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Validation and short form development of the Turkish version of the self-care behaviors related to air pollution protection questionnaire: a psychometric and structural modeling approach

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Abstract

Background. The aim of this study was to validate and culturally adapt the self-care behaviors related to air pollution protection questionnaire (SCBAPPQ) for Turkish university students, develop a short form, and explore the mediating role of self-efficacy within the health belief model using structural equation modeling (SEM). *Methods.* A methodological study was conducted at Pamukkale University between November 1–20, 2024. This study involved 843 undergraduate students recruited via stratified random sampling. A cultural adaptation process included forward-back translation and expert panel review. The sample was split for exploratory factor analysis (EFA, $n = 421$) and confirmatory factor analysis (CFA, $n = 422$). EFA employed principal axis factoring; CFA used unweighted least squares estimation. Reliability was assessed via Cronbach's α, McDonald's ω, composite reliability, average variance extracted, and test–retest intraclass correlation (ICC). SEM tested direct and indirect pathways among threat/benefit perceptions, self-efficacy, and protective behaviors. *Results.* The 14-item Turkish SCBAPPQ demonstrated excellent fit with a three-factor structure: threat/benefit perceptions, self-efficacy, and protective behaviors, explaining 58.015% of total variance. CFA demonstrated excellent fit (comparative fit index = 0.987; Tucker–Lewis index = 0.985; root mean square error of approximation = 0.045; SRMR = 0.056). Internal consistency was high ($\omega = 0.869$; $\alpha = 0.869$), and test–retest reliability was excellent (ICC = 0.908; $\rho = 0.884$). SEM revealed that perceived threat/benefit positively predicted self-efficacy ($\beta = 0.411$, $p < 0.001$), which in turn predicted protective behaviors ($\beta = 0.260$, $p < 0.001$). A suppression effect was observed: the direct path from threat/benefit to behavior was negative ($\beta = -0.240$, $p < 0.001$), while the indirect effect via self-efficacy was positive ($\beta = 0.107$, $p < 0.001$). *Conclusion.* The validated 14-item Turkish SCBAPPQ is a reliable and valid tool for assessing air pollution self-care behaviors. The mediation findings highlight self-efficacy as fundamental for effective health behavior interventions, suggesting that risk communication strategies must incorporate efficacy-building components to successfully translate perceived threats into protective actions.

1. Introduction

Air pollution remains one of the most pressing environmental health challenges worldwide. It is considered the single largest preventable environmental risk factor for illness and deaths, contributing to millions of fatalities annually [1]. Estimates suggest that environmental factors, including air pollution, are responsible for approximately 12.6 million deaths worldwide each year, with particulate matter alone linked to 9 million premature deaths [2]. While some regions, particularly in the global north, have achieved improvements in air quality through significant efforts, air pollutant levels remain alarmingly high in many low- and middle-income countries, notably across Asia and Africa [1]. This disparity highlights a critical global health equity concern, where the burden of air pollution disproportionately impacts vulnerable populations in these regions. Addressing this inequity requires public health interventions that are not only effective but also culturally sensitive and tailored to specific socio-economic contexts.

The escalating global recognition of this crisis is underscored by the World Health Organization's (WHO) issuance of more stringent air quality guidelines, signaling an urgent imperative for both individual protective behaviors and robust policy interventions [3]. This dual need for top-down policy changes and bottom-up individual strategies reinforces the critical importance of research that can inform both large-scale environmental policies and personal health protection measures. While systemic policies aimed at reducing emissions at their source are unequivocally the most desirable long-term solution, individual self-care behaviors play a vital and immediate role in mitigating personal exposure and associated health risks, particularly for susceptible individuals [4].

Implementing protective behaviors can prevent adverse health conditions and promote healthy growth and development, especially among vulnerable populations such as adolescents, whose immature physiological functions make them highly susceptible to conditions like haze weather, which can impair lung capacity and lead to various respiratory issues [5]. Key self-care strategies for air pollution mitigation include staying indoors on days with high air pollution, reducing outdoor air infiltration into homes, utilizing air filters to clean indoor air, limiting physical exertion outdoors, and employing face mask respirators [4]. Other practical steps involve regularly checking air pollution forecasts, avoiding outdoor exercise near high-traffic areas, reducing household energy consumption, and actively advocating for clean air policies.

The effectiveness of individual self-care behaviors in reducing personal exposure to air pollutants is grounded in well-established exposure science. Ambient pollutant concentrations, such as particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), and ozone (O3), represent the outdoor environmental burden; however, personal exposure is a function of both ambient levels and individual behavioral patterns. Behaviors such as staying indoors during peak pollution episodes reduce inhalation by exploiting the filtering capacity of indoor environments, which can have substantially lower PM2.5 concentrations than outdoor air, particularly when combined with reduced infiltration and use of air purifiers [4, 6]. Wearing certified respirator masks (e.g. FFP2/N95) during outdoor activities directly attenuates the dose of fine particulate matter entering the respiratory tract [6]. Avoiding outdoor physical exertion near high-traffic corridors minimizes ventilation rate-driven uptake during periods of elevated local emissions [6]. Collectively, therefore, these behaviors operate as individual-level exposure mitigation strategies that can meaningfully reduce the gap between ambient concentrations and the dose actually received by a person, even in the absence of source-level emission controls.

The identification of these specific behaviors directly links the broad public health problem to concrete, measurable actions. For instance, the 'Self-Care Behaviors Related to Air Pollution Protection Questionnaire' specifically assesses behaviors such as staying indoors during emergencies or peak air pollution hours and using face mask respirators outdoors [7].

This direct correspondence demonstrates the practical utility of instruments designed to capture these tangible, impactful behaviors, making their validation highly relevant for public health interventions. Accurate and meaningful assessment of health behaviors and their determinants across diverse populations necessitates the use of measurement instruments that are not only reliable and valid but also culturally adapted. The 'Self-Care Behaviors Related to Air Pollution Protection Questionnaire' was originally developed by Mirzaei-Alavijeh *et al* in 2020 [7]. This instrument was specifically designed to assess self-care behaviors related to air pollution protection from the perspective of college students. Its theoretical foundation is firmly rooted in the health belief model (HBM), incorporating the core constructs of perceived susceptibility, perceived severity, perceived barriers, perceived benefits, self-efficacy, cues to action, and actual protective behaviors. This original development and initial validation represent a foundational step, but its broader applicability requires an iterative process of cross-cultural adaptation and re-validation to ensure its utility across diverse populations.

Furthermore, the development of a culturally adapted short form of the questionnaire addresses a significant practical need for researchers and practitioners. While comprehensive, longer instruments can impose a considerable burden on participants and extend administration time, potentially impacting data quality and feasibility in large-scale studies or clinical settings. A well-developed short form can enhance data collection efficiency and reduce participant fatigue without compromising the theoretical integrity or core psychometric properties of the original instrument. This reflects a strategic balance between maintaining psychometric rigor and enhancing the practical utility of the instrument for real-world research and public health practice.

While the HBM provides a comprehensive framework for understanding health behaviors, the specific interplay and mediating roles of its constructs, particularly perceived self-efficacy in the relationship between perceived threat/benefit and protective behaviors, have not been fully explored using advanced statistical methods like structural equation modeling (SEM) in the context of this specific questionnaire or air pollution self-care in Türkiye. Understanding these mediating pathways is critical for developing more nuanced and effective health promotion interventions [8]. The explicit aim to explore mediating roles using SEM represents a move beyond basic correlational analysis, seeking to uncover the underlying causal pathways and complex interplay of HBM constructs, thereby contributing to a deeper theoretical understanding of health behavior change.

Building upon the identified global public health challenges posed by air pollution, the imperative for individual self-care behaviors, the explanatory power of the HBM, and the critical need for culturally validated and practically useful measurement tools, this study addresses specific gaps in the existing literature. This study aimed to accomplish three primary objectives. First, we sought to examine the validity and reliability of the Turkish version of the 'Self-Care Behaviors Related to Air Pollution Protection Questionnaire (SCBAPPQ)' originally developed by Mirzaei-Alavijeh *et al* in 2020 through comprehensive psychometric analysis [7]. Second, we aimed to develop a culturally adapted short form that maintains the theoretical integrity of the original instrument while providing practical utility for researchers and practitioners in Türkiye. Third, we explored the mediating role of perceived self-efficacy in the relationship between perceived threat/benefit and protective behaviors, grounded in the HBM, using SEM.

2. Methods

2.1. Study design and participants

This methodological study was conducted between November 1–20, 2024, at Pamukkale University Central Campus in Türkiye. A stratified random sampling method was employed, with the university's six central-campus faculties (including Medicine, Technology, Education, Engineering, Human and Social Sciences, and Economics and Administrative Sciences) constituting the strata. Within each stratum, participant quotas were determined proportionally based on each faculty's share of the total undergraduate enrollment ($N = 21\ 241$), thereby ensuring the sample reflected the actual distribution of the student population across disciplines. Within each faculty, participants were recruited via convenience sampling in classrooms and shared campus spaces. A total of 900 students were approached; 843 agreed to participate and completed the questionnaire, yielding a response rate of 93.67%.

Sample size calculations were based on established guidelines for factor analysis, which recommend a minimum of 10–15 participants per item in the original scale, and SEM requirements of at least 300 participants. The final sample comprised 843 students, substantially exceeding minimum requirements and providing robust statistical power for both exploratory and confirmatory analyses.

The original SCBAPPQ consisted of 26 items distributed across seven theoretical sub-factors, utilizing a 5-point Likert scale format ranging from 1 (strongly disagree) to 5 (strongly agree) [7]. The original validation study reported Cronbach's alpha coefficients ranging from 0.66 to 0.86 across the various subscales, indicating acceptable to good internal consistency reliability. The original scale yields a total score (range 26–130), with higher scores indicating greater engagement in protective behaviors.

2.2. Cultural adaptation process

The cultural adaptation of the SCBAPPQ into Turkish involved a rigorous multi-stage process to ensure both linguistic and cultural equivalence, encompassing translation and content validity assessment.

This process aligned with international guidelines for cross-cultural instrument validation and these stages were as follows:

2.3. Forward translation

Formal permission was obtained from the original developers prior to adaptation. Two bilingual public health specialists independently translated the instrument to Turkish. Both translators were native Turkish speakers and expertise in environmental health terminology. The research team synthesized these translations into a consensus Turkish draft through iterative discussion, resolving lexical discrepancies while preserving conceptual intent.

2.4. Back translation

Two independent translators blinded to the original scale performed reverse translation. The back-translated version was systematically compared with the source instrument by the authors. No meaningful deviations in item semantics or construct representation were identified, confirming translational accuracy.

2.5. Expert panel review for content validity

Ten health professionals (environmental health specialists, epidemiologists, and public health professionals) evaluated cultural appropriateness, conceptual equivalence, and content relevance. Panelists received: (a) the Turkish questionnaire, (b) operational definitions of constructs, (c) HBM theoretical framework, and (d) a 4-point Likert scale for item appraisal (1 = not suitable, 4 = very suitable). This panel assessed whether items maintained their intended meaning within the Turkish cultural context and whether they adequately captured the constructs of interest for Turkish university students. The item–level content validity index (I–CVI) was calculated as the proportion of experts assigning a rating of 3 or 4, and the scale–level content validity index (S–CVI) as the average of all I–CVIs. Minor phrasing adjustments were implemented based on expert suggestions. All items achieved an I–CVI of 1.00, and the overall S–CVI was 1.00, exceeding the recommended threshold ($\geqslant$0.80) and demonstrating excellent content validity [9].

2.6. Data collection procedures

Data collection was conducted through face-to-face interviews administered by trained research assistants to ensure consistency and data quality. All participants provided voluntary informed consent before participating in the study, ensuring compliance with ethical research standards and institutional review board requirements.

The inclusion criteria required participants to be undergraduate students enrolled at Pamukkale University Central Campus with sufficient Turkish language proficiency to understand and respond to questionnaire items. Participants who experienced difficulties with Turkish reading comprehension were excluded from the study to ensure data quality and response validity. This language requirement was essential given that the questionnaire was administered exclusively in Turkish following the cultural adaptation process.

2.7. Statistical analysis plan

Our analytical approach employed a systematic split-sample design to ensure robust psychometric evaluation. The total sample of 843 participants was randomly divided into two subgroups using computer-generated random numbers. The first subsample ($n = 421$) was designated for exploratory factor analysis (EFA) to examine the underlying factor structure of the translated instrument. The second subsample ($n = 422$) was reserved for confirmatory factor analysis (CFA) and SEM to validate the factor structure identified through exploratory procedures.

EFA was conducted using principal axis factoring with Promax rotation, as theoretical considerations suggested potential correlations among factors consistent with HBM predictions. Multiple criteria were employed to determine the optimal number of factors, including eigenvalues greater than one, scree plot examination, and parallel analysis. Item retention decisions were based on factor loadings exceeding 0.40, absence of substantial cross-loadings (defined as secondary loadings above 0.30) [10, 11], and theoretical coherence within factors according to HBM constructs.

CFA utilized unweighted least squares (ULS) estimation to accommodate the ordinal nature of the Likert-scale responses. The ULS estimator was selected as it provides more appropriate parameter estimates for categorical data compared to maximum likelihood estimation, which assumes continuous normally distributed variables [12]. Multiple fit indices were examined to comprehensively assess model adequacy, including the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). Acceptable fit was defined using established cutoff criteria: CFI and TLI values above 0.90 (preferably above 0.95), RMSEA values below 0.08 (preferably below 0.05), and SRMR values below 0.08 [13, 14].

Reliability assessment employed multiple approaches to ensure comprehensive evaluation of internal consistency. We calculated both Cronbach's alpha and McDonald's omega coefficients for each factor, with omega being preferred due to its less restrictive assumptions about tau-equivalence. Values above 0.70 were considered acceptable for both coefficients. Additionally, we computed composite reliability (CR) and average variance extracted (AVE) to provide indicators of convergent validity, with AVE values above 0.50 indicating adequate convergent validity [15, 16].

For test–retest reliability assessment, a subsample of 84 participants was randomly selected and asked to complete the questionnaire again after a two-week interval. Multiple statistical approaches were employed to comprehensively evaluate temporal stability: paired-samples t-tests were conducted to detect systematic mean differences between administrations, Spearman's rank correlation coefficient (ρ) was calculated to assess ordinal consistency, two-way mixed-effects intraclass correlation coefficients (ICCs) with absolute agreement were computed to evaluate temporal stability, and Cohen's weighted kappa statistics were calculated to assess categorical agreement between test and retest administrations.

SEM was implemented to test the theoretical relationships proposed by the HBM, specifically examining the mediating role of perceived self-efficacy in the relationship between perceived threats/benefits and protective behaviors. The structural model incorporated measurement models for each latent construct while simultaneously estimating structural pathways.

2.8. Statistical analysis

All statistical analyses were conducted using R software (version 4.3.1). Descriptive statistics are presented as frequencies and percentages for categorical variables and as means with standard deviations for continuous variables. The dataset contained no missing values, eliminating the need for imputation procedures.

Test–retest reliability was comprehensively evaluated through multiple complementary approaches. Systematic mean differences between time points were assessed using paired-samples t-tests, while ordinal consistency was examined via Spearman's rank correlation coefficient (ρ). Temporal stability was quantified using two-way mixed-effects ICCs with absolute agreement criteria.

Internal consistency reliability was assessed using three established metrics: Cronbach's alpha (α), McDonald's Omega (ω), and CR. All reliability coefficients range from 0 to 1, with values $\geqslant$0.70 considered acceptable for research purposes.

It should be noted that the original SCBAPPQ was theoretically grounded in a seven-construct HBM framework: perceived susceptibility, perceived severity, perceived barriers, perceived benefits, self-efficacy, cues to action, and protective behavior. Our EFA was conducted without presupposing a fixed number of factors; the number of factors was determined empirically using eigenvalues $>$1, scree plot inspection, and parallel analysis. The emergent three-factor structure (threat/benefit perceptions, self-efficacy, and protective behaviors) does not contradict the HBM framework but rather represents an empirically derived, more parsimonious representation of how Turkish university students cognitively organize these constructs. In the HBM literature, perceived susceptibility, severity, and benefits are frequently observed to correlate strongly and to co-load onto a shared threat-appraisal dimension, particularly in populations with limited prior exposure to structured health communication. The implications of the exclusion of perceived barriers and cues to action as independent factors are discussed in the discussion section.

EFA was conducted using principal axis factoring with Promax rotation to examine the underlying factor structure of the instruments and identify potential latent dimensions within the data. Construct validity was subsequently examined through CFA implemented via ULS estimation using the 'lavaan' package. Model fit was evaluated using multiple goodness-of-fit indices, including the CFI, goodness of fit index (GFI), TLI, RMSEA, and SRMR. SEM was implemented to test the theoretical relationships proposed by the HBM, specifically examining the mediating role of perceived self-efficacy in the relationship between perceived threats/benefits and protective behaviors. The structural model incorporated measurement models for each latent construct while simultaneously estimating structural pathways. Both direct and indirect pathways were estimated, with mediation effects tested within the comprehensive model framework. All structural relationships were visualized as a directed acyclic graph using the 'ggdag' and 'dagitty' packages in R. Path coefficients and their corresponding significance levels from the SEM analysis were superimposed onto the graph to provide an integrated visual representation of all hypothesized and tested relationships.

Convergent validity was established through AVE values exceeding 0.50, while discriminant validity was assessed using heterotrait-monotrait (HTMT) ratios with a conservative threshold of less than 0.85. The 'semTools' package facilitated calculations for both AVE and HTMT ratio analyses.

Statistical significance was established at $p < 0.05$ for all inferential analyses.

2.9. Ethical considerations

Ethical approval for this study was obtained from the Pamukkale University Noninterventional Clinical Research Ethics Committee (Approval Date: 22.10.2024 and Approval Number: 18). Participation in the study was voluntary. Written informed consent was obtained from all participants prior to questionnaire administration.

3. Results

3.1. Sample characteristics

The total sample comprised 843 undergraduate students from Pamukkale University Central Campus, recruited through stratified random sampling across six faculties. Demographic analysis revealed that 47.3% of participants were female ($n = 399$) and 52.7% were male ($n = 444$). The mean age was 21.3 years (SD = 2.0), with ages ranging from 18 to 43 years. Faculty distribution was proportional to enrollment, with the largest representation from Economics and Administrative Sciences (26.6%), followed by Human and Social Sciences (24.0%), Engineering (20.2%), Education (13.3%), Technology (8.2%), and Medicine (7.8%).

The dataset was randomly divided into two subsamples for analytical purposes. The EFA subsample ($n = 421$) included 46.3% female participants with a mean age of 21.2 years (SD = 2.2). The CFA subsample ($n = 422$) included 48.3% female participants with a mean age of 21.3 years (SD = 1.9). Chi-square tests for gender distribution ($\chi^2 = 0.346$, $p = 0.556$) and independent t-tests for age differences ($p = 0.264$) confirmed no significant differences between subsamples, supporting the validity of the random split procedure.

3.2. Scale refinement process

The scale refinement process employed a systematic iterative approach guided by both statistical criteria and theoretical considerations to develop a psychometrically sound air pollution protection behavior scale. The refinement process began with an initial 26-item instrument and progressed through multiple exploratory factor analyses to achieve optimal factor structure and item performance.

The scale refinement process followed a sequential, iterative approach guided by predefined statistical and theoretical criteria. In the first iteration, all 26 items from the original SCBAPPQ were entered into an EFA using principal axis factoring with Promax rotation. Items were flagged for removal if they met one or more of the following criteria: (1) a primary factor loading below 0.40, indicating insufficient association with any latent construct; (2) substantial cross-loadings, defined as a secondary loading exceeding 0.30 combined with a primary-to-secondary loading difference of less than 0.20, which would compromise factor interpretability; or (3) theoretical incoherence, meaning the item did not conceptually align with the HBM construct represented by the factor on which it loaded most strongly. Items meeting any of these criteria were removed one at a time in order of the most problematic psychometric profile, and the EFA was re-run after each removal to reassess factor structure stability. This iterative process was repeated until all remaining items met the retention criteria and the factor structure was stable and theoretically interpretable.

Through this rigorous evaluation process, twelve items (H1, H3, H6, H13, H14, H15, H16, H17, H21, H22, H23, H24) were removed from the measurement model. These items were eliminated due to various psychometric deficiencies: some exhibited factor loadings below conventional thresholds, others demonstrated substantial cross-loadings that compromised factor interpretability, and several showed poor theoretical fit within the intended factor structure. Notably, items related to perceived susceptibility (H1, H3) were removed due to weak loadings and potential conceptual redundancy, while barrier-related items (H15, H16) failed to load coherently on any single factor. Social influence items (H21, H22, H23) formed a separate construct that did not align with the core three-factor theoretical model, leading to their exclusion from the final scale.

A supplementary table listing all 12 removed items (H1, H3, H6, H13, H14, H15, H16, H17, H21, H22, H23, H24), their original HBM subscale assignments, their factor loadings at the point of removal, and the specific criterion that triggered removal has been added as supplementary table S1.

The final 14-item structure demonstrated improved psychometric properties compared to the full 26-item version, supporting the value of systematic item reduction in cross-cultural instrument adaptation. The shortened version maintains coverage of all three core HBM constructs while reducing respondent burden and improving practical utility for research and clinical applications.

3.3. EFA

EFA results are presented in table 1. The Kaiser–Meyer–Olkin measure of sampling adequacy achieved a value of 0.843, well above the recommended threshold of 0.70, indicating that the data were appropriate for EFA. Bartlett's test of sphericity produced a significant result ($\chi^2 = 4088.151$, $df = 91$, $p < 0.001$), confirming that the correlation matrix was suitable for factor extraction.

The EFA was conducted using principal axis factoring with Promax rotation to allow for correlated factors, consistent with theoretical expectations that air pollution protection constructs would be interrelated. The analysis focused on 14 items that demonstrated adequate psychometric properties from the

Table 1. Exploratory factor analysis of air pollution protection scale items ($N = 843$)[a].

Item	Factor 1: threat/benefit perception	Factor 2: self-efficacy	Factor 3: protective behaviors	Communality
H7	0.781			0.600
H10	0.772			0.551
H11	0.733			0.522
H8	0.725			0.547
H9	0.719			0.529
H4	0.697			0.549
H12	0.657			0.414
H5	0.654			0.419
H2	0.556			0.431
H26			0.870	0.755
H25			0.811	0.680
H20			0.725	0.523
H18		0.899		0.806
H19		0.888		0.794
Eigenvalue	4.591	2.046	2.101	
% Variance explained	33.255	9.563	15.197	58.015
Cumulative %	33.255	42.818	58.015	

[a] Extraction method: principal axis factoring. Rotation method: Promax with Kaiser normalization. Factor loadings <0.10 are suppressed.

original 26-item scale, representing a systematic refinement process that removed items with insufficient factor loadings, problematic cross-loadings, or theoretical inconsistencies.

The factor extraction process identified three meaningful factors with eigenvalues exceeding 1.0. The first factor explained 33.255% of the common variance, the second factor contributed an additional 9.563%, and the third factor accounted for 15.197% of the variance. Together, these three factors explained 58.015% of the total common variance in the dataset, substantially exceeding the commonly accepted threshold of 50% and indicating that the factor solution captured a substantial proportion of shared variability, thereby supporting the adequacy of the three-factor model.

Examination of the pattern matrix revealed a clear and interpretable factor structure. Factor 1, labeled 'Threat and Benefit Perceptions', emerged as the strongest and most comprehensive factor, with nine items demonstrating substantial loadings ranging from 0.556 to 0.781. These items (H2, H4, H5, H7, H8, H9, H10, H11, H12) conceptually represented threat and benefit perceptions related to air pollution protection, encompassing both perceived risks of exposure and perceived benefits of protective behaviors. Factor 2, named 'Self-Efficacy', consisted of two items (H18, H19) with loadings between 0.888 and 0.899, representing self-efficacy beliefs regarding one's ability to implement air pollution protection strategies. Factor 3, designated as 'Protective Behaviors', comprised three items (H20, H25, H26) with substantial loadings of 0.725–0.870, representing protective behaviors including specific actions taken to reduce air pollution exposure.

All communalities exceeded 0.40 (range: 0.414–0.806), indicating that each item shared a substantial proportion of variance with the extracted components. The overall pattern of communalities supported the retention of all 14 items in the final factor structure.

3.4. CFA

The CFA was conducted on the second subsample ($n = 422$) to validate the three-factor structure identified through exploratory procedures. The analysis demonstrated excellent model fit across multiple indices, providing strong evidence for the validity of the refined factor structure in the Turkish context.

Model fit indices demonstrated exceptional adherence to established criteria for excellent model fit. The CFI achieved a value of 0.987, well above the 0.95 threshold for excellent fit. The TLI reached 0.985, similarly indicating excellent model fit. The RMSEA was 0.045 with a 90% confidence interval of 0.033–0.056, falling well below the 0.05 threshold for excellent fit. The RMSEA p-value of 0.759 for testing the null hypothesis that RMSEA $\leqslant$ 0.050 provided additional evidence supporting excellent model fit. The SRMR was 0.056, comfortably meeting the criterion of acceptable fit ($\leqslant$0.08). Model fit indices were presented in table 2.

The factor loadings demonstrated strong relationships between observed indicators and their respective latent constructs, providing evidence for convergent validity. For the threat/benefit factor

Table 2. Confirmatory factor analysis results and model fit indices[a].

Fit Index	Value	Criterion for excellent fit	Acceptable threshold	Interpretation
CFI	0.987	⩾ 0.95	⩾ 0.95	Excellent
TLI	0.985	⩾ 0.95	⩾ 0.95	Excellent
GFI	0.997	⩾ 0.90	⩾ 0.90	Excellent
SRMR	0.056	⩽0.05	⩽ 0.08	Good
RMSEA	0.045	⩽0.05	⩽ 0.08	Excellent
RMSEA 90% CI	[0.033–0.056]	—	—	Excellent
RMSEA *p*-value	0.759	⩾ 0.05	⩾ 0.05	Excellent

[a] CFI: comparative fit index, GFI: goodness-of-fit index, NNFI: nonnormed fix index, RMSEA: root mean square error of approximation, SRMR: standardized root mean square residual, CI: confidence interval.

Table 3. Internal consistency and convergent validity[a].

Scale	Items	Cronbach's α (95% CI)	McDonald's ω (95% CI)	AVE	CR
Total scale	14	0.869 (0.848–0.890)	0.869 (0.856–0.882)	—	—
Threat/benefit (Factor 1)	9	0.869 (0.848–0.890)	0.869 (0.856–0.882)	0.501	0.889
Self-efficacy (Factor 2)	2	0.768 (0.725–0.810)	—[a]	0.691	0.816
Protective behaviors (Factor 3)	3	0.732 (0.696–0.769)	0.746 (0.718–0.775)	0.591	0.808

[a] McDonald's ω calculation failed for Factor 2 due to insufficient degrees of freedom for the two-item factor.
CR = composite reliability; AVE = average variance extracted.

(Factor 1), standardized loadings ranged from 0.589 to 0.760, with all loadings being statistically significant ($p < 0.001$). The consistency of these loadings across nine items provides strong evidence for the unidimensional nature of this combined construct in the Turkish context. The self-efficacy factor (Factor 2) showed particularly strong loadings of 0.914 and 0.739, indicating that both items strongly represent the underlying self-efficacy construct. The protective behavior factor (Factor 3) demonstrated progressive loadings across its three indicators, with values of 0.593, 0.776, and 0.905, suggesting that the items represent increasing levels of behavioral engagement with air pollution protection.

3.5. Reliability and validity assessment

Internal consistency reliability was assessed using both Cronbach's alpha and McDonald's omega coefficients, providing comprehensive evaluation of scale reliability. For the overall 14-item scale, internal consistency was excellent with an omega coefficient of 0.869 (95% CI: 0.856–0.882) and a Cronbach's alpha of 0.869 (95% CI: 0.848–0.890). The threat/benefit factor (Factor 1) demonstrated excellent internal consistency with both omega ($\omega = 0.869$, 95% CI: 0.856–0.882) and Cronbach's alpha ($\alpha = 0.869$, 95% CI: 0.848–0.890) coefficients. The self-efficacy factor (Factor 2), comprising only two items, showed acceptable reliability ($\alpha = 0.768$, 95% CI: 0.725–0.810), though omega calculation failed due to insufficient degrees of freedom for the two-item factor. While two-item scales present challenges for traditional reliability assessment, the alpha coefficient of 0.768 suggests reasonable internal consistency for this brief measure, and the strong factor loadings provide additional evidence for the coherence of these items. The protective behavior factor (Factor 3) demonstrated acceptable reliability with omega ($\omega = 0.746$, 95% CI: 0.718–0.775) and Cronbach's alpha ($\alpha = 0.732$, 95% CI: 0.696–0.769) coefficients. The CR values of the factors were between 0.808 and 0.899, which are considered acceptable values. (table 3).

Convergent validity was assessed through AVE calculations for each factor. The threat/benefit factor (Factor 1) achieved an AVE of 0.501, just meeting the minimum threshold of 0.50 for adequate convergent validity. The self-efficacy factor (Factor 2) showed excellent convergent validity with an AVE of 0.691, and the protective behavior factor (Factor 3) demonstrated strong convergent validity with an AVE of 0.591. These results indicate that each factor explains more than half of the variance in its constituent indicators, supporting the convergent validity of the measurement model (table 3).

The HTMT ratio analysis provided evidence for discriminant validity between the factors. All HTMT ratios were below the conservative threshold of 0.85, with the highest ratio being 0.47 between self-efficacy and protective behavior factors. The factor correlation matrix revealed moderate relationships between constructs, with correlations ranging from −0.133 to 0.411, indicating sufficient discriminant validity while allowing for theoretically meaningful relationships between constructs as predicted by the HBM.

Table 4. Test–retest reliability results ($n = 84$).

	Value	95% CI	p-value
Mean first administration	$M = 90.42$ (SD = 10.75)	—	—
Mean second administration	$M = 89.86$ (SD = 11.19)	—	—
Paired-t Test	$t = 1.09$	Mean diff = 0.56 (−0.46–1.58)	0.279
Spearman's ρ	0.884	[0.824, 0.924]	< 0.001
Intraclass correlation (ICC)	0.908	[0.861, 0.939]	< 0.001

[a] Temporal stability assessed over a two week interval.
[b] ICC based on two–way mixed effects, absolute agreement.

Table 5. Structural path coefficients and mediation analysis.

Path Direct effects	β	p-value
Threat benefit → self efficacy	0.411	< .001
Self efficacy → protective behavior	0.260	< .001
Threat benefit → protective behavior	−0.240	< .001
Indirect effect		
Threat benefit → self efficacy → protective behavior	0.107	< .001
Total effect		
Threat benefit → protective behavior	−0.133	< .001

3.6. Test–retest reliability

To examine the temporal stability of the instrument, the total scale was readministered to a randomly selected subsample of 84 participants after a two-week interval. Multiple statistical approaches were employed to comprehensively assess test–retest reliability and temporal stability. Results were presented in table 4.

Paired-samples t-tests revealed no significant systematic difference between the first administration ($M = 90.42$, SD = 10.75) and the second administration ($M = 89.86$, SD = 11.19) of total scale scores ($p = 0.279$). The mean difference between administrations was 0.56 points (95% CI: −0.46–1.58), indicating excellent stability of mean scores over the two-week period.

Spearman's rank correlation coefficient between the two administrations was $\rho = 0.884$ (95% CI [0.824, 0.924]; $p < 0.001$), indicating a very strong positive correlation and excellent ordinal consistency between test and retest scores. This high correlation demonstrates that participants' relative rankings on the scale remained highly consistent across the two-week interval.

The two-way mixed-effects ICC for absolute agreement was 0.908 (95% CI: 0.861–0.939) for single measures ($p < 0.001$). The ICC value exceeded the threshold of 0.90 for excellent reliability, indicating exceptional temporal stability and measurement consistency.

These comprehensive test–retest analyses provide robust evidence for the temporal stability and reliability of the Turkish version of the SCBAPPQ.

3.7. SEM

The structural equation model was tested to examine the theoretical relationships proposed by the HBM, specifically investigating the mediating role of self-efficacy in the relationship between threat/benefit perceptions and protective behaviors.

The SEM analysis revealed significant relationships between the three latent constructs in the mediation model. The model demonstrated acceptable fit indices with CFI = 0.987, TLI = 0.985, RMSEA = 0.045 (90% CI: 0.033–0.056), and SRMR = 0.056, indicating good model fit to the data indicating that the structural relationships did not compromise model fit. All fit indices surpassed established thresholds (CFI/TLI > 0.95; RMSEA/SRMR < 0.08), confirming model robustness.

The structural path analysis revealed significant direct effects among the latent constructs that provide important insights into the mechanisms underlying air pollution protection behaviors. The structural model revealed a significant positive relationship between threat and benefit perceptions factor and self efficacy factor ($\beta = 0.411$, $p < 0.001$), supporting the hypothesis that perceived threat and benefit appraisals enhance self-efficacy beliefs. Self Efficacy factor demonstrated a significant positive effect on protective behaviors factor ($\beta = 0.260$, $p < 0.001$), indicating that individuals with higher self-efficacy are more likely to engage in protective behaviors (table 5).

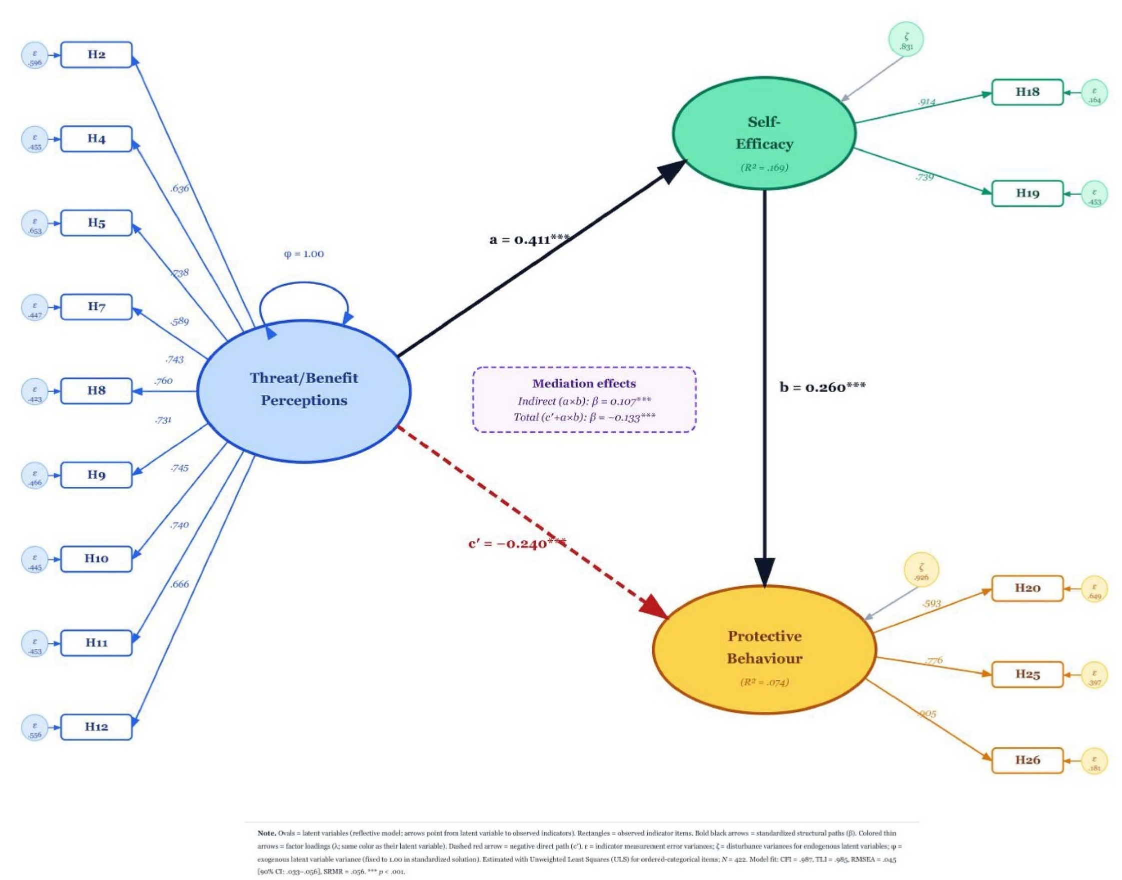

Figure 1. Structural equation model showing relationships between threat/benefit perceptions, self-efficacy, and air pollution protective behaviors.

Interestingly, the direct effect of Threat and Benefit perceptions factor on protective behaviors factor was negative and significant ($\beta = -0.240$, $p < 0.001$), suggesting a suppression effect when controlling for the mediator. This finding indicates that while threat and benefit perceptions may not directly lead to protective behaviors, they operate through self-efficacy beliefs to influence behavioral outcomes (table 5).

3.8. Mediation analysis

The mediation analysis revealed a significant indirect effect of Threat and Benefit perceptions factor on protective behaviors factor through Self Efficacy factor ($\beta = 0.107$, $p < 0.001$). The total effect was negative and significant ($\beta = -0.133$, $p < 0.001$), confirming the presence of a suppression effect. This pattern suggests that the indirect pathway through self-efficacy is the primary mechanism by which threat and benefit appraisals influence protective behaviors (table 5).

The structural relationships among scale factors are visually represented in the directed acyclic graph presented in figure 1, which illustrates both the direct pathways and the indirect mediation pathways shown in table 5.

4. Discussion

This comprehensive psychometric study successfully validated and developed a culturally adapted short form of the SCBAPPQ for Turkish university students. Through rigorous methodological approaches incorporating exploratory and confirmatory factor analyses, SEM, and systematic scale refinement procedures, we have created a psychometrically robust 14-item instrument that addresses a critical gap in environmental health measurement tools for Turkish populations.

The methodological procedures for cross-cultural adaptation and validation of questionnaires require careful planning to deliver instruments with adequate reliability and validity, as the simple translation of a questionnaire may lead to misinterpretation due to language and cultural differences. Our comprehensive approach, including forward and back translation, expert panel review, and content validity assessment, aligns with established international guidelines for cross-cultural instrument adaptation [17]. The achievement of perfect content validity indices (I-CVI = 1.00, S-CVI = 1.00), which exceeded benchmarks established in cross-cultural instrument validation literature [18] provides strong evidence for the cultural appropriateness and conceptual equivalence of the Turkish version. This finding is particularly significant given that environmental health behaviors may be influenced by culture-specific factors such as social norms, environmental awareness, and available protective resources. The unanimous agreement among expert panelists regarding item suitability suggests that the translated items maintain their intended meaning within the Turkish cultural context while adequately capturing the constructs of interest for Turkish university students.

4.1. Factor structure and theoretical implications

The original 26-item SCBAPPQ, initially validated in an Iranian university student population, identified seven distinct factors: perceived susceptibility, severity, barriers, benefits, self-efficacy, cues to action, and behavior, and explained 66.39% of the variance with internal consistency reliability ranging from 0.66 to 0.86 [6]. In contrast, the Turkish adaptation presented a three-factor model. The analyses consistently supported a parsimonious 14-item, three-factor solution, specifically 'Threat and Benefit Perceptions', 'Self-Efficacy', and 'Protective Behaviors'. Our refined three-factor solution, explaining 58.015% of the variance exceeds the 50% threshold recommended by Tabachnick and Fidell [11], thereby demonstrating comparable explanatory power with enhanced parsimony and theoretical coherence.

In the original HBM framework, perceived susceptibility, perceived severity, and perceived benefits are typically conceptualized as distinct cognitive components. However, our results suggest that Turkish university students may cognitively integrate threat appraisals with benefit evaluations when considering air pollution protection behaviors. The merging of perceived susceptibility, severity, and benefits into a single threat/benefit perceptions factor is an intriguing finding that warrants careful interpretation. While this pattern is consistent with a culturally holistic approach to risk-benefit appraisal, whereby Turkish university students may evaluate air pollution threat and protective benefit simultaneously rather than as discrete cognitive constructs. We acknowledge that methodological explanations cannot be ruled out. First, item wording artefacts may have limited cognitive differentiation: the susceptibility, severity, and benefits items share first-person evaluative framing, which may not have generated sufficient response variance to sustain three independent factors. Second, scale reduction to 14 items necessarily reduced within-subscale item diversity, potentially removing the discriminating items that anchored separate constructs in the original instrument. Future research with larger item pools and independent samples is needed to determine whether this merging pattern replicates and reflects genuine cognitive integration or is an artefact of the short-form development process. Additionally, it is important to note that perceived barriers and cues to action, while represented in the original 26-item SCBAPPQ, did not survive the scale refinement process as independent factors. Their exclusion limits the theoretical completeness of the short form from a strict HBM perspective, particularly for studies aimed at identifying structural impediments to behavior or trigger stimuli. Researchers requiring full HBM operationalization are advised to use the complete instrument.

This integrated risk-benefit assessment may reflect a more holistic approach to environmental health decision-making, where individuals simultaneously consider both the potential harms of inaction and the advantages of protective behaviors. This finding has important implications for health communication strategies, suggesting that messages emphasizing both threat severity and protection benefits may be more effective than addressing these concepts separately. The 'Self-Efficacy' factor, while containing only two items, demonstrates the continued relevance of confidence beliefs in environmental health protection. The high factor loadings and theoretical coherence of these items suggest that perceived ability to perform protective behaviors remains a crucial component of air pollution protection models. However, the reduced number of self-efficacy items compared to the original scale indicates that confidence beliefs may be more specific and focused in the environmental health context than in other health domains. The three behavioral items ('Protective Behaviors' factor items) represent practical, accessible actions that individuals can take to reduce their air pollution exposure.

The scale refinement process adhered to a systematic and theoretically informed approach to optimize the psychometric properties of the air pollution protection scale. Beginning with the original 26-item instrument, 12 items (H1, H3, H6, H13, H14, H15, H16, H17, H21, H22, H23, H24) were systematically removed from the measurement model. This elimination was based on various psychometric deficiencies, including inadequate factor loadings (below 0.40), problematic cross-loadings across multiple factors, or theoretical inconsistencies with the intended factor structure. The refined 14-item scale exhibited superior psychometric properties, with all retained items demonstrating factor loadings above 0.55 and clear theoretical alignment with their respective factors. This systematic refinement process resulted in a more parsimonious and theoretically coherent instrument that maintained the essential conceptual domains while eliminating psychometrically problematic items. The CFA, conducted on a separate subsample ($n = 422$), provided strong evidence for the validity of the refined three-factor structure in the Turkish context. Model fit indices demonstrated exceptional adherence to established criteria for excellent model fit.

4.2. Mediation analysis and behavioral mechanisms

The SEM results provide particularly valuable insights into the psychological mechanisms underlying air pollution protection behaviors. The structural model demonstrated excellent fit to the data (CFI = 0.987, TLI = 0.985, RMSEA = 0.045, SRMR = 0.056), indicating that the hypothesized relationships align well with the observed data and confirming model robustness as all fit indices surpassed established thresholds.

A significant positive relationship was observed between the 'Threat and Benefit Perceptions' factor and the 'Self-Efficacy' factor. This finding supports the proposition that individuals' appraisals of the severity and susceptibility to air pollution, combined with their recognition of the benefits of protective actions, significantly enhance their self-efficacy beliefs. This suggests that a comprehensive understanding of the problem and its potential solutions (encompassing both perceived threat and benefit) serves as a precursor to individuals feeling capable of enacting protective behaviors.

Furthermore, the 'Self-Efficacy' factor demonstrated a significant positive effect on the 'Protective Behaviors' factor. This outcome is consistent with the core tenets of the HBM, which indicates that individuals with higher confidence in their ability to perform a behavior are indeed more likely to engage in it [8]. This confirms self-efficacy as a direct and potent driver of protective actions against air pollution.

A noteworthy finding was the negative and significant direct effect of 'Threat and Benefit Perceptions' on 'Protective Behaviors'. This statistical pattern indicates a suppression effect, a complex phenomenon where the inclusion of a mediator (self-efficacy) reveals a direct relationship that might otherwise be obscured or appear non-significant in a simpler bivariate analysis.

This suppression effect carries important conceptual implications for understanding health behavior. It suggests that while perceived threat and benefit appraisals are indeed essential, they do not directly translate into protective behaviors in a straightforward positive manner. Instead, their positive influence is critically channeled and enabled by self-efficacy. Without sufficient self-efficacy, merely perceiving a threat or benefit might not be enough to drive behavior. In fact, an elevated perception of threat without the corresponding confidence to act could potentially lead to maladaptive responses such as fear, denial, or feelings of helplessness, thereby hindering proactive engagement. This aligns with 'environmental helplessness' concepts where perceived uncontrollability undermines motivation [19]. This negative direct pathway could represent this 'paralysis by analysis' or feeling overwhelmed. Conversely, when self-efficacy is high, the positive influence of threat and benefit perceptions can effectively manifest in behavioral change. Therefore, self-efficacy functions as a crucial enabler, allowing threat and benefit perceptions to positively influence behavioral outcomes. This finding has profound intervention implications, contravening risk-centric campaigns and emphasizing the essentiality of efficacy-building components—echoing Bandura's emphasis on efficacy as the 'key determinant' of behavioral change [20]. Our findings suggest that risk communication efforts should be carefully designed to avoid creating feelings of helplessness or fatalism that could actually reduce protective behavior adoption.

The negative direct path from threat/benefit perceptions to protective behaviors ($\beta = -0.240$), combined with a positive indirect effect through self-efficacy ($\beta = 0.107$), constitutes a classic suppression pattern in mediation analysis. We proposed that this may reflect an 'environmental helplessness' mechanism [19], whereby elevated threat perceptions in the absence of sufficient efficacy beliefs lead to motivational paralysis rather than protective action. While this interpretation is theoretically coherent and consistent with social cognitive theory, we acknowledge that it remains speculative and that alternative explanations must be considered. Statistically, suppression effects can arise from multicollinearity between the predictor and mediator—in our model, threat/benefit perceptions strongly predict self-efficacy ($\beta = 0.411$), and controlling for the mediator redistributes this shared variance in ways that can reverse the sign of the direct path. Additionally, the merging of threat and benefit items within a single factor introduces construct heterogeneity: severity-related items may generate a different behavioral response than benefit-related items, and their co-representation in one latent variable may produce artefactual negative direct effects. Longitudinal designs and experimental studies distinguishing threat appraisal from benefit perception would be needed to establish the directionality and psychological reality of this suppression effect.

4.3. Reliability

The comprehensive reliability assessment employed in this study provides robust evidence for the temporal stability and internal consistency of the Turkish SCBAPPQ. The excellent test–retest reliability (ICC $= 0.908$) demonstrates that the instrument produces stable measurements across time. The strong Spearman correlation ($\rho = 0.884$) indicates that participants' relative rankings remain highly consistent, supporting the instrument's utility for individual assessment and comparison studies.

The internal consistency coefficients for the overall scale ($\alpha = 0.869$, $\omega = 0.869$) and sub-factors demonstrate acceptable to excellent reliability. The convergent validity evidence, particularly the AVE values exceeding 0.50 for all factors, demonstrates that each factor explains a substantial proportion of variance in its constituent indicators. This finding supports the distinctiveness of the three factors while confirming their theoretical coherence. The discriminant validity evidence provided by the HTMT ratios below 0.85 indicates that the factors are sufficiently distinct while allowing for theoretically meaningful correlations consistent with HBM predictions.

Beyond its contribution to the measurement literature, the validated Turkish SCBAPPQ has direct applications across three domains of environmental public health. In the domain of environmental health surveillance, the instrument provides a standardized, psychometrically robust tool for monitoring trends in air pollution self-care behaviors among university students over time. Repeated cross-sectional or panel studies using the 14-item short form could track behavioral responses to changes in air quality levels, pollution episodes, or public health communications, thereby enriching conventional air quality monitoring data with individual-level behavioral indicators. In the domain of intervention evaluation, the scale can serve as both a baseline assessment tool and an outcome measure for behavioral health interventions targeting air pollution protection. Public health programs seeking to promote mask use, indoor air management, or activity modification during high-pollution episodes can use the instrument to identify subgroups with lower protective behavior scores and to evaluate post-intervention behavioral change. The SEM-derived finding that self-efficacy mediates the threat-behavior pathway further suggests that efficacy-building components—such as skills training, modeling, and behavioral practice—should be incorporated into intervention designs, and their effectiveness can be gauged via the self-efficacy subscale of this instrument. In the domain of policy-relevant research, the tool can be used to assess whether national air quality awareness campaigns, school-based environmental health curricula, or urban planning policies that affect exposure opportunities (such as pedestrian routing away from high-traffic corridors) translate into measurable behavioral changes at the individual level. Given the instrument's demonstrated validity in a Turkish university population and its theoretical grounding in the HBM, it is particularly well-suited for comparative studies examining whether policy environments in different cities or regions are associated with differential levels of air pollution protective behaviors.

4.4. Limitations

While this study provides robust evidence for the psychometric properties of the Turkish SCBAPPQ, several limitations should be acknowledged. The study was conducted exclusively with university students, which may limit the generalizability of findings to other population groups. University students represent a relatively homogeneous population in terms of educational attainment, age range (predominantly 18–25 years), and socioeconomic background, and they are likely to differ systematically from other populations who also face significant air pollution exposure risks. Older adults, for instance, represent a population with elevated biological susceptibility to pollution-related cardiovascular and respiratory effects, but they may have different health literacy levels, risk perceptions, and behavioral repertoires compared to students. The factor structure and reliability of the SCBAPPQ may not replicate in this group, particularly if items referencing digital information-seeking or mobile health behaviors are less relevant. Less-educated or low-income populations may face stronger perceived barriers to protective behaviors—a construct that was not retained in the short form—making the abbreviated instrument less appropriate for characterizing the full behavioral ecology of these groups. Vulnerable populations including children, pregnant women, and individuals with pre-existing respiratory or cardiovascular conditions have heightened health stakes in the context of air pollution exposure, and their risk perceptions, self-efficacy beliefs, and behavioral responses are likely to differ qualitatively from those of healthy young adults. Additionally, rural populations may face different pollution profiles (e.g. indoor biomass combustion, agricultural burning) compared to urban university campuses, and the behavioral constructs relevant to protection may differ accordingly. We strongly recommend future validation studies targeting these populations to establish the cross-population validity and generalizability of the Turkish SCBAPPQ and to refine the instrument for use in more heterogeneous public health settings. The study relied exclusively on self-reported data for self-care behaviors, which introduces the potential for social desirability bias. The focus on individual-level protective behaviors, while theoretically justified, may not capture the full range of air pollution protection strategies available to individuals or communities. Future research might explore additional behavioral domains, such as advocacy behaviors, community engagement, or lifestyle modifications that reduce air pollution exposure.

5. Conclusion

This study successfully developed and psychometrically validated a culturally adapted 14-item short form of the SCBAPPQ for Turkish university students. The rigorous psychometric evaluation confirmed its reliability and validity, establishing it as a practical and sound instrument for future research and public health assessment in this population. The SEM analysis provided compelling evidence for the mediating role of self-efficacy in translating perceived threats and benefits into protective behaviors, revealing a crucial suppression effect where self-efficacy acts as a critical enabler. As air pollution remains a pressing global health threat, leveraging culturally attuned, psychometrically sound measures such as ours will be essential for monitoring behaviors, evaluating programs, and ultimately empowering communities to protect their respiratory health.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Conflict of interest

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Ethical considerations

This study was performed in accordance with the Declaration of Helsinki and was approved by the Pamukkale University Clinical Research Ethics Committee (Approval Date: 22.10.2024 and Approval Number: 18). Participation in the study was voluntary. Written informed consent was obtained from all participants prior to questionnaire administration.

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