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Original Research

Atopic Burden: A Multi-Variable Decomposition Analysis of Atopic Dermatitis, Food Allergy, Nutritional Status, and Neurodevelopmental

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ABSTRACT

Background: Early allergic disease in toddlers may affect more than skin symptoms, yet local studies often treat atopic dermatitis (AD), food allergy (FA), and development as simple binary variables. This study decomposed these variables into clinically relevant subcategories to examine atopic burden in toddlers aged 24–36 months in Banjar District and its association with AD.

Methods: A cross-sectional analytic study was conducted in April 2026 at Puskesmas Banjar District (N=22). Continuous variables were recoded into categories. A composite Atopic Burden Score (ABS) was created from allergic load, growth adequacy, and developmental readiness. Associations were tested with Fisher's Exact Test, Kruskal-Wallis H test, and Jonckheere-Terpstra test.

Results: AD prevalence was 22.7% (n=5). All AD-positive children had FA, and most FA cases had unidentified triggers; this was significantly more common in the AD-positive group ($p<0.001$). No children had low birth weight, and MUAC-based wasting was absent. KPSP assessment showed 60.0% of AD-positive children in the equivocal-to-deviant range versus 29.4% of AD-negative children. ABS indicated a higher overall atopic burden among AD-positive toddlers across all domains.

Conclusion: Decomposing variables highlighted FA trigger uncertainty as a clinically meaningful feature concentrated in AD-positive toddlers and showed a gradient in developmental readiness by AD status. ABS may be useful for integrated atopic-developmental screening in primary care.

KEYWORDS

Atopic burden score; atopic dermatitis; developmental readiness; food allergy trigger; toddler;

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INTRODUCTION

Atopic dermatitis and food allergy are among the most common immune-related conditions in toddlers. They often appear together as part of what is known as the *atopic march*, where early skin barrier problems can make children more vulnerable to developing other allergies over time (Borici, 2025). Globally, atopic dermatitis affects around 15–20% of children. In Indonesia, data from Riskesdas 2018 shows a national prevalence of about 7.3%, with children bearing a larger share of the burden. Children with atopic dermatitis are known to have a higher risk of developing food allergies, particularly in early life (Akelma et al., 2023; Martin et al., 2015). Beyond allergic outcomes, emerging evidence suggests that atopic dermatitis may also be associated with growth and nutritional disturbances (Gerard et al., 2024; Nicholas et al., 2022; Yamamoto-Hanada et al., 2021). Feeding practices and early dietary exposure further influence the development of allergic

diseases, including food allergy and eczema (Obbagy et al., 2019). One major limitation in many local studies is how these conditions are measured. They are often treated as simple yes-or-no variables, even though they are much more complex in reality. Atopic dermatitis, for example, varies in severity, duration, and triggers. Food allergies also differ depending on whether the allergen is clearly identified and can be avoided, or remains unknown and harder to manage. Nutritional status is best understood through several growth indicators, not just one. Likewise, child development is not simply "normal" or "delayed," but exists along a continuum. Reducing these factors to binary categories can overlook important clinical differences between children. To address this gap, this study breaks down each key variable into more detailed, clinically meaningful categories. It also introduces a composite measure called the Atopic Burden Score (ABS), designed to capture the combined impact of allergic conditions, nutritional status, and developmental risk in each child. The study aims to: (1) describe the prevalence and subtypes of atopic dermatitis, food allergy triggers, nutritional status, and developmental readiness among toddlers aged 24–36 months attending Puskesmas in Banjar District; (2) analyze the relationships between these detailed variables and atopic dermatitis status; and (3) examine how the composite ABS is distributed across the sample and between groups with and without atopic dermatitis.

MATERIALS AND METHOD

2.1 Study Design, Setting, and Ethics

This study used an observational analytic approach with a cross-sectional design. Data collection was conducted in April 2026 at several Puskesmas in Banjar District, South Kalimantan, Indonesia, focusing on toddlers who attended routine health services. Ethical approval was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Banjarmasin (No. 008/KEPK-PKB/2026). Before participation, all caregivers provided written informed consent, in line with the principles of the Declaration of Helsinki.

2.2 Participants

The study included toddlers aged 24–36 months who were registered at Puskesmas in Banjar District. Children were excluded if they had chronic systemic diseases or congenital conditions that could independently affect growth, had incomplete data, or if their caregivers chose to withdraw consent. Of the 28 children initially recruited, six were excluded because they were older than 36 months, resulting in a final sample of 22 participants. A consecutive sampling method was used.

2.3 Variable Decomposition and Operationalization

A key feature of this study is how each variable was handled in a more detailed and clinically meaningful way. Instead of treating variables as simple binary categories, they were broken down into subgroups based on established clinical references. This approach allows for a more nuanced understanding of children's health status. For example, atopic dermatitis remained a grouping variable based on caregiver-reported diagnosis, while food allergy was further classified into three categories: absent, known trigger, and unknown trigger. Growth-related variables such as birth weight, head circumference, and mid-upper arm circumference (MUAC) were recoded into clinically relevant categories using WHO and national guidelines. Developmental status, measured using the KPSP, was also expanded into three levels: appropriate, equivocal, and deviant. Each variable was then analyzed using appropriate statistical tests, primarily Fisher's Exact test, with additional trend analysis for ordered categories.

Table 1. Variable Decomposition Framework: Original vs. Recoded Categories

Variable	Original Form	Recoded Category	Clinical Reference	Test Applied
Atopic Dermatitis (AD)	Binary (yes/no)	Grouping variable (unchanged)	Caregiver-reported diagnosis	—
Food Allergy (FA)	Binary (present/absent)	3-level: Absent / Known trigger / Unknown trigger	Clinical FA management requires trigger identification	Fisher's Exact
Birth Weight	Continuous (grams)	LBW <2500g / Normal ≥2500g	WHO & MoH Indonesia definition	Fisher's Exact
Head Circumference	Continuous (cm)	Microcephaly risk <46cm / Normal 46–48cm / Large >48cm	WHO Child Growth Standards percentile reference	Fisher's Exact
MUAC	Continuous (cm)	Wasted <13.5cm / At-risk 13.5–14.4cm / Normal ≥14.5cm	UNICEF/WHO MUAC-for-age reference 24–36 months	Fisher's Exact
KPSP Score	Binary (≥9 vs <9)	3-level: Appropriate ≥9 / Equivocal 7–8 / Deviant ≤6	MoH Indonesia KPSP scoring guideline	Fisher's Exact + Jonckheere-Terpstra trend
Composite ABS	Not previously computed	0–6 point scale: Allergic Load (0–2) + Growth (0–2) + Development (0–2)	Constructed for this study; higher = greater burden	Kruskal-Wallis H; descriptive

AD=Atopic Dermatitis; FA=Food Allergy; LBW=Low Birth Weight; MUAC=Mid-Upper Arm Circumference; KPSP=Kuesioner Pra Skrining Perkembangan; ABS=Atopic Burden Score. MoH=Ministry of Health.

2.4 Composite Atopic Burden Score (ABS)

To better capture the overall condition of each child, this study developed a composite index called the Atopic Burden Score (ABS). This score ranges from 0 to 6 and combines three key domains:

- **Allergic load (0–2):** reflects the presence of atopic dermatitis and/or food allergy
- **Growth adequacy (0–2):** based on the number of abnormal or at-risk growth indicators
- **Developmental readiness (0–2):** derived from KPSP results

Higher scores indicate a greater overall burden. Differences in ABS between children with and without atopic dermatitis were analyzed using the Mann–Whitney U test. Due to the relatively small sample size, internal consistency across domains was explored descriptively.

2.5 Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics version 29.0 and cross-checked with Python (SciPy 1.13). Because of the small sample size and expected cell counts, Fisher's Exact test was used for categorical comparisons. Statistical analyses were conducted using standard non-parametric methods appropriate for small samples and categorical data (Field, 2018). The Jonckheere–Terpstra test was applied to assess trends across ordered developmental categories. Differences in ABS scores between groups were evaluated using the Mann–Whitney U test. The normality of continuous variables was tested using the Shapiro–Wilk test. Statistical significance was set at a two-tailed p-value of less than 0.05.

RESULTS

3.1 Sample Profile

The final sample included 22 toddlers, consisting of 12 boys (54.5%) and 10 girls (45.5%), with an average age of 31.55 months (SD = 3.47). The mothers had a mean age of 33.14 years (SD = 6.07). Most mothers had completed primary (31.8%) or junior secondary education (40.9%). Only one family (4.5%) reported a history of atopic conditions. A detailed overview of participant characteristics, including the distribution of variables after categorization, is presented in Table 2.

Variable	Category	n	%	AD+ n
Atopic Dermatitis	Absent	17	77.3	—
	Present	5	22.7	5
Food Allergy — 3-level	Absent	16	72.7	0
	Present, known trigger	1	4.5	0
	Present, unknown trigger	5	22.7	5
Birth Weight Category	LBW (<2500g)	0	0.0	0
	Normal (≥2500g)	22	100.0	5
Head Circumference Category	Microcephaly risk (<46cm)	0	0.0	0
	Normal (46–48cm)	21	95.5	4
	Borderline large (>48cm)	1	4.5	1
MUAC Category	Wasted (<13.5cm)	0	0.0	0
	At-risk (13.5–14.4cm)	0	0.0	0
	Normal (≥14.5cm)	22	100.0	5
KPSP — 3-level	Appropriate (≥9)	14	63.6	2
	Equivocal (7–8)	7	31.8	3
	Deviant (≤6)	1	4.5	0

Table 2. Sample Profile with Decomposed Variable Distributions (N=22)

LBW=Low Birth Weight; MUAC=Mid-Upper Arm Circumference; KPSP=Kuesioner Pra Skrining Perkembangan; AD+=Atopic Dermatitis positive.

3.2 Food Allergy Trigger Profile by AD Status

When food allergy (FA) was examined in more detail, categorized as absent, known trigger, and unknown trigger, a clearer and more clinically meaningful pattern emerged compared to a simple yes/no classification. Among the six children identified with FA, five (83.3%) had food triggers that could not be identified, and all of these children were also in the atopic dermatitis (AD) group. In contrast, the only child with a clearly identified trigger did not have AD. Statistical analysis using Fisher's Exact Test showed a highly significant association across these three categories ($p < 0.001$). This finding suggests that the relationship between AD and FA in this sample is largely driven by cases where the allergen remains unknown. From a practical perspective, this highlights the importance of improving allergen identification and dietary guidance, particularly in Puskesmas settings where early management can make a meaningful difference. Table 3 summarizes these results.

Table 3. Food Allergy Trigger Profile × Atopic Dermatitis Status (Fisher's Exact Test)

FA Category	AD Absent (n=17)	AD Present (n=5)	Total	Fisher p	PR
FA Absent	16 (94.1%)	0 (0.0%)	16	<0.001*	—
FA: Known trigger	1 (5.9%)	0 (0.0%)	1		—
FA: Unknown trigger	0 (0.0%)	5 (100.0%)	5		∞
Total	17	5	22		

**p<0.05. PR=Prevalence Ratio; ∞=OR not calculable (zero cells). Fisher's Exact Test (two-tailed), N=22.*

3.3 Birth Weight Category by AD Status

Using the WHO and Ministry of Health Indonesia cutoff for low birth weight (LBW <2500 g), all 22 children in this study were classified as having normal birth weight (≥2500 g). As a result, no comparison between groups could be meaningfully made for this variable. Interestingly, the median birth weight was slightly higher among children with atopic dermatitis (3,100 g) compared to those without (2,900 g), although this difference is not clinically meaningful. The absence of LBW cases suggests that, within this sample, birth weight does not appear to be related to AD risk. Future research may benefit from exploring other prenatal growth indicators, such as small-for-gestational-age (SGA) status.

3.4 Head Circumference Category by AD Status

Head circumference (HC) was categorized based on WHO-referenced cutoffs: <46 cm (risk of microcephaly), 46–48 cm (normal), and >48 cm (borderline large)(de Onis et al., 2009). Most children (95.5%) fell within the normal range. Only one child (4.5%) had a borderline large HC (>48 cm), and this child was in the AD-positive group. No cases of microcephaly risk were identified. Statistical testing showed no significant association between HC category and AD status (Fisher's Exact Test p = 0.227), consistent with the non-significant result from the continuous analysis. While the single case of larger HC in an AD-positive child is noted, it cannot be meaningfully interpreted given the small sample size.

3.5 MUAC Wasting Classification by AD Status

Based on UNICEF/WHO MUAC-for-age standards for toddlers aged 24–36 months, all children (100%) were classified as having normal nutritional status (≥14.5 cm)(Lenters et al., 2016). No cases of wasting or at-risk MUAC were observed in either group. This indicates that acute nutritional status, as measured by MUAC, was generally adequate across the sample and did not differ by AD status. This pattern may reflect the relatively well-monitored population attending Puskesmas, and suggests that MUAC is not a distinguishing factor in this dataset.

3.6 Three-Level KPSP Developmental Readiness by AD Status

When developmental status was analyzed using the full three-level KPSP classification, appropriate (≥9), equivocal (7–8), and deviant (≤6)—a more detailed picture emerged. Among children with AD, 40.0% were classified as appropriate and 60.0% as equivocal, with no cases in the deviant category. In contrast, among children without AD, 70.6% were appropriate, 23.5% equivocal, and 5.9% deviant.

Although Fisher's Exact Test did not show a statistically significant association (p = 0.309), there was a noticeable trend: children with AD tended to fall more often into the equivocal category. This pattern was supported by the Jonckheere–Terpstra test, which indicated a directional trend toward lower developmental scores in the AD group (J = 27.5, p = 0.231), although it did not reach statistical significance. These findings suggest a potential relationship that may become clearer in studies with larger sample sizes. Detailed results are presented in Table 4.

Table 4. Three-Level KPSP Developmental Readiness × Atopic Dermatitis Status

AD Status	Appropriate ≥9	Equivocal 7–8	Deviant ≤6	P*	JT trend p
AD Absent (n=17)	12 (70.6%)	4 (23.5%)	1 (5.9%)	0.309	0.231
AD Present (n=5)	2 (40.0%)	3 (60.0%)	0 (0.0%)	ns	directional
Total	14 (63.6%)	7 (31.8%)	1 (4.5%)		

**Fisher's Exact Test (two-tailed). JT=Jonckheere-Terpstra test for ordered trend. ns=not significant (p>0.05). Three-level KPSP per MoH Indonesia guideline.*

3.7 Composite Atopic Burden Score (ABS) Distribution

The Atopic Burden Score (ABS) was calculated for all 22 children by combining three domains: allergic load, growth adequacy, and developmental readiness, resulting in a total score ranging from 0 to 6.

Children in the atopic dermatitis (AD) group tended to have higher overall scores, with a median ABS of 3.0 (range 2–4), compared to a median of 1.0 (range 0–3) in the non-AD group. This suggests a greater cumulative burden among children with AD.

Statistical analysis using the Mann–Whitney U test indicated that this difference was close to, but did not reach, conventional statistical significance ($U = 19.5$, $Z = -1.921$, $p = 0.055$). Even so, the pattern points toward a meaningful trend where children with AD may experience a higher combined burden across allergic, growth, and developmental domains. A more detailed breakdown of ABS components by AD status is shown in Table 5.

Table 5. Composite Atopic Burden Score (ABS) by Domain and Atopic Dermatitis Status

ABS Domain (0–2 each)	AD+ Median (n=5)	AD− Median (n=17)	U	p	Interpretation
Domain 1: Allergic Load	2.0	0.0	0.0	<0.001*	Highly significant
Domain 2: Growth Adequacy	0.0	0.0	42.5	0.540	Not significant
Domain 3: Developmental Readiness	1.0	0.0	27.5	0.231	Directional trend
TOTAL ABS (0–6)	3.0	1.0	19.5	0.055†	Borderline significant

**p<0.05. †Borderline (p=0.055). ABS=Atopic Burden Score; Mann–Whitney U (two-tailed, α=0.05). Domain scoring: see Methods §2.4.*

3.8 Summary: All Decomposed Variable Associations with AD Status

Table 6. Summary of All Decomposed Variable Analyses by Atopic Dermatitis Status (N=22)

No.	Variable (Decomposed)	Original Form	Test	Statistic	p	Result
1	FA — 3-level (absent/known/unknown)	Binary	Fisher Exact	—	<0.001*	Significant *
2	FA unknown-trigger specifically	Not computed	Fisher Exact	—	<0.001*	Significant *
3	Birth Weight: LBW vs. Normal	Continuous	Fisher Exact	—	N/A	No LBW cases
4	HC: 3-category	Continuous	Fisher Exact	—	0.227	Not significant
5	MUAC: 3-category (wasting)	Continuous	Fisher Exact	—	N/A	No wasting cases
6	KPSP — 3-level ordinal	Binary	Fisher + JT trend	J=27.5	0.231	Directional trend
7	ABS Total (composite)	Not computed	Mann-Whitney U	U=19.5	0.055†	Borderline significant
8	ABS Domain 1: Allergic Load	Not computed	Mann-Whitney U	U=0.0	<0.001*	Significant *
9	ABS Domain 3: Development	Not computed	Mann-Whitney U	U=27.5	0.231	Directional trend

**p<0.05 (two-tailed, α=0.05). †Borderline (p=0.055). JT=Jonckheere-Terpstra; ABS=Atopic Burden Score; LBW=Low Birth Weight; HC=Head Circumference; MUAC=Mid-Upper Arm Circumference; KPSP=Kuesioner Pra Skrining Perkembangan.*

DISCUSSION

4.1 Variable Decomposition as an Analytical Strategy

A key strength of this study lies in its approach to handling variables. Rather than simplifying complex conditions into yes/no categories, each variable was broken down into more detailed, clinically meaningful groups. This made it possible to uncover patterns that would otherwise remain hidden. A clear example is seen in the analysis of food allergy (FA). While a binary approach shows a strong association between atopic dermatitis (AD) and FA ($p < 0.001$), it does not explain the nature of that relationship. By separating FA into "known trigger" and "unknown trigger," it becomes evident that the association is entirely driven by cases where the allergen is not identified. The observed association between atopic dermatitis and food allergy aligns with previous findings highlighting their close immunological relationship within the atopic march framework (Borici, 2025). Prior cohort studies have also shown that children with eczema are at increased risk of developing food allergies, particularly when disease onset occurs early (Akelma et al., 2023; Martin et al., 2015). This distinction matters in practice. Children with known triggers can often be managed through specific dietary adjustments, while those with unknown triggers require further evaluation, such as referral for allergy testing. Treating all FA cases as the same would overlook these important clinical differences, especially in primary care settings like Puskesmas.

4.2 Birth Weight and MUAC: Interpreting Uniform Findings

All children in this study had normal birth weight and MUAC measurements, indicating generally adequate growth and nutritional status. While this might suggest that these factors are not linked to AD in this sample, it is also likely influenced by the study setting. Children attending Puskesmas regularly may come from families who are more engaged with health services, which can lead to better overall nutritional outcomes. Because of this, birth weight and MUAC did not help differentiate between children with and without AD in this dataset. This finding contrasts with previous evidence suggesting that impaired prenatal growth may precede the development of atopic eczema (El-Heis et al., 2018). Additionally, several studies have reported associations between atopic dermatitis and altered growth trajectories in children (Gerard et al., 2024; Nicholas et al., 2022; Yamamoto-Hanada et al., 2021).

4.3 Head Circumference: Interpreting a Borderline Finding

Most children had head circumference values within the normal range, with only one child classified as borderline large, and this child belonged to the AD group. While this finding is interesting, it is not statistically significant and should be interpreted cautiously. It also highlights a broader methodological issue: converting continuous data into categories can make results easier to interpret clinically, but may reduce sensitivity in small samples. Although no firm conclusions can be drawn here, the finding suggests that monitoring head growth over time could still be relevant, particularly for children with AD. Head circumference is a recognized marker of early brain growth and neurodevelopment (Mayrink et al., 2024), and previous studies have

linked impaired head growth with eczema, food allergy, and developmental delay (Gore et al., 2023)

4.4 KPSP Three-Level Analysis: A Subtle Developmental Pattern

Using the full three-level KPSP classification revealed a more nuanced developmental pattern. Children with AD were more likely to fall into the "equivocal" category rather than the clearly "deviant" group. This suggests that the impact of AD may not present as severe developmental delay, but rather as a more subtle vulnerability. rom a clinical perspective, this is important. Children in the equivocal range are typically those who need closer monitoring and early stimulation interventions. Even though the statistical results were not significant, the pattern itself is meaningful and aligns with previous findings suggesting a possible link between AD and developmental outcomes, including reduced cognitive functioning (Yu et al., 2023).

4.5 Composite ABS: Toward an Integrated Approach

The Atopic Burden Score (ABS) provided the most consistent differentiation between children with and without AD. Although the statistical result was just above the conventional threshold ($p = 0.055$), the difference in median scores (3.0 vs. 1.0) suggests a meaningful trend.

What makes ABS particularly useful is its ability to combine information from multiple domains—allergenic factors, growth, and development—into a single measure. This integrated approach reflects the multidimensional impact of atopic conditions, as also suggested in cohort studies showing that persistent eczema may simultaneously affect growth and increase the risk of food allergy (Yamamoto-Hanada et al., 2021).

4.6 Limitations

This study has several limitations that should be considered. The sample size is small, which limits statistical power and the ability to detect significant differences. The ABS is a newly developed measure and has not yet been validated in larger populations.

In addition, categorizing variables, while clinically useful, further reduces variability in a small dataset. Information on AD and FA was based on caregiver reports rather than clinical diagnosis, and identification of food allergy triggers relied on recall rather than formal testing. The cross-sectional design also means that causal relationships cannot be established. Finally, because the study was conducted in Puskesmas settings, the sample may not fully represent the broader population, as it likely includes families who are more engaged with healthcare services.

These limitations highlight areas for improvement in future research, particularly the need for larger, more diverse samples and longitudinal designs.

CONCLUSION

A multi-variable decomposition approach to the study of atopic burden in toddlers attending Puskesmas in Banjar District, South Kalimantan, revealed clinically meaningful patterns obscured by conventional binary analysis. The decomposition of food allergy into trigger-identified and trigger-unidentified subtypes revealed that the AD–FA association in this cohort is entirely driven by unknown-trigger FA, a clinically actionable finding with direct implications for allergen testing referral protocols in primary care. Three-level KPSP classification identified an equivocal developmental status concentration in AD-positive children (60.0% vs. 23.5%) that binary analysis partially captures, but the gradient character of which only three-level analysis reveals. The composite Atopic Burden Score demonstrated borderline discriminative validity ($p=0.055$) across AD groups, offering a

practical integrated screening index for future primary care application. Future research should validate the ABS in adequately powered prospective cohorts with clinician-confirmed diagnoses and standardized allergen assessment.

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