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# Development and Validation of a Knowledge, Attitude, and Practice Questionnaire for Environmental Cardiovascular Awareness Among Allied Health Science Students

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## Abstract

Introduction: Air pollution is a major environmental concern with significant implications for cardiovascular health. As future healthcare professionals, allied health science students play an important role in patient education and preventive healthcare. Assessing their awareness of air pollution and its potential cardiovascular effects is therefore essential. This study aimed to develop and validate a novel psychometric instrument to assess knowledge, attitudes, and practices (KAP) regarding air pollution and its cardiovascular health effects among first-year allied health science students.

Methods: A cross-sectional online survey was conducted among 199 first-year allied health science students at a university-affiliated medical center. A novel questionnaire was developed through expert discussions and subsequently subjected to rigorous evaluation. Content validity was assessed, and exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed to evaluate the instrument's construct validity and model fit. Internal consistency was also assessed. CFA was conducted using the weighted least squares mean and variance adjusted (WLSMV)/diagonally weighted least squares (DWLS) estimator.

Results: The validation process yielded a 26-item questionnaire comprising three domains: knowledge (10 items), attitudes (eight items), and practices (eight items). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.93, and Bartlett's test of sphericity was statistically significant ($p < 0.001$). The three-factor CFA measurement model demonstrated excellent overall fit ($\chi^2(296) = 298.501$, WLSMV-scaled test statistic; $p = 0.448$; Comparative Fit Index (CFI) = 0.999; Tucker-Lewis Index (TLI) = 0.998; Root Mean Square Error of Approximation (RMSEA) = 0.007; Standardized Root Mean Square Residual (SRMR) = 0.052). Internal consistency was high across all three domains, with Cronbach's α values of 0.895 for knowledge, 0.923 for attitudes, and 0.929 for practices.

Conclusions: The newly developed 26-item environmental cardiovascular awareness tool demonstrated promising reliability and validity, supporting its potential use in assessing KAP regarding air pollution and its cardiovascular health effects among allied health science students.

**Categories:** Environmental Health, Cardiology, Medical Education
**Keywords:** cardiovascular health (cvh), environmental health and air pollution, environmental health education, knowledge attitude and practice (kap), psychometric scale development

## Introduction

Air pollution is one of the most significant environmental health challenges of the twenty-first century, contributing to approximately seven million premature deaths annually worldwide, an estimated 68% of which are attributable to cardiovascular diseases, such as ischemic heart disease and stroke [1]. Addressing this environmental threat aligns with the United Nations Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities). Although the respiratory consequences of air pollution exposure are widely recognized and documented, growing evidence highlights its substantial effects on cardiovascular health, including hypertension, ischemic heart disease, stroke, and cardiac arrhythmias [2-4].

Particulate matter with a diameter of ≤2.5 micrometers (PM2.5) and other air pollutants can trigger systemic inflammation, oxidative stress, and endothelial dysfunction, contributing to accelerated atherosclerosis and increased cardiovascular morbidity and mortality [3,5]. Despite the growing body of evidence, awareness of the cardiovascular risks associated with air pollution remains limited among healthcare professionals and the general population.

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The knowledge, attitudes, and practices (KAP) framework provides a structured approach to translating environmental health concepts into measurable domains of awareness and behavior [6]. Gaps in students' clinical preparedness may partly reflect insufficient knowledge, misconceptions, and limited practical skills. The KAP framework can help identify and quantify these gaps [7,8]. By examining awareness across its different domains, researchers can identify knowledge deficits, barriers to health-promoting behavior, and areas requiring targeted public health education.

To address environmental health threats effectively, allied health curricula should move beyond unfocused approaches towards targeted educational interventions and active learning strategies [9,10]. The multidimensional KAP framework can guide this process by identifying areas of relative strength and weakness among allied health students, enabling educators to tailor teaching strategies accordingly. For example, if knowledge levels are high but reported practices are inadequate, curricula may benefit from greater emphasis on practical skills and the application of theoretical knowledge [11]. The practice domain can help assess whether students translate their awareness into health-promoting behaviors and appropriate preventive counselling for patients in areas with high levels of air pollution [12]. Conversely, if attitudes represent a major barrier, educational interventions may need to emphasize health advocacy and the role of healthcare professionals in mitigating environmental health risks [13].

However, developing evidence-based, competency-oriented curricula requires a systematic needs assessment supported by a psychometrically validated instrument. To address this gap, this study aimed to develop and rigorously validate a novel environmental cardiovascular awareness tool for assessing knowledge, attitudes, and practices related to the cardiovascular effects of ambient air pollution among allied health science students. The instrument was evaluated for content validity, construct validity using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), and reliability.

# Materials And Methods

## Questionnaire development

Questionnaire development was conducted in two phases. The first phase involved developing the questionnaire, while the second phase focused on psychometric evaluation, including EFA and CFA.

*Phase I: Questionnaire Development*

In the first phase, the questionnaire was developed based on a review of the literature on air pollution, particularly fine particulate matter (PM2.5), and the associated cardiovascular health effects. This review helped identify the key concepts relevant to questionnaire item development. Content validity was assessed using a structured, two-round Delphi method involving an expert panel of eight professionals: one public health specialist, three environmental physiologists, and four allied health academics. The initial questionnaire draft was distributed electronically using a structured form. Experts independently rated the relevance of each item on a four-point ordinal scale (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, and 4 = highly relevant). The item-level Content Validity Index (I-CVI) was calculated as the proportion of experts who rated each item as relevant.

To adjust for chance agreement, a modified Kappa statistic ($k^*$) was computed for each item using the formula:

$$k^* = \frac{I - CVI - P_c}{1 - P_c}$$

The probability of chance agreement (P_c) was calculated based on a binomial random variable:

$$P_c = \left[\frac{N!}{A!(N-A)!}\right] 0.5^N$$

where N represents the total number of experts, and A represents the number of experts who agreed that an item was relevant. Predefined decision criteria were applied: items with an I-CVI ⩾ 0.79 were retained, those with an I-CVI between 0.70 and 0.78 were revised based on qualitative feedback, and those with an I-CVI below 0.70 were removed. The scale-level Content Validity Index based on the average method (S-CVI/Ave) was calculated as the mean of the I-CVI values across all retained items.

The finalized questionnaire comprised 26 items divided into three main domains: knowledge of air pollution and cardiovascular health, attitudes towards air pollution and health, and protective and clinical practices (Table *1*).

| Domains | No. of Items | Measurements | Response choices |
|---|---|---|---|
| Demography | 3 | Age, gender, education | Open-ended, multiple-choice |
| Knowledge | 10 | Concepts of air pollution, PM2.5, and air pollution-associated cardiovascular health effects | Yes/No/I don't know; 1 = correct answer, 0 = wrong/I don't know |
| Attitude | 8 | Attitudes towards air pollution, environmental health, and cardiovascular risk | 1 = strongly disagree, 2 = disagree, 3 = not sure, 4 = agree, 5 = strongly agree |
| Practice | 8 | Protective behaviors and clinical practices regarding environmental cardiovascular risks | 1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always |

**TABLE 1: Domains and characteristics of the environmental cardiovascular awareness questionnaire**

The complete 26-item questionnaire is provided in Appendix 1. The knowledge domain, which focused on air pollution and cardiovascular health, comprised 10 items assessing participants' understanding of PM2.5 sources, systemic circulation, and cardiovascular risks. Responses were recorded as "True," "False," or "Don't know" and subsequently coded dichotomously, with correct responses scored as 1 and incorrect or "Don't know" responses scored as 0. The eighth item was reverse-coded. The maximum possible score for this domain was 10.

The attitude domain comprised eight items assessing personal concern and professional responsibility regarding air pollution and health. Responses were rated on a five-point Likert scale ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"), yielding a maximum possible score of 40. The third item was negatively worded and reverse-coded for analysis.

The protective and clinical practices domain comprised eight items assessing the frequency of preventive behaviors, such as checking air quality indices and using N95 masks. Responses were rated on a five-point Likert scale ranging from 1 ("Never") to 5 ("Always"), yielding a maximum possible score of 40.

*Phase II: Validation*

A cross-sectional survey was conducted between September and October 2025 to evaluate the psychometric properties of the developed questionnaire. Participants were recruited from among first-year allied health science students at Sri Ramachandra Institute of Higher Education and Research. Participants were briefed on the study and the questionnaire before informed consent was obtained. The KAP questionnaire was administered using Google Forms (Google, Mountain View, CA, USA) and distributed via institutional email and the university's learning management system for self-completion.

Sample size requirements for psychometric validation and factor analysis are commonly guided by the subject-to-item ratio. A ratio of 8:1 has been proposed, while a minimum ratio of 5:1 is also recommended in some methodological guidelines [14,15]. For the 26-item questionnaire, a minimum of 130 participants was required to meet the 5:1 ratio. Of the 229 students invited to participate, 199 completed the survey, yielding a response rate of 86.9%. The final sample provided a subject-to-item ratio of approximately 7.7:1, exceeding the minimum 5:1 requirement, although it was slightly below the proposed 8:1 ratio.

## Ethical statement

The study was approved by the Institutional Ethics Committee (IEC) of Sri Ramachandra Institute of Higher Education and Research (SRIHER), a tertiary care teaching institution in South India (approval reference: IEC-NI/24/FEB/91/24). This approval was granted for the overarching project investigating the association between air pollution and cardiovascular health, of which the present KAP questionnaire validation study formed an integral sub-study. Electronic informed consent was obtained from all participants after they were provided with a clear explanation of the study objectives, the voluntary nature of participation, and measures to ensure data confidentiality.

## Statistical analysis

Data were analyzed using R software (version 4.2.3; R Foundation for Statistical Computing, Vienna, Austria) with the lavaan, psych, and semTools packages. Statistical significance was set at $p < 0.05$.

*Exploratory Factor Analysis*

EFA was conducted to assess the construct validity of the questionnaire and identify the underlying dimensions of its domains. The suitability of the data for factor analysis was evaluated using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. A KMO value greater than 0.80 was considered indicative of adequate sampling, while Bartlett's test was considered statistically significant at $p < 0.001$. Factor extraction was performed using the minimum residual (minres) method based on a polychoric correlation matrix, followed by oblimin rotation to facilitate the interpretation of factor loadings. Items with factor loadings greater than 0.30 were considered acceptable for retention [16].

*Confirmatory Factor Analysis*

CFA was conducted to evaluate the structural validity and model fit of the questionnaire. Because the 10 knowledge items were binary, they were treated as ordered-categorical indicators. The model was estimated using the WLSMV estimator, which is appropriate for categorical indicators and does not assume continuous, normally distributed data. Mardia's test, applied only to the continuous attitude and practice items, did not indicate significant multivariate non-normality. Global model fit was evaluated using a combination of absolute and incremental fit indices. Model fit was considered acceptable if the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) were $\geqslant 0.90$, the Root Mean Square Error of Approximation (RMSEA) was $< 0.08$, and the Standardized Root Mean Square Residual (SRMR) was $< 0.08$.

*Reliability and Convergent Validity*

The internal consistency of each established domain was assessed using Cronbach's alpha and McDonald's omega coefficients to provide complementary estimates of reliability. Reliability coefficients greater than 0.70 were considered indicative of acceptable internal consistency [17]. Composite reliability (CR) and average variance extracted (AVE) were also calculated to assess the convergent validity of the extracted constructs.

*Data Availability*

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request. The data are stored in a de-identified format.

# Results

## Questionnaire development, content, and face validity

The initial development phase yielded a 27-item questionnaire designed to assess environmental cardiovascular awareness. In Round 1 of the structured Delphi process, most items demonstrated strong expert agreement, with I-CVI values ranging from 0.875 to 1.00 and corresponding modified kappa (k*) values ranging from 0.87 to 1.00, indicating excellent agreement beyond chance. Two items fell within the revision threshold (I-CVI = 0.75) and underwent targeted semantic modifications, while one item did not meet the retention criteria (I-CVI = 0.625) and was removed. In Round 2, the revised items were re-evaluated and achieved full expert agreement (I-CVI = 1.00; k* = 1.00).

This structured review process resulted in a final 26-item questionnaire comprising three domains: knowledge of air pollution and cardiovascular health (10 items), attitudes towards air pollution and health (8 items), and protective and clinical practices (8 items). The final questionnaire demonstrated strong content validity, with a scale-level content validity index based on the average I-CVI (S-CVI/Ave) of 0.97.

## Descriptive statistics of the participants

A total of 199 first-year allied health science students completed the survey. The cohort was predominantly female (72.4%, n = 144), while males accounted for 27.6% (n = 55) of respondents. Participants represented four allied health academic programs: Medical Laboratory Technology (38.2%, n = 76), Physiotherapy (22.6%, n = 45), Radiology (22.6%, n = 45), and Optometry (16.6%, n = 33) (Table *2*).

| Characteristics | Mean (SD) | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Age | 20.31 (1.64) | - | - |
| Gender | - | - | - |
| Male | - | 55 | 27.6 |
| Female | - | 144 | 72.4 |
| Academic major | - | - | - |
| Medical laboratory technology | - | 76 | 38.2 |
| Optometry | - | 33 | 16.6 |
| Physiotherapy | - | 45 | 22.6 |
| Radiology | - | 45 | 22.6 |

**TABLE 2: Sociodemographic characteristics of study participants**

Baseline descriptive statistics were calculated for the KAP domains. The knowledge domain, assessed using the sum of 10 binary items, had a mean score of 5.30 (SD = 2.19). The attitudes and practices domains were assessed using mean composite scores derived from Likert-scale and frequency-scale items, respectively, each ranging from 1 to 5. The mean attitude score was 3.94 (SD = 0.58), while the mean practice score was 3.67 (SD = 0.72), indicating relatively high baseline attitude and practice scores. The distributions of these composite scores showed approximate univariate normality, with skewness and excess kurtosis values within the prespecified acceptable thresholds (|Sk| < 2; |Ku| < 7). These findings supported the preliminary distributional assumptions for subsequent factor analyses (Table *3*).

| Domain | N | Mean | SD | Min | Max | Skewness | Kurtosis | Interpretation |
|---|---|---|---|---|---|---|---|---|
| Knowledge | 199 | 5.30 | 2.19 | 0 | 9 | -0.24 | -0.87 | Normal |
| Attitudes | 199 | 3.94 | 0.58 | 2.3 | 5 | -0.51 | 3.12 | Normal |
| Practices | 199 | 3.67 | 0.72 | 1.6 | 5 | -0.29 | 2.71 | Normal |

**TABLE 3: Descriptive statistics of KAP domain composite scores**

The Knowledge score represents the sum of 10 binary items (range: 0-10). Attitudes and Practices scores represent the mean of five-point Likert-scale items (1 = strongly disagree to 5 = strongly agree). Skewness and excess kurtosis values within the acceptable range (|Sk| < 2, |Ku| < 7) indicate approximate normality.

KAP: knowledge, attitude, and practice.

## Exploratory factor analysis

EFA was conducted to assess the construct validity and underlying dimensionality of the 26-item questionnaire. The data demonstrated excellent sampling adequacy, with a KMO value of 0.93. Bartlett's test of sphericity was statistically significant ($p < 0.001$), indicating that the correlation matrix was suitable for factor analysis [18] (Table *4*). Factor extraction was performed using the maximum likelihood method, followed by oblimin rotation to allow for correlations between factors.

| Test/statistic | Value |
|---|---|
| Kaiser-Meyer-Olkin (KMO) MSA | 0.93 (meritorious) |
| Bartlett's test of sphericity $\chi^2$ | 2955.96 |
| Degrees of freedom (df) | 325 |
| Significance (p) | <0.001 |
| Mardia's skewness $\chi^2$ | 1423.18 ($p < 0.001$)* |
| Mardia's Kurtosis z | 4.67 ($p < 0.001$)* |

**TABLE 4: Factorability tests: KMO sampling adequacy and Bartlett's test of sphericity**

A KMO value ≥ 0.80 indicates meritorious sampling adequacy [18].

*Mardia's test restricted to the continuous Attitude/Practice items was not significant (skew p = 0.39, kurtosis p = 0.26); the binary Knowledge items were instead modelled as ordered-categorical indicators using a WLSMV estimator for CFA.

KMO: Kaiser-Meyer-Olkin, CFA: confirmatory factor analysis, WLSMV: weighted least squares mean and variance adjusted.

The EFA results supported a three-factor model corresponding to the established knowledge, attitude, and practice domains. Together, the three factors explained 45.00% of the total variance. Although this value was slightly below the commonly cited guideline of 50%-60%, the retained items demonstrated factor loadings above the prespecified threshold of 0.30. Factor loadings ranged from 0.40 to 0.63 for the knowledge domain, 0.64 to 0.82 for the attitude domain, and 0.66 to 0.76 for the practice domain. Item communalities ($h^2$) ranged from 0.18 to 0.64, indicating that the extracted factors accounted for varying proportions of the variance in individual items (Table *5*).

| Item | Domain | F1: knowledge | F2: attitudes | F3: practices | h² |
|---|---|---|---|---|---|
| K1 | Knowledge | 0.56 | - | - | 0.28 |
| K2 | Knowledge | 0.47 | - | - | 0.37 |
| K3 | Knowledge | 0.54 | - | - | 0.37 |
| K4 | Knowledge | 0.6 | - | - | 0.41 |
| K5 | Knowledge | 0.52 | - | - | 0.27 |
| K6 | Knowledge | 0.42 | - | - | 0.18 |
| K7 | Knowledge | 0.55 | - | - | 0.28 |
| K8 | Knowledge | 0.63 | - | - | 0.41 |
| K9 | Knowledge | 0.4 | - | - | 0.3 |
| K10 | Knowledge | 0.55 | - | - | 0.34 |
| A1 | Attitudes | - | 0.66 | - | 0.48 |
| A2 | Attitudes | - | 0.67 | - | 0.5 |
| A3 | Attitudes | - | 0.7 | - | 0.5 |
| A4 | Attitudes | - | 0.82 | - | 0.64 |
| A5 | Attitudes | - | 0.64 | - | 0.44 |
| A6 | Attitudes | - | 0.69 | - | 0.47 |
| A7 | Attitudes | - | 0.74 | - | 0.59 |
| A8 | Attitudes | - | 0.78 | - | 0.59 |
| P1 | Practices | - | - | 0.71 | 0.49 |
| P2 | Practices | - | - | 0.71 | 0.52 |
| P3 | Practices | - | - | 0.66 | 0.44 |
| P4 | Practices | - | - | 0.74 | 0.53 |
| P5 | Practices | - | - | 0.76 | 0.58 |
| P6 | Practices | - | - | 0.69 | 0.56 |
| P7 | Practices | - | - | 0.74 | 0.57 |
| P8 | Practices | - | - | 0.76 | 0.55 |
| Summary | - | F1 | F2 | F3 | - |
| Eigenvalue | | 2.99 | 4.35 | 4.31 | - |
| % variance | | 12 | 17 | 17 | - |
| Cumulative % | | 12 | 29 | 45 | - |

**TABLE 5: EFA pattern matrix: oblimin rotation, minimum residual extraction**

Note. Factor loadings < |.30| suppressed. Bold values indicate primary factor assignment. h² = communality. Parallel analysis (1,000 iterations) confirmed a three-factor solution. Total variance explained = 45.00%. Model fit: TLI = 0.828, RMSEA = 0.074, SRMR= 0.05. Factor inter-correlations: F1-F2 = 0.35; F1-F3 = 0.23; F2-F3 = 0.27.

TLI: Tucker-Lewis Index, RMSEA: root mean square error of approximation, RMSR: standardized root mean square residual.

## Confirmatory factor analysis and construct validity

The full three-factor measurement model, comprising the KAP domains, was evaluated using the

WLSMV estimator, with the 10 binary knowledge items specified as ordered-categorical indicators. The model demonstrated excellent overall fit to the data: $\chi^2(296) = 298.501$ (WLSMV-scaled test statistic), $p = 0.448$; CFI = 0.999; TLI = 0.998; RMSEA = 0.007 (90% CI: 0.000-0.028); and SRMR = 0.052 (Table 6). The full polychoric correlation matrix used in the analysis is provided in Appendix 2.

| Fit index | Obtained value | Recommended threshold | Verdict |
|---|---|---|---|
| $\chi^2$ (df) | 298.501 (296) | - | - |
| p-value | 0.448 | - | - |
| CFI | 0.999 | ≥0.95 | Excellent |
| TLI | 0.998 | ≥0.95 | Excellent |
| RMSEA | 0.007 | <0.05 | Excellent |
| RMSEA 90% CI | [0.000, 0.028] | Upper < 0.08 | Excellent |
| SRMR | 0.052 | <0.08 | Acceptable |

**TABLE 6: SEM global fit indices**

Estimator: WLSMV. $\chi^2$/df ratio = 1.01 (< 2.0, acceptable). Overall model fit is satisfactory to excellent across all indices.

SEM: structural equation modeling, WLSMV: weighted least squares mean and variance adjusted, CFI: Comparative Fit Index, TLI: Tucker-Lewis Index, RMSEA = root mean square error of approximation, CI: confidence interval, SRMR: standardized root mean square residual.

Construct validity was further supported by the measurement model parameters. Standardized factor loadings for the individual items on their respective latent constructs were strong and statistically significant, supporting convergent validity. The model also indicated positive correlations between the three constructs: knowledge and attitudes (r = 0.42), attitudes and practices (r = 0.31), and knowledge and practices (r = 0.30). These correlations are consistent with the multidimensional nature of the KAP framework, suggesting that the domains are related but distinguishable constructs (Table 7, Figure 1).

| Construct | CR | AVE | √AVE |
|---|---|---|---|
| Knowledge | 0.898 | 0.672 | 0.82 |
| Attitudes | 0.923 | 0.602 | 0.776 |
| Practices | 0.929 | 0.621 | 0.788 |

**TABLE 7: Convergent and discriminant validity: CR, AVE**

Discriminant validity is supported when the √AVE for a construct is greater than its inter-factor correlations. CR > 0.70 and AVE > 0.50 indicate adequate convergent validity.

CR: composite reliability, AVE: average variance extracted, √AVE: square root of average variance extracted.

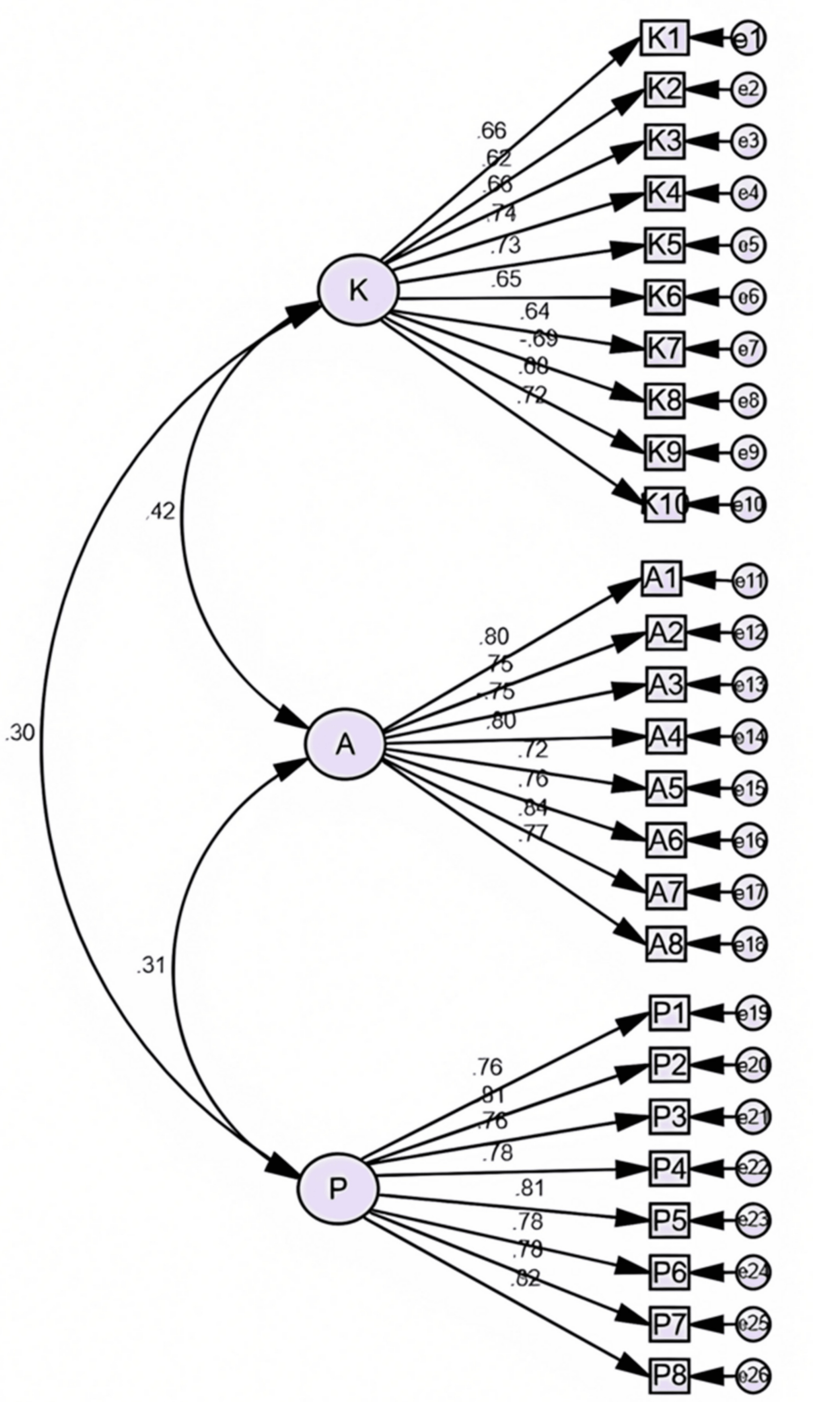


**FIGURE 1: Standardized confirmatory factor analysis (CFA) model of the environmental cardiovascular awareness tool**

Constructs (circles): K (knowledge), A (attitudes), P (practices).

Items (rectangles): K1-K10 (knowledge items), A1-A8 (Attitude items), P1-P8 (practice items).

Error terms (small circles): e1-e26 represent the unique variance (measurement error) associated with each item.

Values: the values on the straight single-headed arrows indicate standardized factor loadings. The values on the curved double-headed arrows indicate inter-construct correlations.

All paths are significant at $p < 0.001$.

### Reliability

Following confirmation of the measurement model, the internal consistency of the finalized 26-item questionnaire was assessed using Cronbach's alpha (α) and McDonald's omega (ω) coefficients. All three domains demonstrated good internal consistency, with both coefficients exceeding the acceptable threshold of 0.70. Specifically, the KAP domains each had α and ω values above 0.80, indicating good reliability within each domain (Table *8*).

| Domain | Items | Cronbach's α | McDonald's ω | Mean IIC | IIC range | Interpretation |
|---|---|---|---|---|---|---|
| Knowledge | 10 | 0.895 | 0.898 | 0.461 | 0.38-0.67 | Good |
| Attitudes | 8 | 0.923 | 0.923 | 0.599 | 0.34-0.62 | Good |
| Practices | 8 | 0.929 | 0.929 | 0.62 | 0.41-0.71 | Good |

**TABLE 8: Internal consistency reliability by KAP domain**

Acceptable thresholds: Cronbach's α ≥ 0.70; McDonald's ω ≥ 0.70; mean IIC = 0.15-0.50.

KAP: knowledge, attitude, and practice, IIC: mean inter-item correlation, CR: composite reliability (McDonald's omega total).

## Discussion

To the best of our knowledge, this is the first study to develop and validate a KAP questionnaire to assess environmental cardiovascular awareness related to ambient fine particulate matter (PM2.5) among allied health science students. The findings indicate that the final 26-item questionnaire demonstrates good reliability and validity, supporting its potential use by educators to assess environmental health literacy related to the cardiovascular effects of air pollution.

Although existing literature extensively documents the physiological mechanisms through which particulate matter contributes to cardiovascular morbidity, educational research linking these environmental threats to specific clinical competencies remains limited [3,19]. Previous KAP validation studies have highlighted differences in conceptual understanding and clinical practices across professional disciplines, suggesting that general knowledge alone may not translate into clinical readiness [20]. However, existing assessments of air pollution have predominantly focused on environmental awareness or general respiratory health rather than specific cardiovascular effects [21,22]. The present study addresses this gap by contributing a specialized, psychometrically evaluated instrument focused on cardiovascular health. By incorporating the pathophysiological effects of PM2.5, including systemic inflammation, oxidative stress, and endothelial dysfunction, the questionnaire extends beyond general environmental awareness to assess KPAs relevant to cardiovascular health. This focus may support educational initiatives aligned with competency-based learning frameworks.

Following a structured content validity assessment, EFA supported a three-factor structure corresponding to the KAP domains. Together, these factors accounted for 45.00% of the total variance. Although this proportion was below the commonly cited guideline of 50%-60%, the retained items demonstrated factor loadings ranging from 0.40 to 0.82 across their respective domains (knowledge: 0.40-0.63; attitudes: 0.64-0.82; practices: 0.66-0.76). These findings support the proposed factor structure, although the proportion of explained variance and the potential for cross-loadings should be considered when interpreting the results [23].

An additional strength of this study was the use of CFA to evaluate the proposed three-factor measurement model. The model demonstrated excellent global fit, with a CFI of 0.999 and an RMSEA of 0.007. The questionnaire also demonstrated good internal consistency, and CR values across the three domains exceeded the 0.70 threshold, ranging from 0.898 to 0.929. Discriminant validity was assessed using the Fornell-Larcker criterion, with the results supporting the distinctiveness of the three constructs despite their theoretical relationships [24].

Although conducting EFA and CFA in independent samples is generally recommended, both analyses were performed using the same sample in this study because of practical sample size constraints. This approach provides an initial evaluation of the factor structure but may limit the extent to which the CFA independently confirms the EFA findings [25]. The final sample comprised 199 participants, yielding a subject-to-item ratio of approximately 7.7:1 for the 26-item questionnaire. Although this ratio falls within commonly cited guidelines, the adequacy of the sample also depends on factors such as communalities, factor loadings, model complexity, and the distribution of the item responses.

This study has several limitations. First, the cross-sectional data were collected from a specific cohort of allied health science students, which may limit the generalizability of the findings to other populations, including practicing clinicians and the general public. Second, responses regarding attitudes and practices were self-reported and may therefore be affected by social desirability and recall biases. Third, although structural equation modelling was used to evaluate the questionnaire's measurement properties, criterion validity, predictive validity, and test-retest reliability were not assessed in this phase. Furthermore, the relatively high Cronbach's alpha values warrant further examination to determine whether some items may be redundant. Future research should validate the questionnaire in larger, multicenter and more diverse populations, assess its test-retest reliability and additional forms of validity, and evaluate its sensitivity to change following targeted environmental health education interventions.

## Conclusions

This study developed and validated a KAP questionnaire to assess environmental cardiovascular awareness among allied health science students. The final 26-item environmental cardiovascular awareness tool demonstrated promising psychometric properties, with evidence supporting the internal structure of its three domains. By incorporating the pathophysiological effects of particulate matter exposure, the instrument extends beyond general environmental literacy to assess KAPs relevant to cardiovascular health. It may serve as a useful tool for evaluating environmental cardiovascular awareness and informing future competency-based educational interventions.

## Appendices

### Appendix 1

| Domain and questionnaire item | Choice 1 | Choice 2 | Choice 3 | Choice 4 | Choice 5 |
|---|---|---|---|---|---|
| Knowledge domain | True | False | Don't know | - | - |
| 1. PM2.5 refers to particulate matter that is 2.5 micrometers or smaller in diameter. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| 2. Indoor environments are safe from PM2.5 pollution if the doors and windows are closed. (Correct: False) | ☐ | ☐ | ☐ | - | - |
| 3. Traffic emissions and construction dust are the only significant sources of ambient PM2.5. (Correct: False) | ☐ | ☐ | ☐ | - | - |
| 4. PM2.5 particles can cross the alveolar-capillary membrane and enter systemic circulation. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| 5. Short-term exposure to high levels of air pollution can trigger acute cardiovascular events, such as myocardial infarctions. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| 6. Long-term exposure to ambient PM2.5 is an independent risk factor for developing hypertension. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| 7. Inhaling fine particulate matter triggers systemic inflammation and oxidative stress in the blood vessels. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| 8. Air pollution primarily damages the lungs and has no direct effect on endothelial function or vascular stiffness. (Correct: False) | ☐ | ☐ | ☐ | - | - |
| 9. Individuals with pre-existing metabolic conditions (like diabetes or obesity) are more vulnerable to the cardiovascular effects of air pollution. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| 10. Diets rich in antioxidants and healthy fats and oils can help mitigate some of the vascular damage caused by air pollution. (Correct: True) | ☐ | ☐ | ☐ | - | - |
| Attitude domain | Strongly disagree | Disagree | Not sure | Agree | Strongly agree |
| 11. I am personally concerned about how the air quality in my city will affect my long-term cardiovascular health. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. I believe air pollution is just as critical to heart health as traditional risk factors like physical inactivity or poor diet. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. I feel that the current air quality guidelines in our region are sufficient to protect public health. | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | |
|---|---|---|---|---|---|
| 14. I believe that wearing an N95/KN95 mask significantly reduces my cardiovascular risk on high-pollution days. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. I believe that consuming a nutrient-dense diet provides a protective shield against the vascular effects of environmental pollution. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. As a future allied health professional, it is my responsibility to educate patients about environmental health risks. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. Taking an "environmental health history" (e.g., asking where a patient lives or works) should be a standard part of cardiovascular risk assessments. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. I feel confident in my current ability to explain the link between air pollution and heart disease to a patient. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Practice domain | Never | Rarely | Sometimes | Often | Always |
| 19. How often do you check the Air Quality Index (AQI) before planning outdoor physical activities? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. How often do you modify the intensity or location of your exercise when AQI levels are "Unhealthy" or worse? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. How often do you wear a well-fitted N95 or KN95 mask when commuting on high-pollution days? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. How often do you use interventions to improve indoor air quality (e.g., using exhaust fans, air purifiers, or closing windows during peak traffic hours)? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. How often do you consciously consume foods rich in antioxidants or healthy fats and oils specifically to counteract environmental stressors? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24. How often do you actively seek out scientific literature regarding the health impacts of climate change or air pollution? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 25. When discussing health with family, peers, or patients, how often do you bring up the importance of checking air quality? | ☐ | ☐ | ☐ | ☐ | ☐ |
| 26. How often do you advise vulnerable individuals (e.g., older adults or those with hypertension) to stay indoors during pollution spikes? | ☐ | ☐ | ☐ | ☐ | ☐ |

**TABLE 9: KAP 26-item questionnaire**

Note: Dash (-) indicates not applicable for the corresponding response scale.

KAP: knowledge, attitude, and practice.

## Appendix 2

| — | K1 | K2 | K3 | K4 | K5 | K6 | K7 | K8 | K9 | K10 | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K1 | 1.00 | 0.14 | 0.20 | 0.34 | 0.39 | 0.18 | 0.14 | 0.30 | 0.12 | 0.46 | -0.05 | 0.12 | 0.12 | 0.12 | 0.20 | 0.04 | 0.04 | -0.07 | -0.03 | 0.02 | 0.03 | 0.00 | -0.05 | 0.14 | 0.01 | -0.14 |
| K2 | 0.14 | 1.00 | 0.39 | 0.27 | 0.25 | 0.19 | 0.38 | 0.38 | 0.44 | 0.39 | 0.24 | 0.26 | 0.27 | 0.23 | 0.34 | 0.40 | 0.31 | 0.38 | 0.16 | 0.10 | 0.13 | 0.12 | 0.23 | 0.17 | 0.22 | 0.19 |
| K3 | 0.20 | 0.39 | 1.00 | 0.41 | 0.25 | 0.37 | 0.33 | 0.33 | 0.40 | 0.26 | 0.14 | 0.39 | 0.24 | 0.31 | 0.25 | 0.15 | 0.22 | 0.24 | 0.00 | 0.17 | -0.04 | 0.08 | 0.08 | 0.13 | 0.17 | 0.04 |
| K4 | 0.34 | 0.27 | 0.41 | 1.00 | 0.33 | 0.20 | 0.33 | 0.45 | 0.31 | 0.34 | 0.25 | 0.30 | 0.20 | 0.20 | 0.27 | 0.10 | 0.15 | 0.14 | 0.17 | 0.18 | 0.11 | 0.21 | 0.15 | 0.27 | 0.23 | 0.05 |
| K5 | 0.39 | 0.25 | 0.25 | 0.33 | 1.00 | 0.22 | 0.19 | 0.34 | 0.18 | 0.33 | 0.09 | 0.05 | 0.06 | 0.07 | 0.16 | 0.10 | 0.12 | 0.00 | 0.10 | 0.05 | 0.15 | 0.23 | 0.16 | 0.16 | 0.11 | 0.21 |
| K6 | 0.18 | 0.19 | 0.37 | 0.20 | 0.22 | 1.00 | 0.29 | 0.19 | 0.24 | 0.26 | 0.10 | 0.10 | 0.14 | 0.10 | 0.18 | 0.02 | 0.07 | 0.10 | 0.05 | 0.19 | 0.05 | 0.04 | 0.11 | 0.18 | 0.09 | 0.05 |
| K7 | 0.14 | 0.38 | 0.33 | 0.33 | 0.19 | 0.29 | 1.00 | 0.35 | 0.38 | 0.18 | 0.16 | 0.06 | 0.22 | 0.01 | 0.12 | 0.20 | 0.03 | 0.07 | 0.01 | 0.06 | 0.09 | -0.03 | 0.04 | 0.09 | 0.01 | -0.06 |
| K8 | 0.30 | 0.38 | 0.33 | 0.45 | 0.34 | 0.19 | 0.35 | 1.00 | 0.29 | 0.39 | 0.26 | 0.21 | 0.07 | 0.10 | 0.11 | 0.23 | 0.15 | 0.22 | 0.19 | 0.10 | 0.24 | 0.15 | 0.10 | 0.28 | 0.23 | 0.04 |
| K9 | 0.12 | 0.44 | 0.40 | 0.31 | 0.18 | 0.24 | 0.38 | 0.29 | 1.00 | 0.22 | 0.25 | 0.31 | 0.32 | 0.24 | 0.16 | 0.31 | 0.31 | 0.23 | 0.21 | 0.17 | 0.20 | 0.19 | 0.23 | 0.23 | 0.07 | 0.20 |
| K10 | 0.46 | 0.39 | 0.26 | 0.34 | 0.33 | 0.26 | 0.18 | 0.39 | 0.22 | 1.00 | 0.17 | 0.22 | 0.16 | 0.11 | 0.15 | 0.16 | 0.23 | 0.27 | 0.18 | 0.11 | 0.19 | 0.09 | 0.17 | 0.18 | 0.29 | 0.10 |
| A1 | -0.05 | 0.24 | 0.14 | 0.25 | 0.09 | 0.10 | 0.16 | 0.26 | 0.25 | 0.17 | 1.00 | 0.47 | 0.46 | 0.54 | 0.43 | 0.49 | 0.51 | 0.60 | 0.15 | 0.20 | 0.15 | 0.14 | 0.20 | 0.28 | 0.20 | 0.18 |
| A2 | 0.12 | 0.26 | 0.39 | 0.30 | 0.05 | 0.10 | 0.06 | 0.21 | 0.31 | 0.22 | 0.47 | 1.00 | 0.49 | 0.61 | 0.45 | 0.43 | 0.55 | 0.53 | 0.13 | 0.20 | 0.14 | 0.17 | 0.15 | 0.23 | 0.18 | 0.07 |
| A3 | 0.12 | 0.27 | 0.24 | 0.20 | 0.06 | 0.14 | 0.22 | 0.07 | 0.32 | 0.16 | 0.46 | 0.49 | 1.00 | 0.54 | 0.52 | 0.53 | 0.52 | 0.50 | -0.01 | 0.11 | 0.12 | 0.11 | 0.13 | 0.19 | 0.20 | 0.09 |
| A4 | 0.12 | 0.23 | 0.31 | 0.20 | 0.07 | 0.10 | 0.01 | 0.10 | 0.24 | 0.11 | 0.54 | 0.61 | 0.54 | 1.00 | 0.54 | 0.53 | 0.65 | 0.57 | 0.19 | 0.15 | 0.11 | 0.14 | 0.21 | 0.25 | 0.12 | 0.16 |
| A5 | 0.20 | 0.34 | 0.25 | 0.27 | 0.16 | 0.18 | 0.12 | 0.11 | 0.16 | 0.15 | 0.43 | 0.45 | 0.52 | 0.54 | 1.00 | 0.44 | 0.48 | 0.49 | 0.02 | 0.11 | 0.07 | 0.03 | 0.08 | 0.15 | 0.09 | 0.11 |
| A6 | 0.04 | 0.40 | 0.15 | 0.10 | 0.10 | 0.02 | 0.20 | 0.23 | 0.31 | 0.16 | 0.49 | 0.43 | 0.53 | 0.53 | 0.44 | 1.00 | 0.47 | 0.53 | 0.07 | 0.10 | 0.15 | 0.06 | 0.11 | 0.10 | 0.08 | 0.06 |
| A7 | 0.04 | 0.31 | 0.22 | 0.15 | 0.12 | 0.07 | 0.03 | 0.15 | 0.31 | 0.23 | 0.51 | 0.55 | 0.52 | 0.65 | 0.48 | 0.47 | 1.00 | 0.57 | 0.18 | 0.24 | 0.20 | 0.22 | 0.26 | 0.34 | 0.27 | 0.21 |
| A8 | -0.07 | 0.38 | 0.24 | 0.14 | 0.00 | 0.10 | 0.07 | 0.22 | 0.23 | 0.27 | 0.60 | 0.53 | 0.50 | 0.57 | 0.49 | 0.53 | 0.57 | 1.00 | 0.21 | 0.13 | 0.09 | 0.10 | 0.16 | 0.21 | 0.19 | 0.12 |
| P1 | -0.03 | 0.16 | 0.00 | 0.17 | 0.10 | 0.05 | 0.01 | 0.19 | 0.21 | 0.18 | 0.15 | 0.13 | -0.01 | 0.19 | 0.02 | 0.07 | 0.18 | 0.21 | 1.00 | 0.51 | 0.47 | 0.50 | 0.56 | 0.49 | 0.48 | 0.51 |
| P2 | 0.02 | 0.10 | 0.17 | 0.18 | 0.05 | 0.19 | 0.06 | 0.10 | 0.17 | 0.11 | 0.20 | 0.20 | 0.11 | 0.15 | 0.11 | 0.10 | 0.24 | 0.13 | 0.51 | 1.00 | 0.47 | 0.51 | 0.52 | 0.58 | 0.57 | 0.52 |
| P3 | 0.03 | 0.13 | -0.04 | 0.11 | 0.15 | 0.05 | 0.09 | 0.24 | 0.20 | 0.19 | 0.15 | 0.14 | 0.12 | 0.11 | 0.07 | 0.15 | 0.20 | 0.09 | 0.47 | 0.47 | 1.00 | 0.50 | 0.49 | 0.49 | 0.54 | 0.42 |
| P4 | 0.00 | 0.12 | 0.08 | 0.21 | 0.23 | 0.04 | -0.03 | 0.15 | 0.19 | 0.09 | 0.14 | 0.17 | 0.11 | 0.14 | 0.03 | 0.06 | 0.22 | 0.10 | 0.50 | 0.51 | 0.50 | 1.00 | 0.54 | 0.55 | 0.53 | 0.54 |
| P5 | -0.05 | 0.23 | 0.08 | 0.15 | 0.16 | 0.11 | 0.04 | 0.10 | 0.23 | 0.17 | 0.20 | 0.15 | 0.13 | 0.21 | 0.08 | 0.11 | 0.26 | 0.16 | 0.56 | 0.52 | 0.49 | 0.54 | 1.00 | 0.56 | 0.58 | 0.56 |
| P6 | 0.14 | 0.17 | 0.13 | 0.27 | 0.16 | 0.18 | 0.09 | 0.28 | 0.23 | 0.18 | 0.28 | 0.23 | 0.19 | 0.25 | 0.15 | 0.10 | 0.34 | 0.21 | 0.49 | 0.58 | 0.49 | 0.55 | 0.56 | 1.00 | 0.52 | 0.54 |
| P7 | 0.01 | 0.22 | 0.17 | 0.23 | 0.11 | 0.09 | 0.01 | 0.23 | 0.07 | 0.29 | 0.20 | 0.18 | 0.20 | 0.12 | 0.09 | 0.08 | 0.27 | 0.19 | 0.48 | 0.57 | 0.54 | 0.53 | 0.58 | 0.52 | 1.00 | 0.57 |
| P8 | -0.14 | 0.19 | 0.04 | 0.05 | 0.21 | 0.05 | -0.06 | 0.04 | 0.20 | 0.10 | 0.18 | 0.07 | 0.09 | 0.16 | 0.11 | 0.06 | 0.21 | 0.12 | 0.51 | 0.52 | 0.42 | 0.54 | 0.56 | 0.54 | 0.57 | 1.00 |

**TABLE 10: Polychoric correlation matrix of the 26-item environmental cardiovascular awareness questionnaire**

K1-K10: knowledge items, A1-A8: attitude items, P1-P8: practice items.

Note: This matrix is generated using the polychoric() function in R (R Foundation for Statistical Computing, Vienna, Austria) to account for binary and ordinal variable structures.

# Additional Information

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