

Validation of the Arabic Version of Asthma Numeracy Questionnaire (ANQ) Among Parents of Asthmatic Children: Factor and Rasch Analyses Study

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Background: The increasing global prevalence of asthma necessitates effective disease management, with patients and their families playing a central role. Enhancing health literacy (HL) among caregivers is critical to improving asthma outcomes.

Purpose: This study aimed to validate the Arabic version of the Asthma Numeracy Questionnaire (Ar-ANQ) to address the gap in HL assessment tools for Arabic-speaking populations.

Patients and Methods: A total of 400 parents of children with asthma completed the Ar-ANQ at an outpatient respiratory clinic. Confirmatory factor analysis (CFA) and Rasch analysis were employed to evaluate the psychometric properties of the instrument.

Results: CFA supported the unidimensional structure of the Ar-ANQ, with excellent model fit indices ($\chi^2/df = 4.6$, SRMR = 0.02, CFI = 0.99, GFI = 0.99, TLI = 0.96) and high internal consistency (Cronbach's $\alpha = 0.82$). Rasch analysis further demonstrated psychometric robustness, with high person and item separation reliabilities (0.74 and 0.99, respectively) and acceptable infit and outfit statistics.

Conclusion: The Arabic version of the Asthma Numeracy Questionnaire (Ar-ANQ) is a reliable and valid instrument for assessing health literacy among parents of children with asthma.

Keywords: Asthma Numeracy Questionnaire, asthma, health literacy, Arabic, pediatric

Introduction

Asthma is the most common childhood chronic disease¹, characterized by bronchial hyper-responsiveness and frequent episodes of airway obstruction.² Asthma contributes to significant mortality and morbidity among both adults and children. Most asthma cases are mild and usually not difficult to diagnose and treat.¹

Asthma is a multifactorial disorder that develops due to genetic and environmental interaction which affects both the severity of asthma and responsiveness to treatment.³ Approximately 300 million people are affected with asthma globally, and it accounts for one in every 250 deaths. Moreover, about 12 million people annually in the United States experience acute episodes of asthma exacerbation.⁴ The highest rates of asthma among children occur in those aged 10 to 14 years.⁵

Uncontrolled asthma can significantly contribute to a wide range of harmful consequences, including poor psychological health, quality of life, and academic performance, which can be attributed to a chronic absence from school.⁶ The

mortality rates among asthmatic patients are stable in developing countries but are increasing in developing countries.⁷ Several factors contribute to these increases, including a lack of follow-up after hospitalization, insufficient clinical management, the absence of an asthma action plan, inadequate usage of preventer medications, and a lack of supervision by a specialist.⁸ Self-care skills are essential for asthma management and achieving asthma control.⁹ These skills include understanding the condition, knowing asthma symptoms and keeping track of them, vaccination, medication adherence, and using the inhalers adequately.⁹⁻¹²

The worldwide prevalence of asthma was reported to be 3.3% in 2021, with the highest prevalence reported in USA (11.5%) and the lowest in Pakistan (1.6%). Asthma prevalence in the Middle East and North Africa is not significantly different from the global values (3.2%).¹³ The prevalence of asthma in Jordan has been reported to be 3.3%.¹³ A cross-sectional study conducted among schoolchildren in Jordan found that the prevalence of asthma across both genders was 2.38%. Moreover, asthma knowledge among primary school teachers was low.⁶ Another study has reported the prevalence of asthma in Jordan to be 9.5%.¹⁴ Uncontrolled asthma can result in unfavorable outcomes in the long run. A cross-sectional study revealed a significant association between uncontrolled asthma and quality of life, mental health, obesity, limitation of activity and bedding and the utilization of healthcare services.^{15,16}

Parents' health literacy (HL) is defined as the "understanding and use of health information", and several studies indicate that lower HL in asthmatic patients predicts poor asthma outcomes.¹⁷ A cross-sectional study indicated that higher HL among parents of asthmatic children was associated with better parent asthma-related knowledge, which in turn led to better asthma control in their children.¹⁷ Additionally, a systematic review found that low HL among parents of asthmatic children was associated with increased healthcare utilization and poor asthma control.¹⁸ Furthermore, a recent cross-sectional study conducted in the USA showed that low HL among primary caregivers of asthmatic children was associated with poor asthma control.¹⁹ A narrative review examining the relevance and role of HL for children and adolescents with asthma highlighted the importance of providing asthma prevention and self-management education early in life to children as well as raising parents' and caregivers' awareness of asthma.²⁰

Many patients struggle with the numerical concepts necessary for asthma self-management, which are distinct from other health literacy skills. Common health literacy assessments often fail to identify adults lacking the numerical skills needed for managing asthma. Since these tools do not directly measure skills specific to asthma self-management, they are more burdensome in clinical settings compared to instruments integrated into asthma-management education. The Asthma Numeracy Questionnaire (ANQ) has been shown to be well-received by asthma patients and effectively highlights numeracy challenges relevant to self-management, providing immediate benefits for clinicians. Even without assessing each patient with the ANQ,²¹ for example, asthma patients have reported difficulty in taking the appropriate dose of oral corticosteroids due to limited patient education related to asthma.²² Furthermore, it is very difficult for patients to understand the risk of developing osteoporosis as a result of the chronic use of corticosteroids.^{23,24} In addition, patients need to understand the interpretation of peak flow meter readings, and how this is reflected in their asthma status.²⁵⁻²⁷ The ANQ is a unique tool that assesses the extent of knowledge related to these aspects in asthmatic patients. These items are closely linked to patient education concepts emphasised in the GINA guidelines, including detecting increasing airflow limitation as an indicator of asthma flare-ups, self-management of asthma exacerbations, and understanding the potential risk factors associated with the use of systemic corticosteroids.²⁸

Few studies have investigated the effect of health literacy on asthma outcomes. The application of the Needs in Asthma Treatment Questionnaire (NEAT) in adult patients found that those with low scores exhibited limited numeracy and literacy related to asthma.^{29,30} The analysis of the Asthma Numeracy Test (ANT) revealed a significant correlation between asthma knowledge and numeracy skills.³¹ The application of a comprehensive health literacy survey among individuals with asthma during the COVID-19 pandemic could have identified their needs, inadequate adherence to asthma management, the quality of care provided, communication strategies, and the psychosocial health impacts experienced during the pandemic.³²

No previous studies have assessed the level of HL among parents of asthmatic children in Jordan or the broader Middle East region. Given the established links between HL and asthma management outcomes in other contexts, the lack of research on HL among parents of asthmatic children in Jordan represents a significant gap in the literature. Improved understanding of this relationship could inform targeted interventions to enhance HL, thereby potentially

improving medication adherence, quality of life, and asthma control among affected children. Therefore, this study aimed to validate an Arabic tool to measure HL in parents of asthmatic children, evaluate their health literacy, and study variables associated with it.

Materials and Methods

Procedure

The current cross-sectional study enrolled 400 parents of asthmatic children attending the Respiratory Therapy Unit at the University of Jordan Hospital (JUH) between the 2nd February and the 6th of May 2024. The inclusion criteria included parents of children who were diagnosed with asthma. The files of asthmatic patients with appointments scheduled for the following day were reviewed, and the parents of these children were approached while they waited. Before participants were enrolled, the interviewer explained the study objectives, informed them that the collected data would stay confidential, and assured them that they could withdraw from the study at any time. Additionally, they were informed that completing the questionnaire would take approximately 10–15 minutes. Written informed consent was obtained from all participants. This study followed the Declaration of Helsinki's ethical guidelines. Ethical approval was secured from the Al-Zaytoonah University of Jordan (Ref#10/12/2023-2024).

Data Collection and Study Instruments

The questionnaire used for this study comprised two sections, in addition to a demographic data collection sheet. The first section contained the Asthma Numeracy Questionnaire (ANQ)²¹ consisting of four items, two multiple-choice questions, and two fill-in-the-blank questions. The first item focuses on a simple calculation of an oral steroid dose, the second is concerned with understanding the likelihood of occurrence of a particular risk when reported as a percentage, while the third and fourth items are calculation questions related to peak flow meter measurements. Each correctly answered item is worth one point and incorrectly answered items receive zero points, with scores ranging from 0 to 4.²¹ The second section focuses on assessing asthma knowledge and is composed of 7 items.^{33,34}

Tool Validation

Content validity was evaluated by three pulmonologists and a clinical pharmacy academic professor. The questionnaire underwent a back-translation process into Arabic, conducted by four independent translators. A pilot study involving 30 parents of asthmatic children was carried out to ensure the questionnaire was clear to participants. The data from the pilot study was excluded from the final statistical analysis. Confirmatory factor analysis (CFA) is an advanced statistical technique used to evaluate the validity of a predefined factor structure for a set of observed variables. It tests the hypothesis that the assumed relationships between the observed variables and their underlying latent constructs are accurate. This technique was applied to evaluate the questionnaire's construct validity. Cronbach's alpha values were examined to ensure the internal reliability of the generated factors. Rasch analysis was carried out to evaluate the ability of the tool to differentiate between parents' levels of asthma literacy and assess the difficulty levels of the questionnaire items.

Sample Size Calculation

The participant-to-item ratio is considered the best way of determining the minimum required sample size for research involving factor analysis, with a suggested maximum ratio of 20:1.³⁵ As the questionnaire included four items, the minimum sample size was 80.

Statistical Analysis

The data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 26 and R software version 4.3.3, the Test Analysis Modules (TAM) package version 4.1–4, and latent variable analysis (lavaan) version: 0.6–17. CFA was applied to the one-factor model suggested in the original questionnaire. To assess goodness of fit, χ^2/df (mini-mum discrepancy), GFI (goodness-of-fit index), CFI (comparative fit index), standardized root mean squared

residual (SRMR), and Tucker–Lewis index (TLI) were computed. Values between 2 and 5 are considered acceptable for χ^2/df .³⁶ SRMR values equal to or less than 0.08 indicate an acceptable fit.³⁷ TLI values equal to one indicate a perfect fit and values close to one indicate a very good fit.³⁸ GFI and CFI values equal to one indicate a perfect fit, values equal to or greater than 0.95 indicate an excellent fit and values equal to or greater than 0.9 indicate a reasonable fit.^{39,40} Factor loadings were evaluated, with acceptable values above 0.4. A dichotomous Rasch analysis was conducted. Person and item separation reliabilities were computed to verify the suitability of the model. Additionally, infit/outfit statistics were produced. Items' infit and outfit mean square (MSQ) values ranging between 0.6 and 1.4 were considered acceptable.⁴¹ For person fit statistics, standardized infits and outfit (z-scores) were computed for all participants, with acceptable values $<\pm 2.5$. The unidimensionality of the model was evaluated by conducting a principal component analysis of the residuals (PCAR). To confirm the model's unidimensionality, the eigenvalue of the first contrast should be <2 .⁴² The percentage of the variance of the ANQ responses explained by the Rasch model was also computed to assess the unidimensionality of the model, with an acceptable percentage being around 20%.⁴³ A Differential Item Functioning (DIF) analysis between genders was conducted by comparing the standardized differences (z) in item difficulty between the two sexes.⁴⁴ Correlations between inter-item residuals were examined by applying the Q3 statistic to confirm the local independence assumption. Acceptable residual correlations were below 0.5.⁴⁵ The item/person distribution was evaluated by producing the Wright map. ANQ scores were computed, and their normality was assessed using Q-Q plots. As the data was not normally distributed a quantile regression was used to assess the relationship between socio-demographic variables and ANQ scores. The model included parents' and children's age and gender in addition to parental education and income levels.

Results

Sample Socio-Demographic Characteristics

The socio-demographic profiles for the 400 enrolled parents of asthmatic children and their children are shown in Table 1. The ages of the children ranged from 3 to 11 years, and more than half of them were males (59.5%). The median age of the parents was 37 (31–43) years; most parents are females (66.5%). Most parents held bachelor's degrees or postgraduate qualifications (56%), and 47.5% of parents reported having a monthly income of 500 Jordanian Dinars (JOD) or more.

Table 1 Sociodemographic Profiles for the Participants

		Count (%)	Median (25–75) Percentiles
Parent's age			37 (31–43)
Parent's gender	Female	266 (66.5%)	
	Male	134 (33.5%)	
Children's age			6 (3–11)
Children's gender	Female	162 (40.5%)	
	Male	238 (59.5%)	
Parent's education	High school degree or less	99 (24.8%)	
	College degree	83 (20.8%)	
	Bachelor's degree / postgraduate	218 (54.5%)	
Income status	Less than 500 JOD*	176 (44%)	
	500 JOD* or more	224 (56%)	

Notes: *JOD: Jordanian dinar (1 JOD = 1.41 USD).

Participants' Responses to ANQ Items

Participants' responses to the ANQ items are displayed in Table 2. The item most correctly answered was "If a patient has a 1% chance of developing osteoporosis or bone loss: that means" (75.5%), followed by the item "You have a peak flow meter. Your Danger or Red Zone is 50% of your best reading. Your best reading is 400 L/min. What is your Danger Zone?" (72.5%). The least correctly answered item was "You are told the Green Zone (the OK zone) is reading between 80% and 100% of your best reading. Your Worry Zone is between 50% and 80% of your best reading. Your best reading is 400 L/min. When are your readings in the Worry Zone?" (48.8%) The median for participants on the ANQ was 3 (1–4) out of a maximum possible score of 4.

Participants' Responses to Asthma Knowledge Questions

Participants' responses to the asthma knowledge items are presented in Table 3. The question most correctly answered was "Do you know how to use the inhalers for treating asthma properly?" (97.8%), followed by the question "Parental smoking may make the child's asthma worse" (96.8%), while the question least correctly answered "What is the aim of treating an asthmatic patient?" (53%). The median knowledge score of participants regarding asthma was 6 (ranging from 5 to 7) out of a maximum possible score of 17.

Confirmatory Factor Analysis

CFA was conducted to evaluate the 1-factor model suggested in the original questionnaire. The result indicated that the 4-item unidimensional model was suitable for the present study. The model yielded acceptable model fit indicators ($\chi^2/df = 4.6$, SRMR = 0.02, CFI = 0.99, GFI = 0.99 and TLI = 0.96). The highest factor loadings were observed for ANQ 2(0.81) followed by ANQ 1(0.74) while the lowest factor loadings were noticed for ANQ 4(0.66), The standardized factor loading for each item is reported in Table 4. Cronbach's α value of the 4 items was high ($\alpha = 0.82$) indicating good reliability (Table 5).

Rasch Analysis

The person separation reliability was 0.742 and the item separation reliability was 0.99, confirming the ability of ANQ to differentiate between various participants' HL levels and the item hierarchy produced by the model. A summary of item and person fit statistics is displayed in Table 4. The means of the items' infit and outfit MSQ were within the acceptable range (0.6–1.4), while the means for the standardized person infits and outfits (z-scores) were within the permissible limit (the misfit indicated by fit residual values $>\pm 2.5$). Table 5 shows ANQ items' outfits, infits, locations, and proportions. The most difficult item to answer was ANQ 2 (Location = -2.19), followed by ANQ 3 (Location = -1.88), while the easiest item to answer was ANQ 4 (Location = 0.16). All the 4 items' infits MSQ and outfits MSQ were within the permissible

Table 2 Participant's Responses on the 4-Item Asthma Numeracy Questionnaire (ANQ)

	Incorrect Response Count (%)	Correct Response Count (%)
Your doctor asks you to take 30 mg of prednisone every day for a week. The pharmacist gives you a bottle of 5 mg tablets. How many pills should you take each day?	159 (39.8%)	241 (60.3%)
If a patient has a 1% chance of developing osteoporosis or bone loss: that means	98 (24.5%)	302 (75.5%)
You have a peak flow meter. Your Danger or Red Zone is 50% of your best reading. Your best reading is 400 L/min. What is your Danger Zone?	110 (27.5%)	290 (72.5%)
You are told the Green Zone (the OK zone) is a reading between 80% and 100% of your best reading. Your Worry Zone is between 50% and 80% of your best reading. Your best reading is 400 L/min. When are your readings in the Worry Zone?	205 (51.2%)	195 (48.8%)

Table 3 Frequency of Responses to Asthma Knowledge Questions

		Count (%)
When an asthmatic patient is exposed to a cold, does exercise, or suffers from flu, this:	Could lead to an asthma crisis. *	309 (77.3%)
	Is not a problem.	42 (10.5%)
	I do not know.	49 (12.3%)
What is the aim of treating an asthmatic patient?	To control the disease. *	212 (53%)
	To completely cure him or her.	165 (41.3%)
	I do not know.	23 (5.8%)
A person with controlled asthma can	work, go to school, and take exercise. *	350 (87.5%)
	only walk, rest, and eat.	34 (8.5%)
	I do not know	16 (4%)
Do you know how to use the inhalers for treating asthma properly?	No	9 (2.3%)
	Yes *	391 (97.8%)
Parental smoking may make the child's asthma worse	No	13 (3.3%)
	Yes *	387 (96.8%)
If one child in a family has asthma then all his/her brothers and sisters are almost certain to have asthma as well	No*	357 (89.3%)
	Yes	43 (10.8%)
Antibiotics are an important part of treatment for most children with asthma	No*	314 (78.5%)
	Yes	86 (21.5%)

Note: "*" is the correct answer.

range (0.6–1.4). The Wright map (Figure 1) indicates that participants were spread across all levels of difficulty and the largest portion of the sample was situated in the middle range.

The scree plot of PCAR is presented in Figure 2. The PCAR confirmed the unidimensionality of the Rasch model, as the highest eigenvalue was 1.35, which is below the cut-off point of 2. Furthermore, 69.33% of the variance in participants' responses to the ANQ items can be explained by the Rasch model. DIF between the two genders was assessed (Figure 3). The results showed significant differences in DIFs between males and females for only one item (item 3). Correlations between inter-item residuals were examined by applying the Q3 statistics, displayed in Table 6.

Table 4 Summary of Item and Person Fit Statistics

Item Logit Scale Location MEAN (SD)	Person Logit Scale Location Mean (SD)	Item Outfit MSE Mean (SD)	Item Infit MSE Mean (SD)	Person Std. Outfit Mean (SD)	Person Std. Infit Mean (SD)
-1.17 (1.07)	-0.43 (1.96)	0.77 (0.21)	0.91 (0.08)	-0.14(0.56)	-0.5 (0.61)

Table 5 Items Standardized Factor Loadings, Outfits, Infits, Locations, and Proportions of ANQ

	Location (SE)	Outfit MSE	Infit MSE	Proportion	Standardized Factor Loading (SE)
ANQ 2	-2.19 (0.16)	0.48	0.79	0.76	0.81 (0.07)
ANQ 3	-1.88 (0.16)	0.97	0.97	0.72	0.71 (0.07)
ANQ 1	-0.78 (0.15)	0.8	0.93	0.6	0.74 (0.00)
ANQ 4	0.16 (0.14)	0.81	0.94	0.49	0.66(0.08)

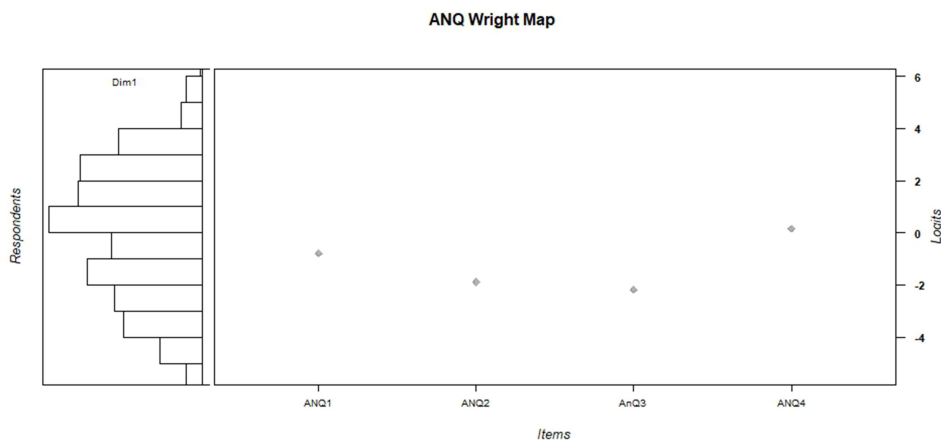
The highest correlation was between ANQ1 and ANQ3 ($r = -0.359$). However, all residual correlations remained within the local independence assumption, below the $r=0.5$ cut-off point.

ANQ Predictivity

Spearman's rank correlation was conducted between ANQ scores and knowledge scores and there was a significant positive correlation ($r=0.42$, $p<0.001$) confirming the predictive validity of the ANQ.

Variables Associated with ANQ Scores

The quantile regression indicated that participants who had a high school degree or less, or a college degree, had significantly lower ANQ scores than those who had bachelor/postgraduate degrees (Coefficient=-2, 95% CI: -2.35, -1.66, $p<0.001$; and Coefficient=-1, 95% CI: -1.35, -0.66, $p<0.001$ respectively). Moreover, parents with high-income levels (500 JOD or more) had higher ANQ scores compared to parents with low income (Coefficient=1, 95% CI: 0.72, 1.66, $p<0.001$).

**Figure 1** Wright map of the Arabic version of the ANQ.

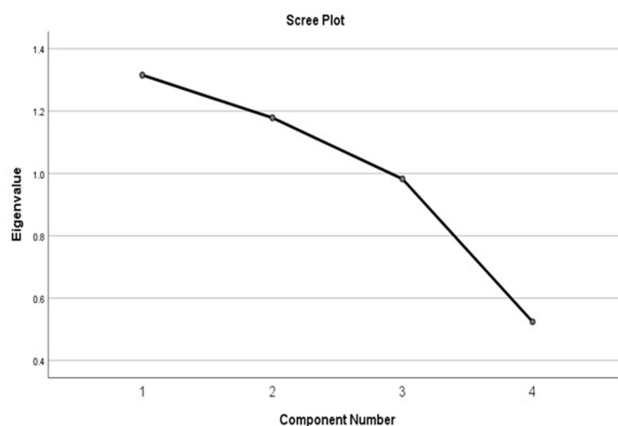


Figure 2 Scree plot of PCA of residuals of the Rasch model.

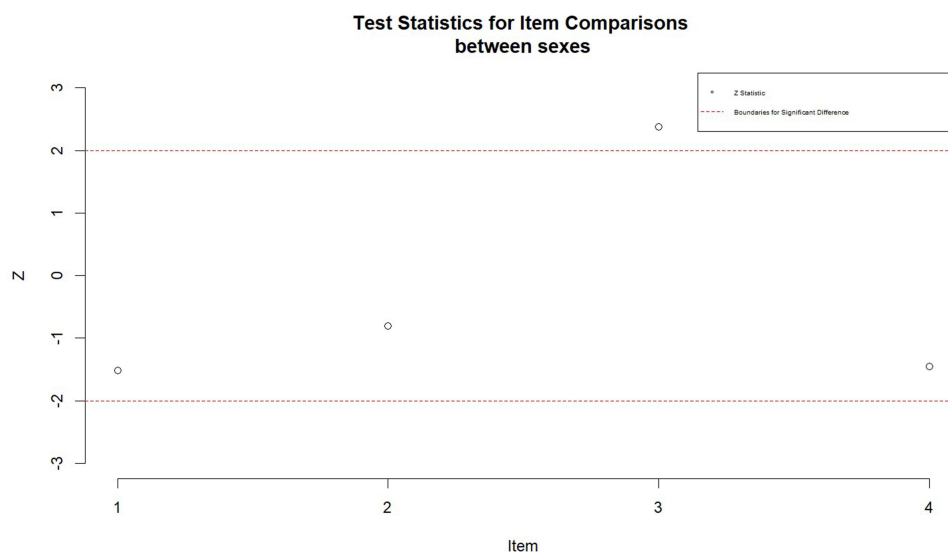


Figure 3 Differential item functioning between genders.

Discussion

This study aimed to validate the Arabic version of the Asthma Numeracy Questionnaire (ANQ) among Jordanian parents of asthmatic children, an area previously unexplored in the literature. The findings provide important insights into the health literacy of parents of asthmatic children in Jordan, a previously understudied demographic.

The validation of the Arabic version of the ANQ through factor and Rasch analyses confirmed its reliability for assessing health literacy related to asthma management in a Middle Eastern context. Its good internal consistency suggests it is a reliable measure for evaluating numeracy skills essential for managing asthma. Confirmatory factor analysis further supported the construct validity of the ANQ, showing that the questionnaire aligns well with the expected theoretical framework and is suitable for the Jordanian population.

These validation outcomes are consistent with the original study,²¹ which highlighted the importance of numeracy in effectively managing asthma. Our findings reinforce the critical role of numeracy in health literacy within the Jordanian context and underline the necessity of such tools in chronic disease management across different populations.

The findings also demonstrated a clear positive correlation between higher levels of health literacy and increased asthma knowledge among parents. This correlation suggests that parents who were better informed and more competent

Table 6 Q3 Correlation Matrix

Items	ANQ1	ANQ3	ANQ2
ANQ1	—		
ANQ3	-0.359	—	
ANQ2	-0.070	-0.100	—
ANQ4	-0.212	-0.204	-0.189

Abbreviations: ANQ, Asthma Numeracy Questionnaire; CFA, Confirmatory factor analysis; CFI, comparative fit index; DIF, Differential Item Functioning; GFI, goodness-of-fit index; HL, Health literacy; JOD, Jordanian dinar; JUH, University of Jordan Hospital; lavaan, latent variable analysis; MSE, Items' infit and outfit mean square; PCAR, principal component analysis of the residuals; SPSS, Statistical Package for the Social Sciences; SRMR, standardized root mean squared residual; TAM, Test Analysis Modules; TLI, Tucker-Lewis index; z-scores, standardized infits and outfit.

in managing health information tended to adopt more effective asthma management practices. These practices included accurate medication dosing and timely response to asthma symptoms, which are critical for preventing exacerbations and improving overall child health outcomes. Studies have consistently shown that better health literacy is crucial for effective asthma management. Previous research has demonstrated that patients with higher health literacy tend to have better disease control and fewer emergency visits due to asthma,⁴⁶ underlining the importance of educating patients to improve health literacy and asthma management outcomes.

Moreover, the present study highlights the specific areas of knowledge and numeracy that are most impactful. For example, the ability of parents to understand and act upon different zones of asthma severity as indicated by peak flow meter readings correlates strongly with better asthma control in children. With prior literature demonstrating a link between peak flow monitoring and child asthma quality of life,⁴⁷ this finding is particularly important as it suggests specific targets for educational interventions that could yield significant benefits in asthma management.

The ANQ offers healthcare providers a practical tool for assessing parental health literacy in outpatient and community settings. By identifying specific numeracy deficits, it allows for tailored education to address gaps in asthma management knowledge. For instance, integrating the ANQ into routine clinical assessments could enable physicians to provide personalized feedback during consultations, focusing on critical areas such as understanding asthma action plans or peak flow meter use. Additionally, it could serve as a pre- and post-measurement tool to evaluate the effectiveness of health literacy interventions. Targeted workshops or digital learning modules could also be developed for parents identified as having lower health literacy.

Recent studies in Jordan provide further support for the importance of tailored interventions in asthma care. For example, Al-Sheyab et al⁴⁸ demonstrated the effectiveness of peer-led asthma education programs for Jordanian adolescents, which resulted in improved self-management skills. Similarly, Alshahwan et al⁴⁹ highlighted a gap in caregivers' knowledge about asthma triggers and management, reinforcing the need for tools like the ANQ to identify and address these deficits. Al-Qerem et al (2023) explored vaccination practices among Jordanian parents of asthmatic children, revealing that knowledge gaps directly impacted healthcare behaviors.¹² Together, these studies underline the important role of education in improving asthma outcomes and the potential of the ANQ in advancing health literacy among parents in Jordan and other Arab-speaking countries.

The quantile regression analysis provided critical insights into the socioeconomic determinants of health literacy as measured by the ANQ scores among parents of asthmatic children. The results indicated a significant disparity in ANQ scores based on educational attainment and income levels. Participants with high school degrees or lower, or a college degree, scored significantly lower on the ANQ compared to those with bachelor's or postgraduate degrees. These findings

suggest that higher educational levels correlate with better numeracy skills essential for effective asthma management. Additionally, the analysis showed that parents with higher income levels had higher ANQ scores compared to those with lower incomes, highlighting the impact of economic status on health literacy. These findings are crucial for understanding how socioeconomic factors influence the ability of parents to manage their children's asthma effectively.

Despite its potential, several barriers may hinder the adoption of the ANQ in diverse healthcare settings. Limited resources in underfunded clinics might make it challenging to integrate new assessment tools into routine care. Time constraints during consultations could also reduce the feasibility of administering the questionnaire without disrupting workflows. Additionally, cultural differences in health beliefs and varying levels of trust in healthcare systems could impact the tool's uptake. Parents with low literacy levels may find health literacy assessments intimidating, further limiting its adoption. Addressing these barriers requires culturally sensitive implementation strategies, staff training, and the use of digital platforms to streamline ANQ administration.

The results from the present study align with findings from prior research in other settings. For example, a Danish population-based survey indicated that lower socio-economic status was associated with reduced health literacy, impacting overall health behavior and status.⁵⁰ Similarly, UK research identified a link between socioeconomic deprivation and poorer asthma outcomes, further emphasizing the impact of economic and educational disparities on health management.⁵¹ These parallels highlight the broader implications of the present findings, suggesting that enhancing educational and economic opportunities may improve health literacy and, consequently, health outcomes.

Strengths and Limitations

The present study has several strengths. Firstly, the use of a validated tool ensured that the measures of health literacy were reliable and grounded in robust psychometric principles. This enhances the credibility of the present findings and facilitates their comparability with other studies using similar tools. Furthermore, the comprehensive statistical analyses employed, including confirmatory factor analysis and Rasch modeling, provided a strong foundation for the conclusions drawn.

Another significant strength of the current study is the diverse participant pool, which included a broad range of socioeconomic backgrounds. This diversity enhances the generalizability of the findings within the Jordanian context and possibly in other similar settings.

Despite its strengths, this study has several limitations that must be considered. Firstly, the cross-sectional design limits the ability to draw causal inferences from the data. Another limitation is the potential for response bias; participants may have provided answers they believed were expected or socially acceptable rather than responses that truly reflected their knowledge or behaviors.

Finally, while the study does include a diverse sample, it is still confined to one geographic and cultural setting. Therefore, while the findings add valuable insights into the validation of the Ar-ANQ in the Jordanian context, they may not be fully generalizable to other countries or regions with different healthcare systems or cultural norms.

Future Directions

With the successful validation of the Arabic version of the ANQ among Jordanian parents, this study's findings open several avenues for future research and practical interventions. Firstly, longitudinal work is needed to track the effectiveness of the ANQ over time. Such studies could assess how changes in numeracy and health literacy affect asthma management in the long term.

Additionally, developing a digital version of the ANQ, such as a mobile app or interactive platform, could modernize its application and expand its reach. These platforms could provide real-time feedback, educational resources, and personalized recommendations to enhance asthma management. Utilizing such technologies, healthcare providers could streamline the ANQ's administration and increase its accessibility in diverse healthcare settings.

Conclusion

The present study successfully validated the Arabic version of the Asthma Numeracy Questionnaire (ANQ) among Jordanian parents of asthmatic children, making an important contribution to the fields of health literacy and asthma

management. The results demonstrated that the ANQ is a reliable and valid tool for assessing the numeracy skills necessary for effective asthma management in a Middle Eastern context, providing critical insights into the health literacy levels of a previously understudied demographic.

This tool may be adopted for targeted educational interventions that can enhance asthma management practices. Such interventions are particularly vital in contexts where numeracy skills may directly influence the ability of parents to manage chronic conditions effectively in their children. By establishing the reliability and applicability of the ANQ, this study paves the way for further studies and applications that can leverage this tool to improve health outcomes.

Moreover, the study revealed significant disparities in health literacy related to socioeconomic factors, such as education and income levels, highlighting the broader social determinants of health that influence asthma management. These insights underline the necessity for strategies addressing these determinants to improve health literacy and ensure equitable healthcare access.

Beyond asthma, the development and validation of the ANQ provide a framework for creating similar tools tailored to other chronic diseases, such as diabetes or hypertension, where health literacy plays a crucial role in disease management. Future research should focus on adapting and validating numeracy-based health literacy tools across diverse cultural and linguistic contexts to address the broader needs of patients managing chronic illnesses. Such efforts could help identify population-specific gaps in health literacy and guide targeted interventions.

Furthermore, the ANQ could influence health policy in the region by providing policymakers with data on parental health literacy levels, which are critical for designing community-wide educational initiatives. By incorporating the ANQ into routine healthcare assessments, governments and healthcare organisations could identify at-risk populations and implement policies aimed at reducing health literacy disparities, ultimately improving disease outcomes, and reducing healthcare costs.

In conclusion, the validation of the Arabic ANQ enhances the understanding of health literacy among parents of asthmatic children in Jordan and provides a foundation for future research and policymaking aimed at reducing asthma morbidity and improving the quality of life for affected families. This work encourages ongoing efforts to integrate effective health literacy tools into clinical and educational settings, fostering better disease management and promoting healthier outcomes.

Institutional Review Board Statement

The authors have obtained ethical approval from the Institutional Review Board and the Deanship of Research at Al-Zaytoonah University of Jordan. This study followed the Declaration of Helsinki ethical guidelines. Ethical approval was secured from Al-Zaytoonah University of Jordan on 10 December 2023 (Ref#10/12/2023-2024).

Data Sharing Statement

The dataset supporting the conclusions of this article is available in the Zenodo repository <https://doi.org/10.5281/zenodo.11670017>.

Informed Consent Statement

Written informed consent has been obtained from the participant (s) to publish this paper.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no conflicts of interest in this work.

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