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Associations between parental protective motivation, behaviors, and child outcomes in allergic diseases: a cross-sectional study based on protection motivation theory

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Abstract

Background The rising burden of pediatric allergic diseases underscores parental intentions and behaviors as critical to allergic prevention and management. This study aims to develop and validate a Protection Motivation Theory (PMT) based scale for parents of children with allergic diseases, and to examine the associations between parental protection motivation, their management intentions and behaviors, and pediatric health outcomes.

Methods We conducted a cross-sectional study among parents of children with allergic diseases at Hangzhou Children's Hospital, Zhejiang Province, China, from July to December 2022. The PMT scale was developed using data from a pilot survey ($N=440$) and validated in an empirical study ($N=443$). Structural equation modeling mapped interconnections between parental protective motivation, intention, and behavior. Multiple linear regression explored PMT dimensions' association with parental intentions and behaviors, while machine learning models evaluated their clinical relevance to children's disease outcomes.

Results The PMT scale demonstrated good reliability (Cronbach's α coefficient = 0.844) and validity ($\chi^2/df = 2.918$, RMSEA = 0.066, GFI = 0.906, CFI = 0.937, NFI = 0.908, IFI = 0.937, TLI = 0.919). In structural equation model, protection motivation showed significant overall interconnections with parental intention (0.78, $p < 0.001$). PMT dimensions were associated to 48.2% and 45.5% of the variance in parental intention and behavior related to allergic diseases in multiple linear regressions, with self-efficacy and perceived susceptibility being the most strongly associated factors. Random forest models demonstrated good discrimination in identifying associations between PMT dimensions and children's atopic severity and attacks, achieving AUC of 0.84 and 0.88 respectively, with all six PMT dimensions among the top-15 related variables.

Conclusions Our findings reveal the relevance of measuring parental protective motivation as captured by the developed PMT scale. It had significant associations with key parental intentions and behaviors in managing

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childhood atopy. This implies the necessity of refined PMT-based interventions to support outcomes in childhood allergic disease management.

Keywords Allergic disease, Protective motivation theory, Parents, Scale development, Prevention and control path

Background

Atopic march refers to the sequential progression of allergic diseases in childhood. It typically begins with atopic dermatitis (AD) in infancy, followed by food allergy (FA), and allergic rhinitis (AR), and often culminates in asthma [1]. Once established, this trajectory is difficult to reverse without timely and effective intervention [2]. Its predictable pattern highlights the critical need for early preventive strategies to reduce the long-term burden of allergic diseases in children.

Recent evidence highlights the substantial and growing global burden of pediatric allergic diseases. Globally, asthma affects 95.7 million children [3] with a prevalence of 10.2% [4], while AD impacts 72.4 million [3]. AR shows significantly increasing prevalence, with physician-diagnosed cases of 8.4% (2012–2015) to 19.9% (2016–2022) [5]. Food allergy (FA) affects 4.3% of children worldwide, demonstrating sharp rises in industrialized regions (e.g., UK: 1.2–4.0%, 2008–2018) [6]. In China, accelerated urbanization correlates with rapidly escalating allergy rates [7]. About 40.9% of urban infants under 2 years old in China experienced allergic symptoms or had a history of allergies [8]. AD prevalence reached 12.94% for children aged 1–7 years and peaks at 30.48% in infants within 1 year old [9, 10]. AR affects 18.46% of children/adolescents (2001–2021), with the highest regional prevalence in East China (22.77%) [11]. Childhood asthma prevalence rose to 3.3% (≤ 14 years, 2011–2018) [12], while FA affects 5.83% of children (0–14 years) [13].

Global data reveal significant regional disparities in pediatric allergic diseases. For instance, asthma incidence peaks in high-income North America but is lowest in South Asia [14]. These geographic patterns correlate positively with sociodemographic index (SDI), confirming urbanization's critical role [14]. As demonstrated previously, industrialization fundamentally alters early-life environments through two key mechanisms: (1) reduced contact with protective microorganisms (hygiene hypothesis) due to diminished microbial diversity in urban settings [15], and (2) increased exposure to allergy-related risk factors including $PM_{2.5}$, NO_2 , indoor pollutants, sedentary lifestyles, and westernized diets [16, 17]. These dual pathways induce immune dysregulation [18], amplifying allergic susceptibility. Consequently, early-life environmental risk intervention is essential for allergy prevention [19].

Substantial evidence confirms that parental knowledge critically influences the occurrence and trajectory of pediatric allergic diseases [20]. However, epidemiological

investigations across diverse geographic settings consistently demonstrate inadequate parental understanding and suboptimal preventive practices regarding core aspects of allergy management [21–24], including medication knowledge [25], allergen avoidance [26], and treatment compliance [20]. Parallel evidence from China was revealed comparable challenges. For instance, Ningbo studies documented discordance between parental poor knowledge and positive attitudes toward AR [27], while Wuhan surveys reported only a 56.7% accuracy rate among parents on the FA knowledge questionnaire [28].

In summary, previous studies have primarily focused on the epidemiological characteristics of pediatric allergic diseases or parents' insufficient knowledge levels. However, systematic research has been lacking on the mechanisms underlying parental behavior change and on the factors or determinants influencing the link between knowledge and actual behavior. To address these research gaps, researchers have increasingly turned to theoretical models of health behavior.

Theoretical framework

Current studies on children's health management have utilized behavioral theories like the Knowledge-Attitude-Practice (KAP) model, Health Belief Model (HBM), and Theory of Planned Behavior (TPB) to explore parental decision-making in chronic conditions such as asthma [29, 30], leukemia [31], dental visits [32] and vaccination [33]. While these frameworks clarify how beliefs and attitudes shape behaviors, they lack an efficient and integrated mechanism to explain why knowledge often fails to translate into action, a critical gap in managing childhood allergies.

Protection Motivation Theory (PMT) addresses this research gap through its unique dual-appraisal framework [34, 35]. PMT dynamically combines threat appraisal (assessing susceptibility, severity, and maladaptive rewards) with coping appraisal (evaluating self-efficacy, response efficacy, and response costs) to activate protection motivation [36, 37]. This process is initiated by background factors like disease knowledge, and directly bridges cognitive evaluations to intentions and behaviors (Fig. 1) [38, 39], offering a comprehensive pathway from risk perception to protective action that specifically targets knowledge-behavior linkage.

From adolescent smoking cessation [40] and sexual behaviors [41] to women's cervical screening [42] and vaccination uptake [43], PMT's explanatory power and association with behaviors has been validated in diverse

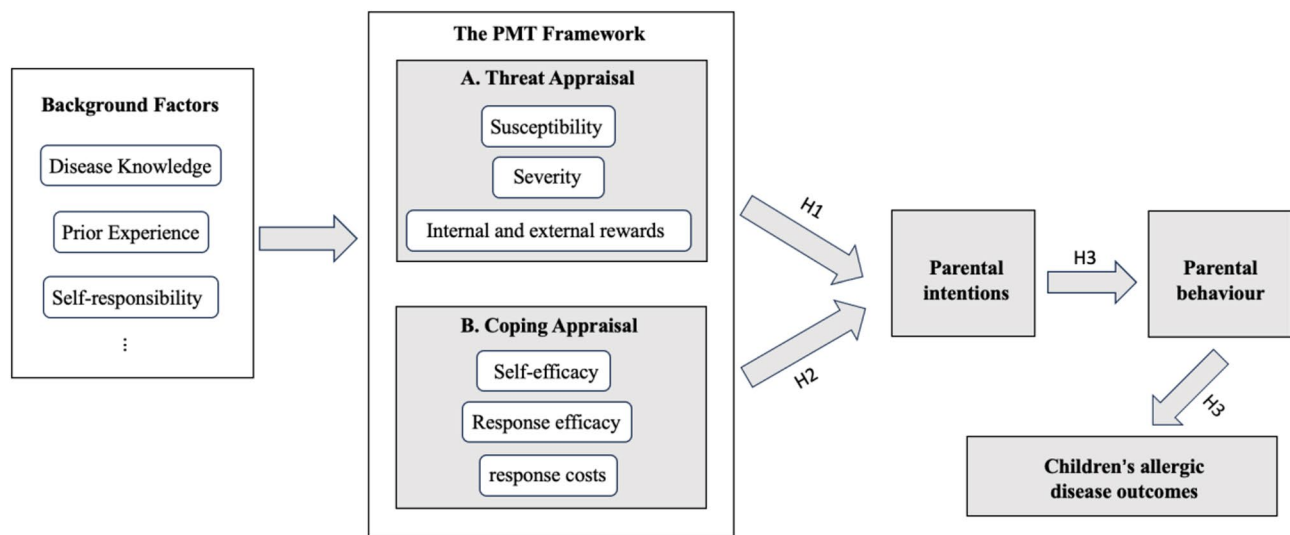


Fig. 1 The theoretical framework of Protection Motivation Theory (PMT)

health contexts, yet it remains underutilized in pediatric allergy management. To employ PMT's capacity for decoding parental decision-making, we developed the first protective motivation scale for parents of allergic children. It is anticipated that this scale will empirically test PMT's dual-appraisal hypotheses, quantify motivation-behavior gaps, and identify intervention targets, ultimately enabling precision strategies to improve allergic disease outcomes.

Hypotheses

To address parental knowledge-behavior gaps in childhood allergic disease management, we propose the following hypotheses based on PMT (Fig. 1). These hypotheses are specifically derived from PMT's dual-appraisal mechanism to explain parental decision-making processes.

H1: Within the framework of PMT, higher perceived threat appraisal (including perceived severity, susceptibility, and rewards) will activate parents' protection motivation and be positively associated with parental intentions of prevention and management regarding their children's allergic diseases. H1: Within the framework of PMT, higher perceived threat appraisal (including perceived severity, susceptibility, and rewards) will activate parents' protection motivation and be positively associated with parental intentions of prevention and management regarding their children's allergic diseases.

H2: Within the framework of PMT, higher coping appraisal (including self-efficacy, response efficacy, and response costs) will also activate parents' protection motivation and be positively correlated to parental intentions.

H3: Greater parental intention will be positively associated with parental actual behavior related to prevention

and management of their children's allergic diseases, thereby contributing to improved disease outcomes in children.

Materials and methods

Scale development

Firstly, we conducted a comprehensive literature review of allergic diseases and protection motivation scales, paired with semi-structured interviews with 20 parents of children with allergic diseases, 15 clinical staff from related hospital departments, and 3 scale development experts. The initial item pool for each of the 7 dimensions of the scale was determined, which are: severity, susceptibility, response efficacy, reaction cost, self-efficacy, internal return, and external return. In this phase, we established a pool of 49 items for the PMT scale.

Secondly, to ensure content validity, we conducted two-round Delphi expert consultations involving 12 multidisciplinary specialists (mean age = 45 years old; 41.7% [5/12] with 10–20 years of relevant field experience, 50.0% [6/12] with >20 years' domain-specific expertise). The panel comprised pediatric clinicians ($n=8$), health management specialists ($n=2$), social medicine researchers ($n=1$), and epidemiology/biostatistics experts ($n=1$). These experts rated the relevance (on a 1–4 scale) and importance (on a 1–5 scale) of each dimension and item, and made necessary modifications accordingly. The response rate of Round 1 achieved 100% completion where 7 experts submitted substantive feedback on items/subdomains, while Round 2 yielded 83.3% completion where 5 experts provided revisions. Expert authority coefficients (Cr), calculated as $(Ca + Cs)/2$ where Ca indicates judgment coefficient and Cs means familiarity score, reached 0.825 ($Ca=0.90$, $Cs=0.75$) and 0.81 ($Ca=0.90$, $Cs=0.72$) for Rounds 1 and 2 respectively,

both exceeding the 0.70 reliability threshold. Statistically significant opinion coordination was evidenced by Kendall's W for dimensions (Round 1: 0.378; Round 2: 0.301) and items (Round 1: 0.321; Round 2: 0.228; all $p < 0.05$). Item importance scores increased from 3.42 to 4.83 (Round 1) to 3.7–5.0 (Round 2), with coefficients of variation decreasing from 0.08 to 0.33 to 0–0.27, indicating improved opinion concentration. Using Round 2 consultation data, we established dimension-specific thresholds (mean $\pm$ SD) for importance scores, coefficients of variation (CV), and full-score rates. As a result, 5 items were eliminated as they met ≥ 2 criteria: (1) mean score or full-score rate below threshold, or (2) CV exceeding threshold. Following the experts' feedback, we removed redundant items, revised ambiguously phrased entries; consolidated thematically similar items (e.g., impacts of allergic diseases on daily life domains); and added cognition-related items as recommended. Finally, a preliminary six-dimensional scale was developed, consisting of 44 items, where the internal and external rewards dimensions were consolidated into one dimension of rewards.

Scale evaluation

Pilot study

The pilot study for testing items and developing the final scale was conducted in Hangzhou Children's Hospital, Zhejiang Province, China from July to August 2022. During pediatric outpatient clinic visits of children with physician-diagnosed allergic diseases, eligible families were approached by attending pediatricians to assess parental willingness to participate in our study. Enrollment was voluntary, with caregivers providing written informed consent after receiving detailed study information. Caregivers were eligible if: (1) they had at least one child diagnosed with allergic diseases, specifically referring to conditions including AD, AR, FA, and asthma; (2) the diagnosed child was under the age of 18. Parents were excluded if: (1) they lived separately from their diagnosed child; or (2) their child had been diagnosed with cognitive and motor limitations or other severe chronic diseases.

For scale evaluation, experts recommended a sample size of 5–10 times the number of scale items [44, 45], as determined by factor analysis requirements. Given our initial 44-item scale, a sample of 440 cases was calculated using the 10:1 ratio. During the pilot study, we actually distributed 450 questionnaires and obtained 440 valid responses without missing data, with a response rate of 97.78%.

Items analysis

In the pilot study, the initial scale is evaluated via Cronbach's α coefficient analysis, correlation coefficient analysis, t-test, and exploratory factor analysis (EFA).

To ensure internal consistency, items were removed if their exclusion increased the Cronbach's α coefficient of the corresponding dimensions or if they had correlation coefficients below 0.5 with their respective dimensions. T-tests excluded items with p-values exceeding 0.05 in high-low score group comparison. EFA determined 6 factors from principal component analysis, supported by results of KMO (0.888) and Bartlett Test of Sphericity ($\chi^2 = 12282.727$, $df = 946$, $p < 0.01$) (Fig. A.1). Factor-item correspondence was assessed based on factor loadings (> 0.5) and communalities (> 0.4). As a result, a 21-item, 6-dimension Protective Motivation Scale emerged from this process, capturing 73.058% of total variance as shown in results of EFA (Table A.1). In addition, since the data of the scale were collected from parental self-reports, we performed Harman's one-factor test to assess potential common method bias. The results showed that the first unrotated factor explained 27.249% of the total variance (Table A.2), which is far below the generally accepted threshold of 40%, indicating that common method bias is not a serious issue in our study scenario.

Finale questionnaire

The final instrument comprises five sections: demographic information, parental knowledge, intention and behavior concerning allergic diseases prevention and management, and the Protective Motivation Scale.

Demographics

The demographic and disease-related characteristics about children and parents. (1) Children's information: age, sex, feeding method at one year of age, allergic disease diagnoses, disease severity, number of recent attacks. (2) Parental information: sex, age, household registration, educational level, occupation, monthly household income, history of allergic diseases.

Knowledge/Intention/Behavior

Parental knowledge, intention, and behavior regarding allergic disease prevention and management were assessed using a 5-point scale (ranging from 1 to 5), with higher scores indicating better understanding, increased awareness, or more positive actions. Both general and specific inquiries were incorporated. General questions included queries such as "How knowledgeable are you about allergic diseases?", "In general, are you willing to take actions related to the prevention and management of your child's allergic disease?", and "In the past year, have you engaged in behaviors aimed at preventing and controlling your child's allergic diseases?". Specific questions referred to the willingness/experience of health education, daily allergen control practices, outpatient visits, and medicine compliance specifically related to allergic diseases.

Table 1 Demographic characteristics of participants. (N = 443)

Child	n (%)	Parent	n (%)
Age (years)		The identity of the caregiver	
0–3	119 (26.9)	Father	112 (25.28)
3–6	220 (49.7)	Mother	296 (66.82)
6–12	99 (22.3)	Grandparent	32 (7.22)
> 12	5 (1.1)	None of above	3 (0.68)
Sex		Age (years)	
Male	261 (58.92)	< 30	33 (7.45)
Female	182 (41.08)	30–39	326 (73.59)
Feeding types within one year of age		40–49	49 (11.06)
Breastfeeding	255 (57.56)	≥ 50	35 (7.90)
Formula feeding	149 (33.64)	Household registration	
Mixed feeding	39 (8.80)	Urban	360 (81.26)
The type of allergic disease		Rural	83 (18.74)
Atopic dermatitis	166 (37.47)	Highest level of education	
Food allergies	56 (12.64)	Junior high school or below	45 (10.16)
Allergic rhinitis	166 (37.47)	High School/Technical Secondary	73 (16.48)
Asthma	55 (12.42)	Technical or vocational school	83 (18.74)
Disease severity in the past year		Bachelor's degree	206 (46.50)
Very severe	6 (1.35)	Master's degree or higher	36 (8.13)
Severe	116 (26.19)	Occupations	
Moderate	173 (39.05)	Public sector employee	83 (18.74)
Mild	140 (31.60)	Private sector employee	162 (36.57)
Very mild	8 (1.81)	Self-employed	87 (19.64)
The frequency of attacks in the past year		Agricultural workers and others	33 (7.45)
Almost no attacks	12 (2.71)	Homemakers	78 (17.61)
1–2 attacks in half a year	124 (27.99)	Monthly household income (rmb)	
3–4 attacks in half a year	91 (20.54)	≤ 5k	10 (2.26)
1 attack per month	107 (24.16)	5k–10k	58 (13.09)
≥ 2 attacks per month	109 (24.60)	10k–15k	142 (32.05)
		15k–20k	129 (29.12)
		> 20k	104 (23.48)
		Number of parents with allergy history	
		0	133 (30.02)
		1	249 (56.21)
		2	61 (13.77)

Table 2 Internal consistency coefficient of parental protection motivation scale for children with allergic disease

Dimensions and total	Cronbach's α	Split-half reliability
Susceptibility	0.792	0.836
Severity	0.772	0.790
Self-efficacy	0.710	0.767
Reaction efficiency	0.918	0.883
Response costs	0.677	0.664
Rewards	0.831	0.795
Total Motivation for Protection Scale	0.844	0.775

21-item protective motivation scale for parents

The PMT scale had six dimensions: parental perceived susceptibility and severity to allergic diseases, self-efficacy, response efficacy, response cost, and rewards

related to prevention and management of children's atopic status. Participants rated their agreement with each statement on a 5-point Likert-style scale, ranging from strongly disagree (1 point) to strongly agree (5 points) (Table A.3).

Susceptibility

Susceptibility was measured by three items, indicating parents' perceptions of whether their children are susceptible to allergic diseases (e.g., "Compared to other children, my child is more susceptible to allergic diseases"). Higher scores indicate greater concerns of susceptibility.

Severity

Severity was measured by two items, indicating parental awareness of the impact of allergic diseases on children (e.g., "Allergic disease attacks can affect children's daily

Table 3 Correlations between PMT dimensions and parental intention or behaviors of preventing and controlling children's allergic diseases

Variables	1	2	3	4	5	6	7
1. Intention							
2. Behavior	0.667**						
3. Susceptibility	0.428**	0.526**					
4. Severity	0.194**	0.331**	0.480**				
5. Self-efficacy	0.493**	0.501**	0.502**	0.192**			
6. Response efficacy	0.521**	0.480**	0.386**	0.315**	0.399**		
7. Response cost	0.429**	0.452**	0.275**	0.201**	0.327**	0.312**	
8. Rewards	-0.121*	-0.004	0.159**	0.111*	0.207**	-0.072	-0.002

3 to 8 were PMT dimensions

** $p < 0.01$; * $p < 0.05$

lives, such as attendance rates, social activities, sleep, etc.). Higher scores indicate greater perceived severity of allergic diseases.

Self-efficacy

Self-efficacy was measured by three items. Two items indicated parental confidence in controlling children's allergic diseases (e.g., "I believe I am capable of preventing and controlling my child's allergic diseases"), and one item gauged their perceived ability to access knowledge of their child's allergic diseases (i.e., "I am proactive in searching for knowledge related to my child's allergic diseases"). Higher scores indicate higher level of parental self-efficacy.

Response efficacy

Response efficacy was measured by seven items, indicating parental beliefs that taking actions to prevent and control allergic diseases would have many benefits for their children (e.g., "Taking actions to prevent and control my child's allergic diseases can promote his/her healthy growth"). Higher scores indicate higher perceived response efficacy.

Response costs

Response costs was measured by three items, reflecting parents' perceptions of the challenges they face in preventing and controlling of their children's atopic conditions. (e.g., "I am concerned about the side effects of the medication (such as hormone drugs, etc.)"). Reverse scoring was then adopted, as a result, higher scores indicated lower response cost.

Rewards

Rewards was measured by three items, indicating the benefits that parents perceived from non-engagement. (e.g., "If I don't need to prevent my child's allergic diseases, I can have more free time"). Reverse scoring was also applied; therefore, higher scores indicated less perceived benefits of parents' non-engagement.

Data collection and analysis of the main study

Data collection

During the scale validation phase, purposive sampling was employed at Hangzhou Children's Hospital and a community health center in Hangzhou, Zhejiang Province, China. Parent recruitment procedures and inclusion/exclusion criteria were consistent with those used in the pilot study. Although the number of scale items was reduced from 44 to 21 in this validation phase, we retained the pilot study's predetermined sample size of 450 as it exceeded minimum requirements for factor analysis. Finally, researchers obtained 443 valid responses, yielding a 98.44% response rate.

Statistical analysis

The scale's reliability was assessed using Cronbach's α coefficient and split-half reliability: α coefficients over 0.8 signify excellent internal consistency, while between 0.6 and 0.8 suggests good consistency. The scale's validity was assessed by content and structure validity. Content validity was established by reviewing relevant literature, expert opinions, and conducting in-depth interviews with parents of pediatric atopic patients and medical professionals. Confirmatory factor analysis (CFA) was utilized to validate the final scale's structure validity. In CFA, the maximum likelihood method was employed to assess the model's goodness of fit. To evaluation of the scale's overall fit and parsimony, several measures were adopted, including the chi-square statistic, chi-square to degrees of freedom ratio (χ^2/df), root mean square error of approximation (RMSEA), goodness of fit index (GFI), comparative fit index (CFI), normed fit index (NFI), incremental fit index (IFI), and non-standard fit index (TLI). Good fit is indicated by a non-significant chi-square ($p > 0.05$) and $\chi^2/df < 3$. A desirable RMSEA is ≤ 0.08 . Acceptable values for GFI, CFI, NFI, IFI, and TLI are ≥ 0.90 .

In hypothesis testing, Pearson correlation examined the relationship between PMT dimensions and parental intention or behavior. Multiple regression assessed the

association of parental intention/behavior with PMT dimensions, while structural equation modeling (SEM) evaluated theoretical paths based on proposed hypotheses, using $p < 0.05$ for significance. To explore the associations of PMT dimensions with children's allergic disease outcomes, we developed preliminary association models for parent-reported children's atopic severity and frequency of attacks in the past year (Table 1). Two 5-point Likert-style questions were used. Severity was rated from not severe (1 point) to very severe (5 points). Frequency categories ranked from almost none (1 point) to ≥ 2 times per month on average (5 points). We selected random forest, XGBoost, LASSO regression, and logistic regression for model development based on their complementary strengths and established utility in health prediction research [46–48]. Random forest and XGBoost were chosen for their ability to capture complex nonlinear relationships and feature interactions through ensemble tree-based architectures [49], while LASSO regression was included for its integrated variable selection and regularization capabilities suited to high-dimensional data [50]. Logistic regression served as an interpretable baseline model due to its simplicity [51]. To evaluate performance, data were randomly partitioned into training and test sets at a 2:1 ratio. Models were compared using the area under the receiver operating characteristic curve (AUC), with values ranging from 0.5 to 1 indicating discrimination capacity. The optimal model was determined by selecting the algorithm achieving the highest AUC in the test set. IBM SPSS (version 26.0), AMOS (version 24.0), and R software (version 4.2.3) were used for analysis.

Results

Demographics characteristics of the sample

By employing purposive sampling, we balanced the sample of children diagnosed with each of the four allergic diseases at a ratio of approximately 3:1:3:1 for atopic dermatitis, food allergy, allergic rhinitis, and asthma. This ratio aligns with the incidence ratios observed in epidemiological studies of Chinese children [52–54]. In cases where a child presented with concurrent allergic diseases, this study accorded priority to the condition reported as the primary concern during the medical assessment. As shown in Table 1, the total of 443 parents participated in the main study. Their children ranged from 0 to 14 years old, with over half (58.92%) being male. The majority of the parents involved were mothers (66.82%), and their ages predominantly fell within the 30–39 years bracket (73.59%). Regarding education, occupation, and monthly household income distribution, 46.50% of the parents held a bachelor's degree, 36.57% worked in the private sector, and 32.05% reported a monthly income between 10,000 and 15,000 RMB.

Measurement model

Reliability of the 21-item protective motivation scale for parents

The reliability of the 21-item scale was evaluated by Cronbach's α coefficient and split-half reliability. As shown in Table 2, the Cronbach's α coefficient for the PMT scale was 0.844. Specifically, the Cronbach's α coefficients for each dimension ranged from 0.677 to 0.918, indicating good to excellent internal consistency for both the overall scale and its individual dimensions. Besides, the overall split-half reliability coefficient of the scale was 0.775, and the split-half coefficients for each dimension ranged from 0.664 to 0.883, indicating that both the overall scale and its individual dimensions were reliable.

Validity of the 21-item protective motivation scale for parents

For content validity, the 21 items in the final scale were derived from the real-life experiences of parents, adjusted by two rounds of expert consultation. Clearance and validation of the content were further ensured through semi-structured interviews and focus group discussions. The scale's 6 dimensions captured the theory-based essence of parents' protective motivation for children with allergic diseases. Regarding construct validity, a Confirmatory Factor Analysis (CFA) was performed on data from the main study ($N = 443$) to validate the factor structure's stability. After post-model adjustments, optimal fit indices were achieved, including a χ^2/df of 2.918, RMSEA of 0.066, and GFI, CFI, NFI, IFI, and TLI all exceeding 0.9 (Fig. 2). This indicated the successful identification of six latent variables, each demonstrating a high degree of representativeness for its corresponding items.

Testing the PMT-related hypotheses

Univariate association between the PMT dimensions and parental intentions and behaviors

Before the correlation analysis, the Kolmogorov-Smirnov test was used to test the normality of PMT dimensions and parental intention and behavior (see Table A.4). All of them did not meet the normal distribution assumption ($p < 0.05$). Therefore, the non-parametric Spearman rank correlation was adopted to evaluate the pairwise correlation. As shown in Table 3, most PMT dimensions were significantly correlated with each other ($p < 0.01$), except the rewards dimension, which lacked significant associations with response efficacy and response cost. Meanwhile, parental prevention and treatment intention showed significant positive correlations with susceptibility, severity, self-efficacy, response efficacy, and response cost ($p < 0.01$), and a significant negative correlation with rewards ($p < 0.05$). Moreover, parental prevention and treatment behavior also had significant positive correlations with susceptibility, severity, self-efficacy, response efficacy, and response cost ($p < 0.01$), but no significant

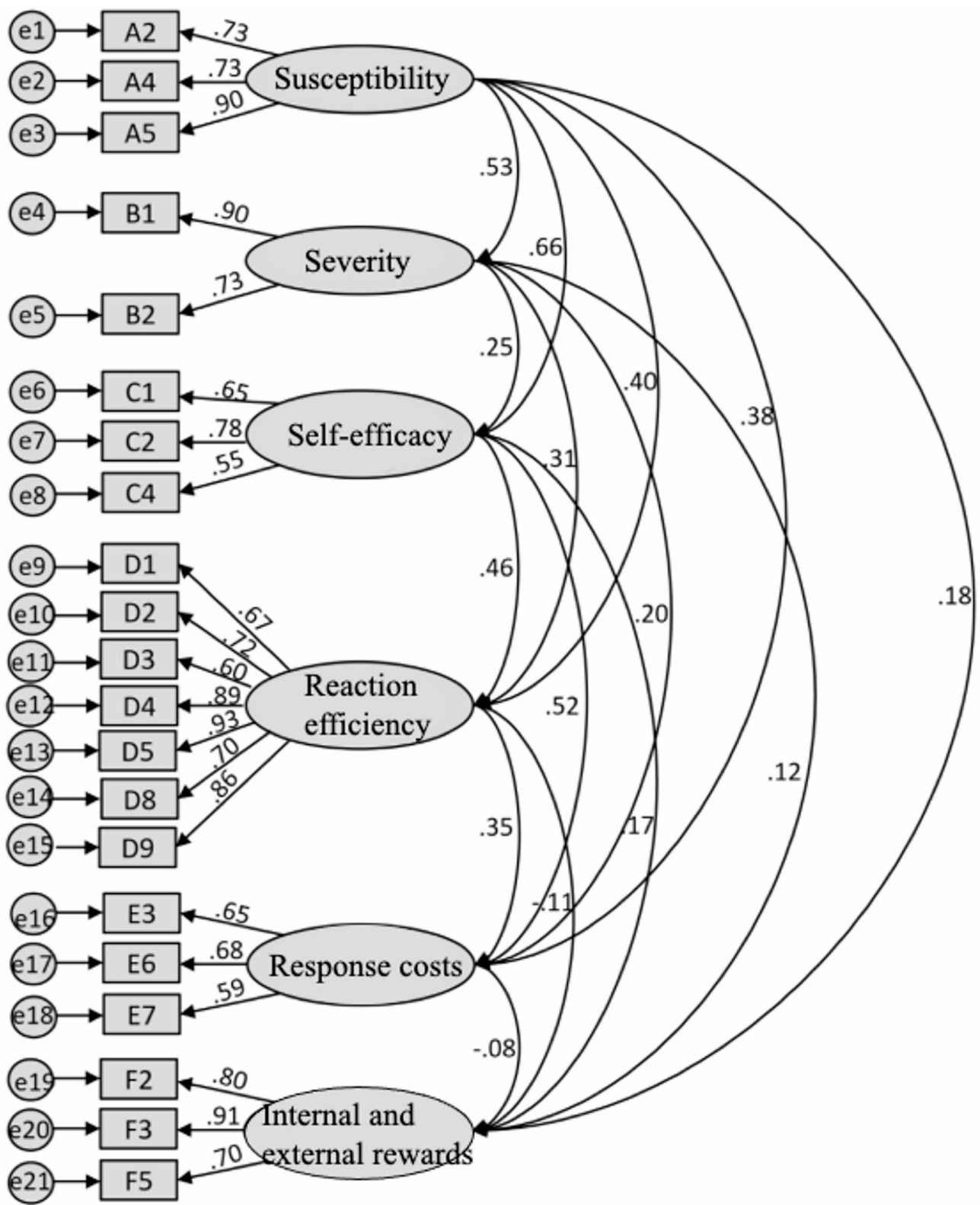


Fig. 2 The validity of the final 21-item scale by the Confirmatory Factor Analysis. Note: $\chi^2/df=2.918$, $RMSEA=0.066$, $GFI=0.906$, $CFI=0.937$, $NFI=0.908$, $IFI=0.937$, $TLI=0.919$

Table 4 Multiple linear regression analysis of intentions using PMT dimensions

Variables	Unstan- dardized Coefficients	Standardized Coefficients	95% CI	t	p
(Constant)	1.494		[1.063, 1.925]	6.813	0.000
Suscepti- bility	0.010	0.239	[0.007, 0.014]	5.266	0.000
Severity	−0.004	−0.091	[−0.008, −0.001]	−2.354	0.019
Self-efficacy	0.012	0.302	[0.009, 0.016]	6.905	0.000
Response efficacy	0.017	0.251	[0.012, 0.022]	6.250	0.000
Response cost	0.007	0.187	[0.004, 0.010]	4.973	0.000
Rewards	−0.007	−0.172	[−0.010, −0.004]	−4.693	0.000

$R^2=0.482$, $F=69.492$, $p<0.001$

Table 5 Multiple linear regression analysis of behaviors using PMT dimensions

Variables	Unstan- dardized Coefficients	Standardized Coefficients	95% CI	t	p
(Constant)	0.529		[0.053, 1.005]	2.186	0.029
Suscepti- bility	0.013	0.265	[0.008, 0.017]	5.710	0.000
Severity	0.004	0.076	[0.000, 0.008]	1.921	0.055
Self-efficacy	0.009	0.213	[0.006, 0.013]	4.750	0.000
Response efficacy	0.014	0.198	[0.008, 0.020]	4.826	0.000
Response cost	0.009	0.219	[0.006, 0.012]	5.673	0.000
Rewards	−0.004	−0.086	[−0.007, 0.000]	−2.272	0.024

$R^2=0.455$, $F=62.472$, $p<0.001$

correlation with rewards. Additionally, intention and behavior were significantly correlated with each other ($p<0.01$).

Combined effects of PMT dimensions on intention and behavior

To further examine the adjusted associations between parenting intention/behavior and the dimensions of PMT, we constructed two multiple linear regression models respectively. Following model constructions, we conducted Kolmogorov-Smirnov tests on the residuals to evaluate the assumption of normality (see Table A.5). The results showed that the residuals approximated the normal distribution ($p>0.05$), and no systematic nonlinear trend and heteroscedasticity were detected, indicating the models met multiple linear regression assumptions.

As illustrated in Table 4, the regression model for parental intention was successfully built (adjusted $R^2=0.482$, $F=69.492$, $p<0.001$), indicating that the independent variables in this model can explain 48.2% of the variance in parental intention of preventing and controlling children's allergic diseases. Significant explanatory variables were susceptibility, severity, self-efficacy, response efficacy, response cost, and rewards ($p<0.05$), with severity and rewards negatively correlated. Based on β coefficients, self-efficacy showed the strongest association in generating the parental intention to prevent and control allergic diseases. Regarding disease prevention and control behavior, as shown in Table 5, the regression model (adjusted $R^2=0.455$, $F=69.472$, $p<0.001$) identified susceptibility, self-efficacy, response efficacy, response cost and rewards as significantly associated variables ($p<0.05$), while susceptibility having the strongest association for adopting disease prevention and control behavior, with the rewards negatively correlated.

Role of PMT in allergic disease prevention and management: a structural equation model

We constructed a second-order structural equation model linking PMT to parents' knowledge, intention and behavior of preventing and controlling allergic diseases in children, to verify our hypotheses. By taking protection motivation as a latent variable, and knowledge, intention, and behavior as observed variables, we successfully constructed the structural equation model. As shown in Fig. 3, the intention served as a mediating variable between protection motivation and the prevention behavior. The model demonstrated a good fit to the data ($\chi^2/df=2.666$, CFI=0.944, TLI=0.929, RMSEA=0.061, NFI=0.970). In terms of standardized effect coefficients, the model revealed a significant positive association between parental knowledge of allergic diseases and their protection motivation, with a standardized path coefficient of 0.76 ($p<0.001$). Furthermore, parental protection motivation exhibited a substantial positive association with both their intention and behavior, as indicated by standardized path coefficients of 0.78 ($p<0.001$) and 0.66 ($p<0.001$), respectively. Additionally, parental intention exhibited an extra association with their behavior, supported by a standardized path coefficient of 0.16 ($p=0.019$).

Table 6 provided the details of the structural equation model. An indirect association (0.59) was identified between parental knowledge and intention, with protection motivation as a potential mediator. An indirect association was also found between parental knowledge and behavior (0.59, $p<0.001$), potentially mediated by protection motivation and intention. Notably, the total correlation coefficient between protection motivation and parental behavior was 0.78 ($p<0.001$), which included a

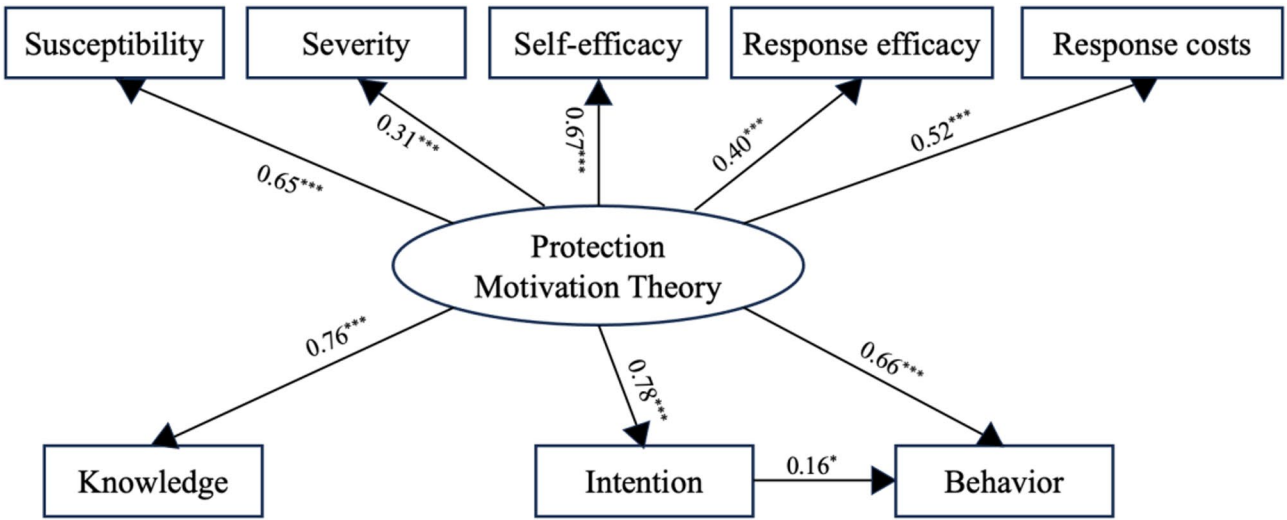


Fig. 3 The structural equation model of PMT, knowledge, intention and behavior, only significant paths are demonstrated. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ ($R^2 = 0.58$; CFI = 0.981; TLI = 0.964; NFI = 0.970; RMSEA = 0.061)

Table 6 Direct, indirect and total standardized effects of prevention knowledge and PMT on parental intentions and behaviors

Indirect Path			Standardized Direct Effects	Standardized Indirect Effects	Standardized Total Effects	p
Knowledge	→	PMT	0.76	/	0.76	< 0.001
Knowledge	→	Intention	/	0.59	0.59	< 0.001
Knowledge	→	Behavior	/	0.59	0.59	< 0.001
PMT	→	Intention	0.78	/	0.78	< 0.001
PMT	→	Behavior	0.66	0.12	0.78	< 0.001
Intention	→	Behavior	0.16	/	0.16	0.019

direct association (0.656, $p < 0.001$) and an indirect association through willingness (0.120, $p < 0.001$).

Association between PMT dimensions and children’s allergic disease outcomes

In this phase, we developed two association models for children’s allergic disease attacks and severity to explore the role of parental protection motivation in children’s atopic outcomes. Six protective motivation dimensions, parental and children’s demographics, parental knowledge, intention, and behavior were input variables. Since these factors were potentially correlated, we employed machine-learning algorithms to address this issue. The dataset was split into training and testing sets in a 2:1 ratio, while ROC curves and AUCs were used for model evaluation.

Regarding allergic disease severity, the association model constructed by the Random Forest algorithm demonstrated the highest AUC of 0.84 on the testing set (Fig. 4A and B), rendering a relatively high discriminatory capacity of the model. Following that, the XGBoost model achieved an acceptable accuracy (AUC = 0.82), while models of LASSO Regression and Logistic Regression exhibited lower accuracy. In the Random Forest model, response cost from the PMT scale carried the

largest weights, and the remaining five PMT dimensions were important factors, confirming the association between parental protection motivation and allergic disease severity (Fig. 4C). Other crucial covariates included parents’ and children’s ages, parents’ occupation, education, and income levels, parental knowledge of allergic diseases, and first-year infant feeding types.

For allergic disease attacks, the random forest model continued to demonstrate the highest accuracy among the four machine learning algorithms, with an AUC of 0.88. (Figure 4A and B). In the Random Forest model, self-efficacy revealed the highest importance, and all the remaining five PMT dimensions were consistently recognized as valuable factors. Other significant variables included daily allergen control practices, medicine compliance, and experience with health education.

Discussion
Key findings

This study developed/validated a PMT scale for parents of children with allergic diseases. Results indicated that the scale was appropriate for measuring parental protective motivation and identifying its associations with intentions and behaviors. Structural equation modeling supported the hypothesized role of intention as a

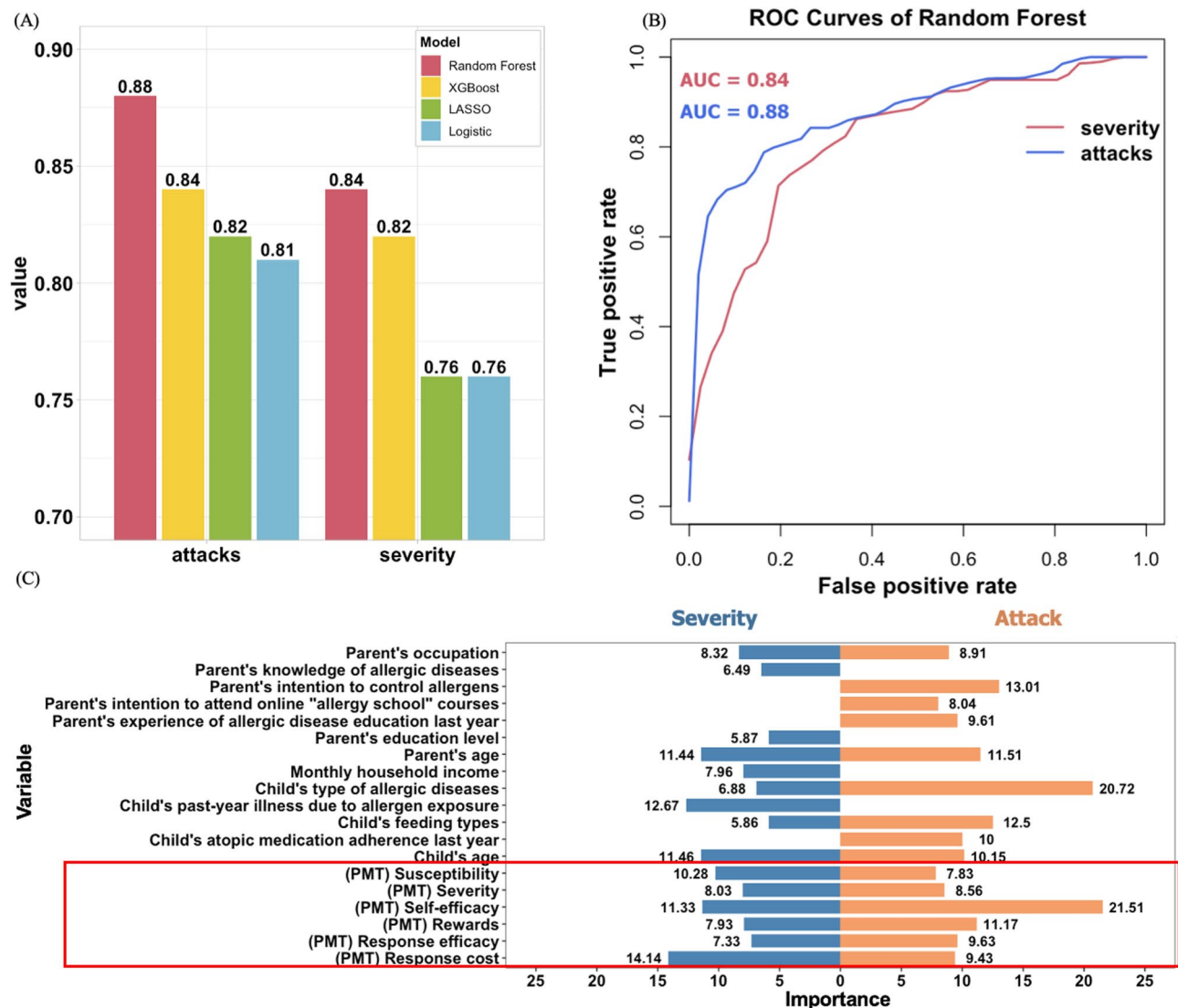


Fig. 4 The results of machine learning algorithms in the association model of children's allergic disease outcomes using PMT dimensions and other relevant variables: **(A)** Comparison of model accuracy across four algorithms on the testing set; **(B)** ROC curves for children's allergic disease severity and attacks in the random forest models on the testing set; **(C)** Variable importance derived from in the random forest models for severity and attacks

potential mediator in the association between motivation and behavior [33], aligning with PMT's cognitive appraisal-to-action framework. Knowledge positively correlated with motivation, aligning with evidence that information enhances threat/coping appraisals [55]. PMT dimensions significantly associated with child health outcomes, suggesting potential utility of PMT-informed interventions targeting reduced disease episodes and symptom severity, which was consistent with established roles of coping appraisals (particularly self-efficacy) in health behaviors [56].

Verification of the PMT scale for parents of children with allergic diseases

Our tailored PMT scale was designed for parents of atopic children, distinguishing it from typical PMT scales focusing on patients with diseases themselves. This deviation necessitated us to gauge parental protection motivation without parents' direct experience of the condition, while considering empathy, comprehension, and proactive engagement as important aspects. In the main study, our scale showed strong reliability with an overall α coefficient of 0.844 and good split-half reliability at 0.775. Compared with existing PMT scales, our scale performed well, surpassing scales of intention to quit smoking scale (overall Cronbach's $\alpha=0.71$) [57] and predicting schistosomiasis protective behaviors in adolescents (overall

Cronbach's $\alpha=0.76$) [58], while slightly lower than the Stroke Protection Motivation Scale (overall Cronbach's $\alpha=0.90$) [59], and slightly higher in split-half reliability (all domains=0.743) [59]. CFA supported our scale's validity, with excellent fit indices ($\chi^2/df=2.918$, RMSEA=0.066, GFI, CFI, NFI, IFI, TLI>0.9), comparable to other protective motivation scales [60, 61]. The scale is suitable for identifying variations in caregiver threat and coping appraisals, which may help tailor educational interventions. For example, parents with low perceived threat may benefit from risk communication, while those with low efficacy may need skills-based support [39].

As noted in psychometric standards, Cronbach's α coefficients ≥ 0.7 indicate acceptable reliability, while values between 0.6 and 0.7 reflect marginal consistency [62]. In our scale, 5 dimensions demonstrated $\alpha > 0.7$, and the total scale achieved good reliability ($\alpha=0.844$), whereas the rewards dimension showed relatively low reliability ($\alpha=0.677$). The limitation may be attributed to two factors, conceptual specificity of items and the conditional phrasing complexity. Specifically, the three items in this dimension (Q19: Feels more relaxed; Q20: Has more free time; Q21: Has more leisure activities) narrowly measure time/leisure benefits of non-prevention, potentially omitting aspects like financial savings. On the other hand, items used hypothetical phrasing (e.g., "if don't need to prevent."), which may introduce interpretive variability. To address this in future studies, we will simplify item wording and expand the construct by adding more emotional/financial reward items, thereby enhancing construct validity and reliability in subsequent scale validations.

Associations of parental PMT and its dimensions with their intentions and behaviors related to pediatric allergic diseases

This study explored associations between parental protective motivation, their protective intentions, and related behaviors in managing pediatric allergic diseases. Path analysis suggested that parental protective motivation was statistically associated with protective behaviors (0.66), and this association was partially mediated by intentions (indirect effect=0.12). This supports our hypothesis that protective motives are associated with parental intentions, which in turn are associated with relevant behaviors [63], aligning with findings from previous studies based on protective motivation theory in contexts such as vitamin E and C intake [64] and diabetes prevention among Thai populations [55]. This application and validation of the PMT theoretical framework highlights the potential of protective motivation to relate to behavior modification and be associated with outcomes in pediatric patients.

The univariate and multiple linear regression results indicate that both the threat appraisal and coping appraisal dimensions of protective motivation are significantly associated with intentions. Among the six specific dimensions, self-efficacy and response efficacy emerged as the strongest correlates of parental intention to prevent and control allergic diseases, consistent with previous research [65, 66]. Parents with higher self-efficacy and response efficacy were more confident in managing their children's allergic diseases, which was associated with greater willingness to participate in preventive actions and to handle related challenges effectively. In our findings, perceived susceptibility showed a strong positive association with intention formation. Higher perceived susceptibility reflects deeper recognition and concern about children's health, which may correlate with an increased intention to engage in protective actions. Similar associations have been reported in studies on schistosomiasis prevention [65], vaccination willingness among travelers [67] and nurses [68]. After reverse scoring, response cost was also positively correlated with intention in our study, consistent with previous findings [69, 70]. This highlights that without reverse scoring, response cost served as barriers to proactive preventive actions, reflecting parents' concerns about the time, financial, and energy costs associated with managing allergic diseases.

Additionally, our study initially revealed a positive correlation in univariate analysis, but in multiple linear regression, we found a negative correlation between perceived severity and intention formation, differing from previous studies [69–71]. In chronic conditions like allergic diseases, perceived severity can lead to prolonged illness duration, causing psychological fatigue and feelings of overwhelm among parents. This sense of powerlessness may act as a barrier to intention formation when combined with other factors [72, 73].

While factors associated with intention and behavior largely overlapped, subtle differences emerged. Specifically, susceptibility was the strongest factor associated with protective behaviors, consistent with prior research [55]. The importance of susceptibility lies in its close association with readiness to act and behavior implementation. Although self-efficacy and response efficacy remained significantly associated with behavior, as seen in previous studies [64, 74], the strength of these associations was slightly lower than that observed with intention. This difference may be related to external factors such as social support, environmental conditions, and resource accessibility. Although individuals are confident in their abilities, these factors are often associated with the implementation of behaviors and may be linked to variability in the observed associations between self-efficacy, coping efficacy, and actual behaviors [75, 76]. At the

same time, in our regression analysis, perceived severity did not show a significant correlation with behavior. This difference may be explained by both the above-mentioned parents' sense of powerlessness and the variation across the four different atopic diseases we studied, which may correspond to differing behavioral patterns [77, 78].

Finally, our study identified a positive correlation between higher perceived time/leisure rewards of non-prevention and more active parental intentions/behaviors toward their children's atopic management, contradicting PMT's assumption that such rewards diminish protective actions [61, 70, 79]. This divergence may stem from the fact that most caregivers inherently view disease management as an obligatory responsibility rather than an incentive-driven behavior [80]. Consequently, even when recognizing substantial time/leisure benefits from reduced caregiving, parents still exhibit superficially high motivation and intention of protection due to social expectations and internalized parental duties [81]. This obligation-driven motivation may represent a context-specific moderator of PMT's reward-behavior pathway and warrants theoretical refinement in the parent-to-child health management context. In addition, as mentioned above, two methodological limitations could contribute to this inconsistency: our narrow operationalization of rewards may neglect other salient incentives like financial savings or emotional relief [82, 83], while conditional phrasing of reward items potentially caused interpretive challenges among actively engaged parents who struggle to conceptualize non-prevention scenarios given their caregiving commitments and social desirability biases [84, 85].

Exploring the association between parental protective motivation and pediatric atopic outcomes

We demonstrated that all six dimensions of parental protective motivation were associated with childhood atopic symptoms. Specifically, for atopic severity modeling, response cost, self-efficacy, child's past-year illness due to allergens, and parental and child ages were key associators. In attacks modeling, self-efficacy, child's allergic disease type, parental allergen control, child's feeding types, and parental age, were crucial. Unlike current allergy symptom models that focus on single disease types and clinical tests [86, 87]; our multidimensional framework concurrently profiles social/demographic factors, protection motivation, knowledge, willingness, and behavioral patterns. This enables comprehensive mapping of modifiable factors associated with atopic symptom manifestation, providing potential intervention strategies.

Overall, our findings have several implications for future interventions [88–90]. Firstly, Given the crucial role of parents' confidence and competence in

successfully managing atopic symptoms, health professionals can offer educational and training programs to bolster parental self-efficacy and coping skills [91], such as coping with indoor and outdoor allergens and effective daily symptom management [92]. Secondly, we should help parents accurately evaluate the severity of pediatric allergic diseases to enhance their threat appraisal [93]. Thirdly, addressing barriers to action (response costs) is another critical aspect. Providing financial assistance, waiving medical expenses, and ensuring easy access to medical services are necessary steps to alleviate the burden on parents managing these diseases [94–96]. Moreover, community workers should establish supportive networks to help parents manage pediatric allergic diseases [97]. Lastly, healthcare providers should clearly illustrate the long-term benefits of preventive measures to parents, emphasizing cost savings and improvements in quality of life. By adjusting reward expectations and highlighting the positive outcomes associated with proactive behaviors, parents can be motivated to prioritize preventive actions for their children [98–100].

Concerns exist that parental protective motivation may inadvertently evolve into “overprotective” behaviors, particularly in chronic allergy management, potentially limiting adolescent autonomy [101]. Although PMT under the parental stress model emphasizes the role of threat appraisal and coping efficacy in promoting adaptive behaviors, it inadequately addresses the potential tension between parental protective behaviors and the development of children's autonomy [102]. Overprotection, often driven by parents' own anxiety or exaggerated vulnerability perceptions of their children, manifests as avoiding risks, limiting children's exploration and restricting their autonomy development, ultimately increasing child anxiety, dependency, and social withdrawal [103, 104]. Research has found that “autonomy-supportive protective motivation” is a more adaptive path [105, 106]. This approach combines high PMT dimension scores (threat perception, coping/self-efficacy) with collaborative parent-teacher-clinician behavioral strategies encouraging child-led disease management (e.g., personalized allergen coping in children [107], self-management in adolescents with type 1 diabetes [108]). Self-determination theory (SDT) interventions improving medication adherence in asthmatic adolescents further validate this pathway [109]. Therefore, PMT does not encourage overprotection, but can benefit from balancing high threat perception and children's autonomy through empowerment strategies, such as gradually cultivating children's medical autonomy during adolescence [110] to prevent parental protective behavior from evolving into controlling behavior.

In addition, deterioration in the condition of children are likely to cause increased anxiety among parents [111]. Future studies can further explore the interaction

between psychological factors such as personality traits, coping strategies, and locus of control and PMT structures in the classification and management of allergy and other chronic diseases in children. Personality traits such as trait anxiety may affect protective motivation by enhancing threat appraisal (such as perceived susceptibility and severity) [112, 113]. For example, studies have found that neurotic personality is positively correlated with threat perception in COVID-19 prevention behavior [114].

Limitations

First, as participants were restricted to parents of children with diagnosed atopic conditions, the derived model demonstrates utility for this clinical subgroup but requires validation in general populations (e.g., children without pre-existing allergic diagnoses). Second, aggregating diverse allergic pathologies (e.g., asthma, atopic dermatitis) into a unified framework may mask disease-specific mechanisms. Furthermore, this design might inadequately address developmental particularities in preadolescent/adolescent populations, particularly their growing autonomy needs in disease management; thus, future stratified analyses by disease subgroup and developmental stage are warranted. Third, as a cross-sectional investigation, this study cannot establish temporal precedence or causal relationships between protection motivation factors and disease management outcomes. Consequently, reported associations should be interpreted as correlational rather than directional effects, and future longitudinal validation is required for causal claims. Finally, self-reported data may introduce recall and social desirability bias. Parental reports could inflate estimates of protective intentions and behaviors due to socially favorable responses, especially regarding treatment adherence. Future studies should incorporate objective metrics (e.g., medical records, observational checks) to mitigate this limitation.

Conclusion

The established protective motivation scale for parents of atopic children demonstrated good performance and reliability in assessing parental preventive actions and disease management. This study expanded the practical applications of PMT and confirms its significance. Our findings highlighted the crucial role of parental protective motivation in managing pediatric allergic diseases, with self-efficacy and response efficacy were strongly associated with intentions and susceptibility was associated with behaviors. These findings could guide program design and outcomes tracking, aiming to empower parents through various strategies. Such measures could help better manage pediatric allergic diseases and contribute to larger public health goals.

Supplementary Information

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Supplementary material 1.

Supplementary material 2.

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Authors' contributions

Yinan He: Methodology, Writing—original draft, Validation, Visualization. Jinghua Wu: Conceptualization, Methodology, Investigation, Writing—original draft. Xianglong Huang: Data Curation, Investigation, Writing—reviewing & editing. Qinzhen Zhang: Investigation, Writing—reviewing & editing. Xinmeng Yao: Investigation, Writing—reviewing & editing. Yi Yu: Investigation, Writing—reviewing & editing. Weihong Tang: Conceptualization, Data Curation, Supervision. Chengyin Ye (Corresponding author): Conceptualization, Methodology, Writing—original draft, reviewing & editing.

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Data availability

The authors will supply the relevant data in response to reasonable requests.

Declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Hangzhou Normal University (No. 2023002).

Competing interests

The authors declare no competing interests.

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