onset: aOR = 0.10 [0.03–0.37]; Figure S7, Table 3).

AR and AC were the most frequent comorbidities in atopic controls (Table 1). AR decreased the odds of childhood-onset AD

(aOR = 0.22 [0.09–0.53]; Figure 2), AC the odds of adult-onset AD (aOR = 0.36 [0.14–0.91]; Figure 3) compared to controls<sup>atopic</sup>. Conversely, FA nearly tripled the odds of childhood-onset AD versus controls<sup>atopic</sup> (aOR = 2.94 [1.43–6.03]; Figure 2). Compared to controls<sup>atopic</sup>, also asthma was associated with infancy-onset AD (aOR = 2.25 [1.39–3.65]), but not with later onsets (Figure S6, Table 2).

Patients with childhood-onset AD were more prone to eczema herpeticum (EH) and bacterial infections than adult-onset AD and both more susceptible to bacterial and mycotic infections than controls in univariate analyses (Figure 1, Table S2). Stratification revealed higher odds of EH in infancy-onset (aOR = 4.49 [1.89–10.67]) and adolescent-onset (aOR = 3.43 [1.08–10.91]) than in adult-onset AD (Figure S8), particularly versus early-adult onset (Table 3, Figures S7 and S14).

**TABLE 2** Atopic dermatitis (AD) versus controls: associations with clinical and epidemiological factors from multinomial logistic regression models with stratification by age at onset of AD.

Age at AD onset	0 to <24 months	≥2 to <7 years	≥7 to <12 years	≥12 to <18 years	≥18 to <41 years	≥41 to <61 years	≥61 years
Ref. controls	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
<b>Biomarkers</b>							
<b>Eosinophils [G/L]</b>							
Non-atopic	14.47 [1.97–106.44]	10.89 [1.42–83.35]	12.95 [1.54–109.26]	14.01 [1.69–116.17]	7.57 [0.93–61.46]	18.63 [2.23–155.35]	46.39 [4.78–450.19]
Atopic	8.35 [1.99–35.01]	6.29 [1.42–27.84]	7.53 [1.49–38.02]	8.16 [1.65–40.28]	4.41 [0.92–21.17]	10.72 [2.15–53.38]	25.44 [4.19–154.32]
↑ tlgE							
Non-atopic	18.91 [9.75–36.66]	13.94 [6.84–28.41]	22.83 [8.59–60.65]	14.50 [5.93–35.43]	15.04 [6.90–32.76]	10.14 [4.09–25.13]	9.86 [2.99–35.21]
Atopic	3.69 [2.24–6.08]	2.72 [1.55–4.79]	4.36 [1.81–10.49]	2.73 [1.25–6.00]	2.80 [1.46–5.36]	1.83 [0.82–4.09]	1.59 [0.51–4.97]
<b>Atopic stigmata</b>							
<b>Atopic stigma (no.)</b>							
Non-atopic	3.09 [2.48–3.86]	2.69 [2.16–3.36]	2.53 [2.00–3.20]	2.74 [2.16–3.46]	2.60 [2.08–3.26]	2.51 [1.97–3.19]	2.50 [1.89–3.32]
Atopic	2.02 [1.77–2.31]	1.76 [1.53–2.02]	1.65 [1.41–1.94]	1.79 [1.52–2.10]	1.70 [1.47–1.96]	1.63 [1.38–1.93]	1.59 [1.27–2.00]
<b>White dermogr.</b>							
Non-atopic	18.02 [8.01–40.53]	11.06 [4.75–25.75]	9.71 [3.68–25.60]	26.72 [9.78–72.97]	7.99 [3.31–19.32]	6.58 [2.43–17.80]	4.18 [1.21–14.45]
Atopic	12.07 [6.30–23.12]	7.39 [3.70–14.75]	6.55 [2.82–15.17]	18.00 [7.46–43.43]	5.34 [2.55–11.17]	4.22 [1.76–10.10]	2.42 [0.76–7.71]
<b>Dennie–Morgan fold</b>							
Non-atopic	11.61 [5.58–24.17]	8.79 [4.06–19.05]	7.16 [2.88–17.80]	6.55 [2.66–16.15]	7.06 [3.12–16.01]	4.74 [1.80–12.48]	12.97 [3.66–45.87]
Atopic	3.44 [2.08–5.68]	2.61 [1.49–4.56]	2.11 [1.01–4.42]	1.93 [0.93–4.00]	2.08 [1.12–3.86]	1.39 [0.62–3.11]	3.65 [1.16–11.46]
<b>Herthoge sign</b>							
Non-atopic	7.67 [3.55–16.57]	5.85 [2.60–13.19]	5.71 [2.22–14.70]	5.38 [2.11–13.70]	6.37 [2.74–14.83]	4.50 [1.72–11.74]	4.36 [1.35–14.05]
Atopic	4.47 [2.45–8.16]	3.40 [1.77–6.55]	3.33 [1.47–7.53]	3.13 [1.40–6.99]	3.67 [1.83–7.36]	2.49 [1.08–5.74]	2.20 [0.74–6.48]
<b>Facial pallor/erythema</b>							
Non-atopic	37.02 [11.41–120.18]	20.43 [6.14–67.99]	19.99 [5.48–72.93]	20.56 [5.68–74.39]	32.36 [9.47–110.65]	16.26 [4.40–60.10]	21.55 [4.95–93.83]
Atopic	7.53 [4.13–13.70]	4.17 [2.19–7.97]	4.05 [1.81–9.07]	4.16 [1.88–9.20]	6.53 [3.25–13.13]	3.22 [1.40–7.39]	3.94 [1.34–11.61]
<b>Palmar hyperlinearity</b>							
Non-atopic	13.28 [6.77–26.04]	9.73 [4.76–19.92]	7.13 [3.01–16.90]	14.88 [6.06–36.53]	7.16 [3.36–15.25]	6.03 [2.48–14.68]	3.33 [1.05–10.60]
Atopic	7.67 [4.44–13.26]	5.65 [3.10–10.28]	4.13 [1.91–8.92]	8.60 [3.83–19.32]	4.13 [2.16–7.92]	3.42 [1.53–7.65]	1.63 [0.53–5.02]
<b>Comorbidities</b>							
<b>Asthma</b>							
Non-atopic	NA	NA	NA	NA	NA	NA	NA
Atopic	2.25 [1.39–3.65]	1.25 [0.72–2.15]	0.92 [0.44–1.94]	1.75 [0.86–3.55]	0.65 [0.35–1.21]	0.55 [0.25–1.23]	0.29 [0.08–1.00]

TABLE 2 (Continued)

Age at AD onset	0 to <24 months	≥2 to <7 years	≥7 to <12 years	≥12 to <18 years	≥18 to <41 years	≥41 to <61 years	≥61 years
Ref. controls	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Allergic rhinitis							
Non-atopic	NA	NA	NA	NA	NA	NA	NA
Atopic	0.82 [0.44–1.53]	<b>0.50 [0.26–0.98]</b>	<b>0.33 [0.14–0.74]</b>	0.48 [0.21–1.10]	0.53 [0.25–1.09]	<b>0.18 [0.08–0.42]</b>	<b>0.09 [0.03–0.28]</b>
Food allergy							
Non-atopic	NA	NA	NA	NA	NA	NA	NA
Atopic	<b>4.85 [2.94–7.99]</b>	<b>1.85 [1.07–3.21]</b>	0.90 [0.42–1.94]	1.67 [0.82–3.42]	1.38 [0.75–2.54]	0.74 [0.33–1.67]	0.65 [0.20–2.14]
Allergic conjunctivitis							
Non-atopic	NA	NA	NA	NA	NA	NA	NA
Atopic	1.39 [0.86–2.25]	1.13 [0.66–1.93]	0.80 [0.39–1.64]	0.98 [0.48–1.98]	1.03 [0.57–1.86]	<b>0.39 [0.18–0.84]</b>	<b>0.27 [0.09–0.81]</b>
Bacterial inf.							
Non-atopic	<b>5.03 [2.65–9.54]</b>	<b>2.72 [1.36–5.43]</b>	1.46 [0.59–3.61]	<b>2.89 [1.26–6.64]</b>	<b>2.29 [1.09–4.80]</b>	1.84 [0.75–4.52]	<b>3.71 [1.11–12.38]</b>
Atopic	<b>5.18 [2.84–9.43]</b>	<b>2.80 [1.45–5.40]</b>	1.50 [0.62–3.62]	<b>2.98 [1.34–6.66]</b>	<b>2.36 [1.16–4.78]</b>	1.89 [0.79–4.51]	<b>3.77 [1.14–12.46]</b>
CVD							
Non-atopic	1.58 [0.64–3.92]	0.83 [0.28–2.41]	0.97 [0.27–3.52]	1.18 [0.36–3.91]	0.50 [0.17–1.51]	1.05 [0.35–3.20]	1.70 [0.49–5.93]
Atopic	1.39 [0.61–3.17]	0.73 [0.27–1.98]	0.84 [0.25–2.91]	1.03 [0.33–3.20]	0.43 [0.15–1.23]	0.91 [0.32–2.60]	1.50 [0.45–4.99]
Lifestyle factors							
Active smoking							
Non-atopic	2.04 [0.93–4.46]	<b>3.18 [1.40–7.26]</b>	1.76 [0.61–5.10]	<b>2.79 [1.04–7.50]</b>	<b>4.82 [2.04–11.41]</b>	<b>4.09 [1.47–11.33]</b>	0.83 [0.09–7.85]
Atopic	1.87 [0.92–3.83]	<b>2.93 [1.37–6.25]</b>	1.62 [0.59–4.46]	<b>2.56 [1.01–6.53]</b>	<b>4.42 [1.99–9.39]</b>	<b>3.72 [1.41–9.82]</b>	0.71 [0.08–6.55]
ETS (daily)							
Non-atopic	1.68 [0.79–3.56]	1.68 [0.74–3.80]	2.00 [0.74–5.37]	1.40 [0.50–3.92]	<b>2.77 [1.20–6.41]</b>	<b>3.20 [1.21–8.49]</b>	<b>4.72 [1.22–18.22]</b>
Atopic	<b>2.29 [1.05–5.00]</b>	<b>2.29 [0.99–5.32]</b>	<b>2.74 [1.00–7.53]</b>	1.92 [0.67–5.50]	<b>3.83 [1.61–9.08]</b>	<b>4.48 [1.65–12.16]</b>	<b>6.86 [1.72–27.30]</b>
Never-sports							
Non-atopic	1.59 [0.72–3.51]	1.08 [0.44–2.67]	1.00 [0.31–3.28]	1.82 [0.65–5.13]	<b>2.72 [1.13–6.55]</b>	<b>3.61 [1.33–9.85]</b>	<b>7.74 [2.17–27.63]</b>
Atopic	1.12 [0.58–2.18]	0.76 [0.35–1.67]	0.70 [0.23–2.11]	1.27 [0.50–3.24]	1.87 [0.87–4.00]	2.41 [0.98–5.94]	<b>4.89 [1.47–16.26]</b>
Household ≥ 4 pers.							
Non-atopic	<b>0.56 [0.33–0.96]</b>	0.73 [0.40–1.34]	0.44 [0.18–1.07]	<b>0.37 [0.15–0.91]</b>	0.51 [0.25–1.04]	0.95 [0.38–2.36]	0.44 [0.06–2.99]
Atopic	<b>0.50 [0.30–0.82]</b>	<b>0.65 [0.37–1.14]</b>	<b>0.40 [0.17–0.92]</b>	<b>0.33 [0.14–0.79]</b>	<b>0.45 [0.23–0.90]</b>	0.87 [0.36–2.11]	0.46 [0.06–3.31]
Academic <sup>a</sup>							
Non-atopic	0.99 [0.54–1.83]	1.20 [0.60–2.39]	1.36 [0.54–3.43]	0.53 [0.24–1.87]	0.63 [0.31–1.26]	<b>0.42 [0.18–0.96]</b>	0.36 [0.12–1.04]
Atopic	1.15 [0.67–2.00]	1.39 [0.73–2.62]	1.58 [0.65–3.83]	0.62 [0.29–1.32]	0.72 [0.38–1.39]	0.47 [0.22–1.03]	0.37 [0.13–1.07]

(Continues)



TABLE 2 (Continued)

Age at AD onset	0 to <24 months	≥2 to <7 years	≥7 to <12 years	≥12 to <18 years	≥18 to <41 years	≥41 to <61 years	≥61 years
Ref. controls	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Family history							
Maternal AD							
Non-atopic	7.03 [2.50–19.79]	5.00 [1.69–14.75]	8.64 [2.65–28.14]	6.44 [1.96–21.21]	6.46 [2.13–19.63]	2.71 [0.71–10.37]	2.21 [0.35–13.83]
Atopic	34.93 [4.80–254.50]	24.84 [3.33–185.52]	42.78 [5.42–337.60]	31.82 [4.01–252.59]	31.56 [4.16–239.56]	12.85 [1.48–111.71]	11.77 [1.06–130.47]
Paternal AD							
Non-atopic	3.41 [1.19–9.78]	3.20 [1.05–9.71]	3.25 [0.89–11.82]	0.75 [0.13–4.29]	2.03 [0.61–6.81]	0.76 [0.13–4.40]	1.29 [0.14–11.67]
Atopic	3.28 [1.27–8.52]	3.08 [1.12–8.52]	3.14 [0.94–10.57]	0.73 [0.14–3.94]	1.99 [0.65–6.14]	0.76 [0.14–4.18]	2.38 [0.39–14.66]
Maternal FA							
Non-atopic	29.54 [4.04–215.87]	18.95 [2.52–142.34]	13.84 [1.64–117.04]	13.37 [1.58–112.92]	15.66 [2.00–122.75]	2.54 [0.15–42.20]	-
Atopic	2.28 [1.21–4.33]	1.47 [0.71–3.01]	1.07 [0.39–2.92]	1.03 [0.38–2.81]	1.21 [0.53–2.78]	0.20 [0.02–1.59]	-

Note: Associations of clinical and epidemiological factors with AD ( $n = 736$ ) versus controls ( $n = 167$ , non-atopic;  $n = 76$ , atopic;  $n = 91$ ) from multinomial logistic regression models with strata of onset at age: (i) 0 to <2 years (infancy,  $n = 325$  (44.17%)); (ii) ≥2 to <7 (n = 142 (19.3%)); (iii) ≥7 to <12 (n = 142 (11.5%)); (iv) ≥12 to <18 years (n = 49 (6.7%)); (v) ≥18 and <41 years; n = 94 (12.8%); (vi) ≥41 and <61 years; n = 46 (6.2%) and (vii) ≥61 years; n = 34 (4.6%). All effect sizes are adjusted (a) for age and sex and given in aOdds Ratios (aOR) with 95% Confidence intervals (CI). Bold and yellow shaded values:  $p$ -values < .05.

Abbreviations: AD, atopic dermatitis; AR, allergic rhinitis; FA, food allergy.

<sup>a</sup>Academic defined as education at least A-level up to university degree.



TABLE 3 Atopic dermatitis (AD) with strata of childhood- and adult-onset versus infancy-onset: associations with clinical and epidemiological factors from multinomial logistic regression models.

Age at AD onset	AD onset strata with reference 0 to <2 years					
	≥2 to <7 years	≥7 to 12 years	≥12 to 18 years	≥18 to <41 years	≥41 to <61 years	≥61 years
	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
<b>Biomarkers</b>						
tlgE/100IU/mL	0.99 [0.99–1.00]	0.99 [0.98–1.00]	1.00 [1.00–1.00]	1.00 [0.99–1.00]	1.00 [1.00–1.00]	0.99 [0.98–1.01]
↑ tlgE	0.74 [0.46–1.17]	1.18 [0.52–2.68]	0.74 [0.36–1.52]	0.76 [0.43–1.34]	0.50 [0.23–1.05]	0.43 [0.14–1.32]
Eosinophils [G/l]	0.74 [0.40–1.36]	0.88 [0.37–2.06]	1.34 [0.78–2.32]	0.50 [0.21–1.20]	1.33 [0.78–2.27]	1.46 [0.66–3.24]
eos > 0.5 G/L	0.75 [0.42–1.34]	0.90 [0.38–2.12]	0.97 [0.43–2.21]	0.53 [0.24–1.13]	1.29 [0.56–2.99]	3.15 [0.97–10.22]
<b>Atopic stigmata</b>						
Number of atopic stigmata	0.87 [0.81–0.93]	0.82 [0.73–0.91]	0.88 [0.79–0.98]	0.84 [0.77–0.92]	0.81 [0.71–0.92]	0.80 [0.65–0.97]
White dermographism	0.61 [0.41–0.91]	0.54 [0.29–1.01]	1.48 [0.75–2.92]	0.44 [0.27–0.72]	0.36 [0.19–0.71]	0.22 [0.08–0.61]
Dennie–Morgan fold	0.76 [0.51–1.13]	0.61 [0.33–1.15]	0.56 [0.30–1.03]	0.60 [0.37–0.97]	0.40 [0.20–0.82]	1.07 [0.37–3.14]
Hertoghe sign	0.76 [0.51–1.15]	0.75 [0.40–1.42]	0.71 [0.38–1.33]	0.85 [0.53–1.37]	0.60 [0.31–1.18]	0.56 [0.21–1.46]
Facial pallor/erythema	0.55 [0.37–0.82]	0.54 [0.29–1.00]	0.55 [0.30–1.01]	0.86 [0.53–1.40]	0.43 [0.22–0.84]	0.55 [0.21–1.45]
Dirty neck	0.71 [0.44–1.16]	0.45 [0.19–1.06]	0.55 [0.27–1.09]	0.43 [0.23–0.80]	0.85 [0.41–1.77]	1.36 [0.47–3.97]
Periorbital darkening	0.68 [0.45–1.03]	0.45 [0.19–1.06]	0.55 [0.25–1.19]	0.81 [0.50–1.33]	0.94 [0.48–1.84]	1.14 [0.43–3.06]
Anterior neck fold	0.70 [0.46–1.04]	0.82 [0.44–1.53]	0.41 [0.21–0.80]	0.50 [0.31–0.83]	0.57 [0.29–1.12]	0.32 [0.11–0.89]
Ear rhagades	0.51 [0.32–0.79]	0.41 [0.19–0.87]	0.55 [0.27–1.09]	0.46 [0.26–0.80]	0.78 [0.38–1.59]	0.19 [0.04–0.89]
Keratosis pilaris	0.72 [0.46–1.11]	0.63 [0.31–1.30]	1.10 [0.58–2.09]	0.83 [0.49–1.41]	0.44 [0.18–1.04]	1.43 [0.48–4.28]
Nipple eczema	0.67 [0.34–1.34]	0.78 [0.26–2.34]	0.96 [0.35–2.63]	0.60 [0.24–1.51]	0.21 [0.03–1.65]	0.00 [0.00–0.00]
Cheilitis sicca	1.10 [0.74–1.64]	0.43 [0.22–0.85]	0.66 [0.35–1.23]	0.74 [0.45–1.21]	0.83 [0.42–1.64]	0.61 [0.21–1.74]
Perleche	0.65 [0.42–1.02]	0.75 [0.37–1.52]	0.71 [0.35–1.43]	0.63 [0.36–1.10]	0.64 [0.29–1.43]	0.79 [0.23–2.76]
Pityriasis alba	0.64 [0.36–1.11]	1.43 [0.68–2.99]	0.52 [0.20–1.39]	0.45 [0.20–0.9966]	0.78 [0.30–2.04]	0.97 [0.24–3.86]
Palmar hyperlinearity	0.73 [0.48–1.11]	0.53 [0.28–1.01]	1.11 [0.56–2.21]	0.53 [0.32–0.88]	0.45 [0.22–0.91]	0.22 [0.08–0.65]
Xerosis cutis	0.45 [0.24–0.81]	0.36 [0.15–0.86]	0.52 [0.20–1.34]	0.79 [0.32–1.91]	0.49 [0.15–1.59]	0.72 [0.07–7.07]
<b>Distribution of eczema</b>						
Trunk eczema	0.59 [0.36–0.96]	0.60 [0.28–1.28]	0.90 [0.42–1.90]	0.63 [0.34–1.15]	1.04 [0.42–2.54]	1.46 [0.30–7.19]
Hand eczema	0.79 [0.51–1.22]	0.68 [0.35–1.35]	1.12 [0.56–2.24]	0.75 [0.44–1.29]	0.62 [0.29–1.32]	0.54 [0.18–1.64]
Hands dorsal	0.95 [0.61–1.47]	0.54 [0.27–1.10]	1.12 [0.57–2.19]	0.78 [0.46–1.34]	0.79 [0.38–1.64]	0.58 [0.20–1.64]
Palmae	0.70 [0.46–1.08]	0.60 [0.30–1.20]	0.89 [0.47–1.68]	0.88 [0.54–1.43]	0.65 [0.33–1.28]	1.12 [0.40–3.15]
Head neck	0.58 [0.36–0.95]	0.42 [0.20–0.86]	0.63 [0.30–1.34]	0.54 [0.29–0.99]	0.68 [0.29–1.64]	0.99 [0.27–3.57]
Arms	0.61 [0.35–1.05]	0.67 [0.29–1.55]	0.74 [0.31–1.74]	0.91 [0.43–1.93]	0.91 [0.32–2.55]	0.78 [0.18–3.42]
Legs	0.69 [0.42–1.12]	0.72 [0.34–1.54]	0.87 [0.41–1.84]	0.66 [0.36–1.21]	1.13 [0.47–2.72]	0.66 [0.18–2.41]
<b>Course and comorbidities</b>						
Atopic com. (3–4, Ref 0–2)	0.45 [0.30–0.67]	0.37 [0.20–0.69]	0.45 [0.24–0.83]	0.27 [0.16–0.44]	0.10 [0.05–0.23]	0.07 [0.02–0.24]
Asthma	0.55 [0.37–0.83]	0.41 [0.22–0.78]	0.78 [0.42–1.43]	0.29 [0.17–0.48]	0.24 [0.12–0.50]	0.13 [0.04–0.42]
Allergic rhinitis	0.61 [0.39–0.97]	0.40 [0.21–0.78]	0.59 [0.30–1.18]	0.66 [0.38–1.15]	0.23 [0.12–0.47]	0.11 [0.04–0.32]
Food allergy	0.38 [0.25–0.57]	0.19 [0.10–0.37]	0.35 [0.19–0.65]	0.29 [0.18–0.48]	0.16 [0.08–0.34]	0.15 [0.05–0.46]
Allergic conjunctivitis	0.81 [0.54–1.22]	0.58 [0.31–1.09]	0.71 [0.39–1.32]	0.76 [0.47–1.23]	0.29 [0.15–0.58]	0.20 [0.07–0.57]
Allergies	0.55 [0.31–1.00]	0.35 [0.16–0.79]	0.27 [0.13–0.57]	0.25 [0.14–0.47]	0.16 [0.07–0.34]	0.04 [0.01–0.12]
Cardiovascular diseases	0.53 [0.31–1.00]	0.35 [0.16–0.79]	0.27 [0.13–0.57]	0.33 [0.14–0.75]	0.70 [0.30–1.63]	1.15 [0.41–3.24]
Eczema herpeticum	0.56 [0.28–1.09]	0.39 [0.11–1.30]	0.75 [0.30–1.89]	0.23 [0.08–0.66]	0.35 [0.10–1.23]	NA
Herpes simplex	0.76 [0.50–1.15]	0.53 [0.28–1.03]	1.20 [0.64–2.26]	0.48 [0.29–0.79]	0.36 [0.18–0.72]	0.39 [0.15–1.05]

(Continues)

TABLE 3 (Continued)

Age at AD onset	AD onset strata with reference 0 to <2 years					
	≥2 to <7 years	≥7 to 12 years	≥12 to 18 years	≥18 to <41 years	≥41 to <61 years	≥61 years
	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Bacterial inf.	<b>0.54 [0.36–0.82]</b>	<b>0.29 [0.14–0.60]</b>	0.58 [0.31–1.08]	<b>0.46 [0.28–0.76]</b>	<b>0.37 [0.18–0.76]</b>	0.77 [0.26–2.31]
Verrucae	1.10 [0.73–1.65]	1.23 [0.64–2.35]	1.78 [0.90–3.51]	<b>0.45 [0.28–0.73]</b>	<b>0.46 [0.24–0.90]</b>	<b>0.24 [0.09–0.67]</b>
Lifestyle and perinatal factors						
Active smoking	1.56 [0.98–2.48]	0.87 [0.38–1.96]	1.38 [0.67–2.81]	<b>2.39 [1.40–4.06]</b>	2.04 [0.95–4.40]	0.40 [0.04–3.42]
ETS (daily)	<b>1.00 [0.60–1.67]</b>	1.19 [0.56–2.55]	0.84 [0.37–1.89]	1.67 [0.97–2.90]	1.98 [0.94–4.17]	3.05 [0.91–10.24]
Never-doing-sports	0.68 [0.37–1.24]	0.62 [0.23–1.66]	1.13 [0.51–2.49]	1.68 [0.95–2.98]	<b>2.19 [1.03–4.65]</b>	<b>4.43 [1.48–13.23]</b>
Mold exposition	0.85 [0.57–1.27]	0.58 [0.31–1.11]	1.26 [0.68–2.33]	0.85 [0.53–1.37]	0.57 [0.29–1.15]	<b>0.19 [0.05–0.82]</b>
Household-size ≥ 4 persons	1.32 [0.85–2.06]	0.80 [0.37–1.76]	0.67 [0.30–1.51]	0.95 [0.52–1.72]	1.85 [0.80–4.25]	0.92 [0.13–6.51]
Academic <sup>a</sup>	1.20 [0.73–1.98]	1.36 [0.62–3.01]	0.53 [0.28–1.02]	0.62 [0.37–1.04]	<b>0.41 [0.21–0.81]</b>	<b>0.32 [0.12–0.87]</b>
Cesarean	0.62 [0.33–1.18]	0.83 [0.31–2.27]	0.48 [0.14–1.63]	0.75 [0.32–1.77]	0.31 [0.04–2.48]	0.27 [0.01–7.47]
Birthweight	1.03 [0.99–1.08]	1.01 [0.93–1.09]	1.00 [0.91–1.01]	1.06 [0.9995–1.12]	1.02 [0.92–1.13]	1.06 [0.89–1.27]
Family history						
Family history positive for allergies	1.06 [0.69–1.64]	0.62 [0.33–1.18]	<b>0.41 [0.22–0.77]</b>	0.58 [0.36–0.95]	0.22 [0.10–0.48]	0.47 [0.14–1.58]
Maternal AD	0.71 [0.45–1.13]	1.23 [0.63–2.38]	0.91 [0.46–1.81]	0.92 [0.54–1.56]	<b>0.38 [0.15–0.97]</b>	0.36 [0.09–1.47]
Maternal FA	0.64 [0.40–1.03]	0.47 [0.20–1.09]	0.45 [0.19–1.05]	<b>0.53 [0.28–0.99]</b>	<b>0.09 [0.01–0.64]</b>	NA
Maternal AR	1.09 [0.72–1.65]	0.80 [0.40–1.60]	0.77 [0.39–1.53]	0.98 [0.58–1.66]	0.59 [0.24–1.41]	0.30 [0.04–2.52]
Mat. asthma	0.90 [0.54–1.52]	0.97 [0.43–2.20]	0.66 [0.27–1.62]	0.58 [0.28–1.20]	0.63 [0.23–1.74]	0.83 [0.19–3.64]
Paternal AR	1.08 [0.68–1.73]	1.04 [0.49–2.22]	0.76 [0.34–1.70]	0.69 [0.36–1.33]	0.23 [0.05–1.02]	0.33 [0.04–3.08]

Note: Associations of clinical and epidemiological factors with AD ( $n=736$ ) versus controls ( $n=167$ , non-atopic:  $n=76$ , atopic:  $n=91$ ) from multinomial logistic regression models with strata of onset at age: (i) 0 to <2 years (infancy,  $n=325$  (44.17%)); (ii) ≥2 to <7 ( $n=142$  (19.3%)); (iii) ≥7 to <12 ( $n=142$  (11.5%)); (iv) ≥12 to <18 years ( $n=49$  (6.7%)); (v) ≥18 and <41 years:  $n=94$  (12.8%); (vi) ≥41 and <61 years:  $n=46$  (6.2%) and (vii) ≥61 years:  $n=34$  (4.6%). All effect sizes are adjusted (a) for age and sex and given in aOdds Ratios (aOR) with 95% Confidence intervals (CI). Bold and yellow boxes:  $p$ -values < .05.

Abbreviations: AD, atopic dermatitis; AR, allergic rhinitis; FA, food allergy.

<sup>a</sup>Academic defined as education at least A-level up to university degree.

### 3.8 | FAMD and cluster analyses

Analyses of (i) all subjects (Figure 2) and (ii) only AD patients (Figure 3) revealed three clusters each with distinct characteristics detailed in the Results S1, Tables S7 and S8. Patients with childhood-onset, particularly infancy-onset, were mainly represented in the most “atopic” clusters with highest numbers of atopic comorbidities, atopic stigmata, higher levels of tlgE, and eosinophils (Figures 2 and 3, Table S8). Adult-onset AD, especially onset ≥61 years, grouped mainly in clusters with lower contributions of personal and familial atopy and higher frequencies of physical inactivity (Figures 2 and 3, Table S8).

## 4 | DISCUSSION

The prevalence and incidence of AD overall are increasing,<sup>1,6,54</sup> as well as the evidence for AD with onset in adulthood in previously

unaffected subjects or relapses of AD in adulthood after long remission phases.<sup>1,2,9,12,13,20,30</sup> Thus, a better understanding of factors associated with adult-versus childhood-onset AD is needed to design adequate preventive strategies. We found (i) maternal AD being the main familial RF for both onset-groups; (ii) maternal FA being an additional RF for childhood-onset AD; (iii) active smoking the main lifestyle factor associated with adult-onset AD versus controls; (iv) an academic background doubling the odds of childhood-onset AD versus controls; (v) each additional atopic stigma approximately doubling the odds of AD versus controls; (vi) palmar hyperlinearity associated with childhood-onset versus controls<sup>atopic</sup>; (vii) white dermographism associated with childhood-versus adult-onset AD; (viii) a “pure” AD without atopic comorbidities in only 12% of patients with childhood-onset, but in 28% of adult-onset AD overall with infancy-onset AD as the most atopic (9% pure), late-adult-onset (50% pure) the least atopic subgroup; (ix) adult-onset AD more prone to AR, but with reduced odds of multiple atopic comorbidities than childhood-onset AD; (x) FA nearly tripling the odds of childhood-onset AD versus

no-AD; (xi) increased IgE levels associated with both childhood- and adult-onset AD versus controls; (xii) childhood-onset AD, particularly infant-onset, grouping mainly in “high-atopic”-clusters, middle- and late-adult-onset AD preferentially in clusters with lower contributions of personal and familial atopy and high frequencies of physical inactivity. Associated factors and their impact partly differed depending on AD onset in different phases of child- and adulthood.

Our observed proportion of adult-onset  $\geq 18$  years in 23.6% of patients aligns with other European countries.<sup>12</sup> The distribution and associated factors of adult-compared to childhood-onset of AD in the literature are varying depending on study design: longitudinal versus cross-sectional, self-reported versus physician-diagnosed AD, diagnostic criteria of AD, numbers of participants, cohorts from countries with different conditions potentially influencing the onset and phenotype of AD such as ethnicity, climatic conditions, sociodemographic factors, particulate matter, and others.

Here, we analyzed cross-sectional data of mainly Caucasian adults from Germany and Switzerland with the strengths of physician-diagnosed AD according to Hanifin and Rajka, a large age range from 18 to 89 years, detailed assessment of AD severity and phenotypic traits by experienced dermatologists plus self-reported information on the disease course and numerous other clinical and epidemiological factors not only for AD, but also controls.

We found active smoking to be the main modifiable factor for onset of AD in early and middle adulthood compared to controls. Also, daily ETS tended to be associated with AD compared to controls, especially with adult-onset AD. Both active smoking and daily ETS doubled the odds of AD with onset in early adulthood compared to childhood. Active smoking can exert multiple pathophysiological effects on cellular and humoral immunity<sup>55</sup> and also contribute to skin barrier dysfunction via reactive oxygen species.<sup>56–58</sup> Current and former active smoking as well as ETS have also been shown to be associated with physician-diagnosed adult-onset AD compared to controls in a Taiwanese study,<sup>59</sup> but not with self-reported adult-onset AD in US women.<sup>60</sup> The BCS associated adulthood smoking with adult-onset AD both versus controls and childhood-onset AD with slightly lower effect sizes than our study.<sup>2</sup> Conversely, an US study did not find differences between adult- and childhood-onset AD depending on the current smoking status.<sup>15</sup> Generally, passive and active smoking have been associated with an increased prevalence of AD,<sup>56</sup> active smoking also with both self-reported<sup>61,62</sup> and physician-assessed<sup>8,62</sup> AD severity. Besides biological effects, this might potentially be ascribed to a worse health behavior because of a higher psychological burden<sup>6,63</sup> in severe AD.

Regarding other lifestyle factors, we observed a trend towards protective effects of sports on adult-onset AD compared to controls. Broad anti-inflammatory effects have been reported for regular PA.<sup>64</sup> Our findings align with previously found protective effects of PA on atopic diseases overall,<sup>65</sup> on AD severity,<sup>8</sup> and less PA in AD in United States,<sup>66</sup> although not in Swedish<sup>67</sup> adults. Moderate-intensity aerobic exercise also improved dermatitis in allergic inflammation in mouse models.<sup>68</sup> We further found an academic background associated with childhood-onset AD versus

controls<sup>atopic</sup> and reduced odds of middle- and late-adult-onset AD versus childhood-onset. This concurs with the association of a lower childhood socioeconomic status with adult-onset AD found in the BCS.<sup>2</sup> Our analyses of a possible relationship between sociodemographic and lifestyle factors revealed a higher frequency of smokers and lack of PA in AD patients without compared to those with academic background. This aligns with the generally found association of smoking and nicotine dependence with a lower educational level and socio-economic status, single marital status, older age, higher stress, and BMI also irrespective of AD.<sup>69,70</sup> Our findings further support previously reported associations of a small household size and mold exposition with increased probability of AD.<sup>1</sup>

We found maternal AD being the main familial RF associated with both adult- and childhood-onset AD versus controls, childhood-onset AD additionally with maternal FA. Consistently, several epidemiological studies have suggested a preferential transmission of allergy risk through mothers.<sup>71,72</sup>

Regarding the phenotype, a higher number of atopic stigmata was associated with higher odds of both childhood- and adult-onset AD compared to controls in our study. However, adult-onset AD featured less atopic stigmata and comorbidities than childhood-onset AD with varying effect sizes depending on type of comorbidities and life period. Patients with adult-onset AD had reduced odds of multiple atopic comorbidities at once, especially in late adulthood. The association to multiple type 2 (T2) related atopic comorbidities might indicate a more pronounced T2-inflammation in childhood compared to adult-onset AD where other factors might have a higher impact. Accordingly, we also observed two third lower odds of self-reported allergies in adult compared to childhood-onset AD. Also, other studies reported adult-versus childhood-onset to be associated with lower proportions of allergies and personal or familial allergic diseases<sup>2,9,12,15</sup> with AR as the most frequent atopic comorbidity<sup>2,12</sup> and asthma with lower<sup>2,15,33</sup> or similar<sup>12</sup> proportions in adult-versus childhood-onset AD.

In our cohort, AR was associated with adult-onset AD and with atopic controls versus childhood-onset AD. We further found FA increasing the odds of childhood-onset AD threefold compared to atopic controls consistent with multiple studies associating food sensitization with AD onset in early infancy.<sup>10,73,74</sup>

We found nearly all atopic stigmata more frequent in childhood- than in adult-onset AD than in controls consistent with other studies.<sup>9,15</sup> White dermographism showed the highest differences and doubled the odds of childhood-onset AD compared to adult-onset AD with the lowest odds of late-adult-onset AD. Palmar hyperlinearity has been associated with filaggrin loss-of-function mutations,<sup>1,53,75</sup> of which at least some have been previously linked only to AD with childhood-onset before age 8, but not in later child- or adulthood.<sup>76</sup> Herein, palmar hyperlinearity doubled the odds of childhood-onset AD overall versus controls<sup>atopic</sup> and was less likely with disease onset in adulthood than in infancy. Our findings are consistent with higher frequencies of cheilitis,<sup>9,15</sup> Dennie-Morgan fold,<sup>9,15</sup> pityriasis alba,<sup>9,15</sup> anterior neck fold,<sup>15</sup> perleche,<sup>9</sup> dirty neck,<sup>9</sup> periorbital darkening<sup>9</sup> in childhood versus adult-onset

reported in the United States,<sup>15</sup> and/or another German<sup>9</sup> cohort. The German,<sup>9</sup> but not the United States<sup>15</sup> cohort also found higher frequencies of white dermographism. None of the upper-mentioned atopic stigmata was found to differ by AD onset in an Korean cohort,<sup>33</sup> suggesting a large variation of adult-onset phenotypes among ethnicities.

We did not find systemic differences in severity and localization of eczema between adult- and childhood-onset AD overall. Similarly, clinician-<sup>9,15,33</sup> or patient-reported<sup>15</sup> AD severity,<sup>9,15,33</sup> pruritus,<sup>15</sup> or xerosis<sup>15,33</sup> did not differ in other cohorts by AD onset. Herein, trunk eczema tended to be associated with adult-onset versus childhood-onset AD consistent with a Korean study.<sup>33</sup> However, after adjustment for all covariates including severity, we did not find significant differences between adult- and childhood-onset overall in any body region in contrast to other studies reporting a higher probability of hand and/or head-neck dermatitis,<sup>12,15</sup> potentially due to differences in ethnicity and study design.

The susceptibility of AD to cutaneous infections is well-known.<sup>1,6</sup> Herein, adult-onset AD tended to be less prone to bacterial infections than childhood-onset AD consistent with a Korean study.<sup>33</sup> We further found a higher proneness to EH in patients with onset in infancy and adolescence while being less likely in early-adult-onset. Besides the association with tIgE with both childhood- and adult-onset AD, we also observed a trend towards stronger associations of circulating eosinophils with middle- and late-adult-onset-AD providing an interesting link to the eosinophilic endotype in adult-onset asthma.<sup>77</sup> Due to the explorative approach with a focus on the evaluation of factors associated with age of AD onset in different life periods, no corrections for multiple testing were applied in the LR models, only in the cluster analyses. Other limitations of our study include lack of genotyping, no measurement of specific IgE and biomarkers other than tIgE and eosinophils, and the cross-sectional design with a potential recall-bias of the self-reported age of AD onset, especially in older patients. However, this recall bias applies to nearly all studies about adult-onset AD, which are mostly cross-sectional. A longitudinal follow-up of birth cohorts up to late adulthood with physician-assessed AD would be highly desirable, but is unfortunately difficult due to economic reasons and drop-out-rates. Most longitudinal birth cohort studies on AD cover the childhood, some also adolescence, but data from early and middle adulthood are sparse and longitudinal data on AD up to late-adulthood to our knowledge non-existent. Further, our number of participants was lower than those from survey- or insurance-data-based studies, yet more detailed and with physician-based diagnosis, assessment of AD severity and atopic stigmata. The herein identified partly common, but also different associated factors (i) suggest varying endo- and exogeneous mechanisms underlying adult-versus childhood-onset AD, (ii) might contribute to a deeper understanding and better assessment of the individual risk to develop AD in different life periods with (iii) potential for prevention of modifiable factors. Further studies are warranted to investigate the underlying differences in the endotype and genotype of adult-versus childhood-onset of AD.

## AUTHOR CONTRIBUTIONS

Study concept and design: LM, MTS, NH, ER, EB, PSG, CTH, CA, RL, MCB, TB. Acquisition of data: LM, MTS, NH, JB, SM, RH, AD, EB, DF, GH, DL, CL, ER, PSG, MCB, CTH, TB. Recruitment of patients: LM, JB, RH, SM, EB, DF, GH, DL, CL, ER, MCB, PSG, CTH, TB. Analysis and interpretation of data: LM, MTS, MS, TB. Drafting of the manuscript: LM, MTS, MS, TB. Critical revision of the manuscript for important intellectual content: NH, SM, RH, JB, DF, CR, AD, AN, EB, GH, MR, DL, CL, ER, PSG, CTH, CA, MCB, RL, TB. Obtained funding: PSG, CTH, CA, MCB, RL, TB.

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## CONFLICT OF INTEREST STATEMENT

Thomas Bieber was speaker, and/or consultant and/or investigator for: AbbVie, Allmiral, AnaptysBio, Arena, Asana Biosciences, ASLAN pharma Bayer Health, BioVerSys, Böhringer-Ingelheim, Connect Pharma, Dermavant/Roivant, Domain Therapeutics, Eli Lilly, Galderma, Glenmark, GSK, Incyte, Innovaderm, IQVIA, Janssen, Kirin, Kymab, LEO Pharma, LG Chem, L'Oréal, MSD, Novartis, Numab, OM Pharma, Pfizer, Pierre Fabre, Q32bio, RAPT, Sanofi/Regeneron, UCB. Thomas Bieber is founder and chairman of the non-profit biotech company "Davos Biosciences". Laura Maintz is or was investigator for AbbVie, Allmiral, Bristol-Myers Squibb, Eli Lilly, Galderma, LEO Pharma, OM Pharma, Pfizer, Sanofi/Regeneron, was advisor for Eli Lilly, speaker for AbbVie and LEO Pharma and received research funding from Eli Lilly, LEO Pharma and Sanofi Genzyme. M.C. Brügggen has received grants and research funding from the Swiss National Science foundation (SNF), Freenovation foundation, LEO

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### SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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