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Development and psychometric evaluation of the vaccine knowledge test for childhood vaccinations: using Rasch analysis

Deniz Kocoglu-Tanyer[1] and Deniz S. Yorulmaz Demir[2*]

Abstract

Background There is a clear need for an up-to-date, comprehensive, and methodologically tested tool to assess parents' knowledge of childhood immunization. The aim of this study was to develop a vaccine knowledge test for childhood immunization and to evaluate its validity and reliability.

Methods This methodological study consists of three phases: creating an item pool, preparing a draft form, and psychometric evaluation. The draft form was developed with the help of a table of specifications and expert opinions. The psychometric assessment includes classical item analysis, Rasch analysis, KR-20, Cronbach's alpha, and multiple regression analysis.

Results The Vaccine Knowledge Test had an average item difficulty index of 0.498 and an average item discrimination index of 0.447. The WMS values of the items ranged from 0.81 to 1.14, and the UMS values ranged from 0.80 to 1.35, indicating good dispersion. The person separation index and the person number of strata of the Rasch analysis were 2.3 and 3.4. Cronbach's alpha was 0.84. It was found that receiving vaccine education, having confidence in vaccines, being a parent, and having a university education were the determinants of vaccine knowledge, and these variables accounted for 29% of the variance in vaccine knowledge.

Conclusion The Vaccine Knowledge Test, consisting of a single dimension and 28 items, is a valid and reliable measurement tool. It can reliably discriminate between individuals with different levels of knowledge or skills as low and high. It can be used as part of public health education and programs aimed at reducing vaccine hesitancy and preventing the destructive effects of vaccine misinformation in the community.

Keywords Vaccine, Knowledge, Test, Validity, Reliability, Rasch analysis, Childhood vaccination

*Correspondence:
Deniz S. Yorulmaz Demir
denizyrlmz.20144@gmail.com
[1]Faculty of Nursing, Department of Public Health, Selcuk University, Konya, Turkey
[2]Faculty of Health Sciences, Nursing Department, Artvin Çoruh University, Artvin, Turkey

Introduction

Vaccination, recognized as one of the most effective public health interventions, has dramatically reduced child mortality worldwide. Data and predictions suggest that it can continue to achieve this outcome in the coming years [1]. Despite these measurable outcomes, vaccine hesitancy and refusal are increasing rapidly globally, posing a threat to public health gains [2]. To understand and address vaccine hesitancy, the World Health Organization (WHO) established the Strategic Advisory Group of Experts on Immunization (SAGE). The group categorized the reasons for vaccine hesitancy into three subcategories: (a) contextual, (b) individual and group influences, and (c) vaccines and vaccine-related factors. Contextual reasons include policies, communication channels, and lobbying, while individual and group influences include concepts such as experiences, beliefs, knowledge, trust, and social norms. Vaccine-related factors include vaccine content, vaccination schedules, and accessibility [3]. In addition to these explanations, the epidemiological model also emphasizes that individual/host factors directly impact vaccine acceptance, hesitancy, and refusal. In particular, it is stated that an individual's information about vaccines is an essential determinant of their attitude, risk perception, and vaccine behavior [4].

These findings have focused researchers' attention on individual perceptions and beliefs about vaccines. Numerous measurement tools have been developed, and important publications have been produced to assess vaccine beliefs [5, 6]. Many studies have shown that perceptions and beliefs about vaccines influence vaccination behavior [7]. However, just as important as perceptions is an individual's knowledge about vaccines, as the presence or absence of knowledge can shape attitudes. When health models/theories used to explain behavior and behavior change are examined, it is found that an individual's knowledge about a topic can influence their attitudes and behavior [8]. Research has shown that vaccine knowledge is protective against belief in conspiracy theories and vaccine hesitancy [2]. Studies have shown that parents with high vaccine knowledge complete immunization programs [9, 10], and low vaccine knowledge increases the likelihood of missing vaccine doses [11]. Furthermore, systematic reviews and meta-analyses of vaccine hesitancy and refusal have shown that an individual's vaccine knowledge determines vaccine intentions, beliefs, and behaviors [12–14].

To prevent vaccine hesitancy and refusal, maintain vaccination inclusiveness, and protect public health, SAGE recommends assessing community vaccine knowledge and providing information about vaccines. In addition, studies emphasize that informing the public about vaccines provides a vital opportunity to shape the community's vaccine beliefs and behaviors in the future [3, 15]. Furthermore, in today's rapidly changing, where information can be sought and obtained much more quickly through mass media, social media platforms, and the internet, having accurate information about vaccines has become crucial [16]. Therefore, disseminating information by healthcare professionals and reliable social media sources is essential to this process.

In light of this information, it is clear that assessing vaccine knowledge is important; however, the question of how to assess it comes to the fore. Health professionals and researchers need a valid and reliable vaccine knowledge scale. In the literature, there are several different measures of vaccine knowledge. Some instruments assess not only knowledge but also attitudes and behaviors. However, due to the scale's date of development date, they may be less comprehensive in covering current knowledge needs [11]. Some studies have developed scales specifically for pediatricians [17], students [18], and medical students [19]. Some tests are specific to a particular vaccine, such as hepatitis B [20–22]. Another knowledge test developed in a study consisted of ten questions primarily targeting vaccination knowledge, and its psychometric evaluation was conducted with 88 parents [9]. Therefore, there is a clear need for an up-to-date, comprehensive, and methodologically sound measurement tool to assess parents' knowledge of childhood immunization. In addition, the crucial role of vaccine knowledge in combating vaccine refusal has made this need even more important and urgent. This study aims to develop a vaccine knowledge test for childhood vaccinations and assess its validity and reliability. The developed knowledge test is expected to be used as part of public health education and programs aimed at reducing vaccine resistance and preventing the destructive effects of vaccine misinformation in the community.

Method

Study design

This study was methodologically designed to develop the Vaccine Knowledge Test (VKT) and to test its validity and reliability. The study consists of three phases: (a) item pool creation, (b) final drafting (based on content validity), and (c) psychometric evaluation. The Vaccine Knowledge Test (VKT) was developed to assess adults' knowledge of childhood vaccinations. The test focuses on cognitive processes and is not intended to measure attitudes or behavior. Items in the test are answered with the options 'true,' 'false,' and 'don't know,' and the 'don't know' response is scored as incorrect.

Phase 1: Literature review, interviews, and observation for creating the item pool

As a first step, a literature search was conducted to determine the structure of the knowledge test and to obtain

items. The literature review was conducted using the keywords 'vaccine, vaccine knowledge, vaccine health literacy, vaccine literacy, test, and knowledge test' in Google Scholar, PubMed, MEDLINE, Embase, and CINAHL databases. During the development of the item pool, surveys and scales assessing vaccine knowledge from different countries [9, 11, 17, 19, 23] and scales and surveys related to vaccine hesitancy, vaccine attitude, vaccine indecision, and vaccine confidence were reviewed [24–28]. In addition, the websites of the World Health Organization, the University of Oxford, and the Ministry of Health of the Republic of Turkey were consulted during the literature review [29–31]. The headings and subheadings on the Oxford University Vaccine Knowledge Project website were an important guide to the item pool and topics [29]. Following the literature review, the items identified were evaluated by five nurses working in immunization services. These nurses contributed to the knowledge test by considering the explanations they gave to parents or the most common questions parents asked about vaccines. Then, for five consecutive days, one of the researchers (DS-YD) observed the nurse's process of informing parents and the parents' questions about vaccination in the vaccination room of a family health center. In particular, this observation has contributed to our understanding of what parents are most likely to ask. At the end of these processes (literature review, interviews, and observation), 31 items for the Vaccine Knowledge Test (VKT) were generated under six main topics.

Phase 2: Preparation of the specification table, expert opinions, and development of the final draft form through piloting

After the first draft was created, a list of learning outcomes was created to check the content validity of the knowledge test, and an item table based on Bloom's Taxonomy was created. The specification table is used to ensure that the test measures the intended content and to assess the ability to measure the thinking skills of the test. First, it was assessed to which of the processes 'knowing,' 'understanding,' 'knowing for application,' 'analyzing/synthesizing,' and 'evaluating' each item in the test belonged. The appropriateness of the questions in the first draft to the learning outcomes and the taxonomy was assessed by three experts in the field of education. According to the list of learning outcomes, it was determined that there was no need for additional items, and the knowledge test included test items that reflected the outcomes and processes (Supplementary Table 1). Expert opinion was then sought to assess the clarity, readability, understandability, and appropriateness of the items in the VKT to measure what they were intended to measure. The knowledge test was sent to 13 experts with doctoral degrees in public health, pediatrics, and psychiatric nursing, with research experience in child health, immunization, instrument development, and adaptation. Responses were received from 8 experts. The experts rated the items using the Davis technique (1: item is unsuitable, 2: item needs significant revision, 3: minor modification, 4: item is suitable). Based on expert opinion, one item was removed from the test, resulting in a draft form of 30 items. Once the draft form had been produced, a pilot study was carried out with 35 parents taking their children for vaccination, and the feedback received was analyzed. There was no negative feedback regarding the comprehensibility of the items, so the draft form was finalized. Parents reported that the knowledge test was comprehensive and interesting to answer. The time taken to complete the knowledge test in the pilot study was found to be between 5 and 8 min. The reliability coefficient for the knowledge test in the pilot phase was 0.89.

Phase 3: Psychometric evaluation

In this evaluation, the difficulty and discriminative power of the items were first determined. The reliability coefficient was then assessed using KR20. The standard range for item difficulty is 0.25 to 0.75 [32]. The classification for item discrimination is as follows: $0.00 \leq rjx \leq 0.19$ indicates very weak discrimination/the item should be removed; $0.20 \leq rjx \leq 0.29$ indicates that the item needs improvement; $0.30 \leq rjx \leq 0.39$ indicates that the item is adequate and can be improved; items with values greater than 0.40 are considered good [33]. The knowledge test was then examined using the Rasch model, one of the methods of item response theory. The Rasch model aims to determine the difficulty of items and the ability of individuals. It attempts to obtain realistic measures by examining the behaviors underlying individuals' choices and responses to items. This analysis, which allows an individual's ability to be matched to the difficulty of items on the same measurement scale, allows a better test of the expected complex measurement structure of the knowledge test. The range of item difficulty obtained by Rasch analysis is from −3 logits (very easy) to +3 (very difficult). When the infit value, which analyzes items that match well with the person ability, and the outfit value, which analyzes outlier responses, are >1.50, they are considered misfits. Items with infit and outfit values between 0.5 and 1.5 are considered efficient and appropriate for the measurement tool [34]. In addition, this analysis examines the functional relationship between the actual score and the ability scale, the test information function, and the distribution of standard errors using the person plot. This plot provides an opportunity to assess knowledge acquisition across various ability levels. Finally, the factor structure of the test can also be determined through Rasch analysis [34]. In the final stage of the validity assessment, the relationship between individual variables (education,

income, childbearing status, information seeking about vaccines, trust in vaccines) that may influence an individual's vaccine knowledge and the knowledge test was assessed using multiple regression analysis. These variables are expected to predict the vaccine knowledge test. The KR20 value was calculated to test reliability. This value measures the consistency between all the items in the test and is referred to as the 'internal consistency coefficient.'This analysis yields a value between 0 and 1, with higher values indicating more excellent reliability. A value greater than or equal to 0.70 is sufficient [35].

Data collection instruments

The research data was collected using a personal information form and a vaccine knowledge test developed by the researchers.

Personal information form

Personal information form: This form contains 14 questions that assess demographic characteristics, including age, gender, education level, marital status, occupation, childbearing status, having received certain vaccines (e.g., influenza, HPV), having received education about vaccines, and thoughts about vaccine administration.

Vaccine Knowledge Test (VKT)

The VKT assesses the community's knowledge of childhood vaccines. It contains questions that can be answered with the options 'true,' 'false,' or 'don't know.' In the test, items 1, 2, 3, 5, 6, 8, 10, 11, 12, 14, 16, 17, 18, 21, 22, 25, 26, 27, 28, and 29 should be marked as 'correct,' while items 4, 7, 9, 13, 15, 19, 20, 23, 24 and 30 should be marked as 'incorrect,' and these items should be reverse-coded. When scoring the VKT, '1' points are given for correct answers '0' points for incorrect answers and 'don't know' answers. As two questions (8 and 23) were removed from the test after the analysis, the maximum possible score for the knowledge test in its final version is 28. An increase in the total score is interpreted as a higher level of vaccine knowledge (For the final version, the reverse-coded items are 4,7,8,12,14,18,19,22 and 28). The readability index for the final Turkish form is 78.4, with the level of readability corresponding to the 7th-grade level. The average word length is 2.68, with sentences averaging 4.9 words (Supplemental Table 4).

Participants

Participants were adults. In addition to parents (%76,6), individuals without children of vaccination age (%23.3) were included in the study. This was done to assess the ability of the vaccine knowledge test to discriminate between knowledgeable and unknowledgeable groups as part of the validity assessment. Parents who have their children vaccinated may have a higher level of knowledge than the general population due to their experience with vaccination and contact with the health facility. For the same reason, a group as heterogeneous as possible is needed for Rasch analysis to evaluate the ability of this test to distinguish individuals according to information. The adult group (24–65 years old) was included in this study, and no restrictions were made on participants in terms of education and occupation, and all people who volunteered were included in the study. In psychometric studies, it is recommended that the required sample size for factor structure assessment should be between ≥200 and 500 [36]. This study was conducted with 402 participants.

Data collection process

Study data were collected between 1 February and 31 April 2023 at family health centers (FHCs) in the province's central districts. Adults aged 18 years and older who visited the FHC for any reason were informed about the subject and content of the study. Voluntary participants were given data collection forms. Participants took about 5–6 min to complete the data collection forms. No participants encountered difficulties in answering the questions or required an extended amount of time to respond. As the data for this study were collected by the researcher, who was also a member of the research team, this inference can be made with confidence.The researchers collected the research data after obtaining ethical committee and institutional approval.

Data analysis

Data were analyzed using numbers, percentages, means, and standard deviations. The validity of the VKT was assessed using the content validity index, item analysis (item difficulty index and item discrimination index), and item fit (with Rasch analysis) (Jmetrik 4.11). The reliability of the VKT was assessed using KR-20, KR-21, and Cronbach's alpha values. The relationship between the VKT and certain variables was assessed using multiple regression analysis (enter model) (Statistical Package for Social Sciences v.27.0). Categorical variables included in the model were transformed into dummy variables, and assumptions were checked before analysis. Data from the pilot study were not included in the analysis. There was no missing data in the research, and no imputation method was used to locate it. All analysis results were interpreted at the 95% confidence level with a margin of error 0.05.

Ethical considerations

Prior to the research, ethical committee approval (Approval Committee: Republıc of Turkey, Artvin Çoruh Unıversıty Rectorate, Scientific Research and Publication Ethics Committee, number: E-18457941-050.99-68849,

date: 01.11.2022) and institutional approval (Artvin Provincial Health Directorate, number: E-17720518-514.03.02-207936246, date: 25.01.2023) were obtained. Participants were informed about the research topic during the study, and their consent was obtained. All participants were 18 years of age or older; informed consent was obtained without any potential for coercion. This research was conducted by the tenets of the Declaration of Helsinki.

Results

It was found that 56.0% of participants have a bachelor's degree or higher, 64.7% are employed, and 76.6% have children. In addition, 59.2% of the participants had received no previous education about vaccines, 23.1% thought that the administration of childhood vaccines should be optional for parents, and only 51.0% thought that vaccines were completely safe. Among participants with children ($n = 308$), 13.7% of their children are incompletely vaccinated (see Supplementary Table 2).

Table 1 Item analysis results of vaccine knowledge test (30 items)

Items	Item Difficulty (Pj)	Discrimination index (rjx)	KR-20 If Item deleted
Item 1	0.55	0.56	0.845
Item 2	0.50	0.53	0.845
Item 3	0.31	0.51	0.845
Item 4	0.25	0.42	0.845
Item 5	0.43	0.54	0.845
Item 6	0.43	0.57	0.845
Item 7	0.34	0.47	0.845
Item 8¥	0.17	0.15	0.851
Item 9	0.63	0.46	0.846
Item 10	0.79	0.49	0.843
Item 11	0.51	0.51	0.846
Item 12	0.66	0.42	0.843
Item 13	0.49	0.46	0.846
Item 14	0.76	0.39	0.847
Item 15	0.39	0.38	0.846
Item 16	0.44	0.42	0.846
Item 17	0.71	0.52	0.849
Item 18	0.84	0.32	0.848
Item 19	0.64	0.58	0.844
Item 20	0.40	0.53	0.845
Item 21	0.17	0.30	0.847
Item 22	0.36	0.37	0.848
Item 23¥	0.17	0.10	0.852
Item 24	0.71	0.40	0.845
Item 25	0.49	0.61	0.843
Item 26	0.46	0.54	0.845
Item 27	0.62	0.51	0.845
Item 28	0.85	0.36	0.844
Item 29	0.57	0.51	0.846
Item 30	0.32	0.47	0.845
Mean Item Difficulty: 0.498	Median score: 15.00		KR-20
Mean Discrimination index: 0.447	Mean score: 14.913 ± 5.996		(alpha): 0.850 KR-21: 0.819

¥: Items with item difficulty lower than 0.25

Experts ($n = 8$) assessed the content validity of the draft scale (31 items). The content validity index of the items ranged from 0.88 to 1.00, except for the item 'Childhood vaccinations are a legal requirement', which had a value of 0.25. This item was dropped from the scale. The content validity index for the 30-item scale was 0.95 (see Supplementary Table 3).

When the item analysis of the VKT (30 items) was examined, the average item difficulty value was 0.498, and the average item discrimination index was 0.447. It was found that the item difficulty of items 8, 21, and 23 were difficult, and items 8 and 23 had weak item discrimination values. The item discrimination scores of the other items ranged from 0.30 to 0.61. Although item 21 ('A child with complaints such as an ear infection or a runny nose, or who is being treated with antibiotics on the day of vaccination, can still be vaccinated') was 'difficult' in terms of item difficulty, it was not removed from the knowledge test. It has good item discrimination and essential public health content. In addition, the KR-20 (alpha) value of the knowledge test was found to be 0.850. Removing items 8 and 23 improved the alpha value while removing item 21 did not change the alpha value. Therefore, items 8 and 23 were removed at this stage, resulting in a 28-item VKT (Table 1).

According to Rasch analysis, the most difficult item in the 28-item knowledge test is 20, while the easiest item is 26. Items 9 and 17 are other notable easy items, and item 4 can be described as another difficult item. The rest of the items have a moderate level of difficulty. Item fit was assessed using WMS (infit) and UMS (outfit) values. The infit values of the items range from 0.81 to 1.14, while the outfit values range from 0.80 to 1.35 (Table 2). Figure 1 shows the functional relationship between actual scores and the ability scale, the test information function, and the distribution of standard errors. This figure shows that knowledge is obtained across a wide range of ability levels and indicates that the items are well distributed (Fig. 1). The Rasch analysis also provides scale quality statistics. According to this, the item reliability was 0.98, the item separation index was 7.9, and the number of strata was 10.9 (Table 3). For the person, these values are 0.84, 2.3, and 3.4, respectively. The Rasch analysis can also provide information about the scale's factor structure. This analysis concluded that the knowledge test is unidimensional due to slight differences in the eigenvalues between the first and second factors.

For the final version of the VKT, the mean score is 14.5 ± 5.7, and the median is 14.0 (IQR = 7.0). The KR-21

Table 2 Rasch analysis results of the vaccine knowledge test (28 items)

Item	Item Difficulty	WMS	UMS
1. Some components found in vaccines (such as sodium and potassium salts and formaldehyde) are naturally present in small amounts in the human body.	−0.13	1.00	1.11
2. Antibiotics, proteins, stabilizers, and other substances present in vaccines do not harm the human body because they are within the safe limits recommended by the World Health Organization.	0.15	1.00	0.97
3. The measles vaccine does not cause autism.	1.09	0.97	1.00
4. Vaccines can lead to conditions such as asthma, allergies, epilepsy, and infertility.	1.52	0.90	0.93
5. The rate of severe allergies (general anaphylaxis) after vaccination is very low.	0.46	1.02	1.35
6. Combination vaccines for childhood diseases (4-in-1 or 5-in-1 vaccines) are prepared to reduce the number of injections.	0.48	0.01	1.06
7. Administering multiple vaccines at the same time weakens the immune system.	0.97	0.97	1.00
8. Vaccines are not monitored or tracked after receiving patent and licensing.	−0.54	1.01	0.95
9. Vaccines in the routine immunization schedule undergo extensive and rigorous examination processes, including cell experiments, animal experiments, and human trials.	−1.47	0.81	0.67
10. Achieving herd immunity also protects individuals who cannot be vaccinated for various reasons, such as babies and elderly individuals, and those with conditions like cancer or leukemia.	0.09	1.03	1.00
11. The protection provided by vaccines is more effective than drugs.	−0.67	1.07	1.09
12. The protection against infectious diseases provided by vaccines does not last for many years; vaccines offer short-term protection.	0.16	1.02	0.96
13. The goal of vaccination programs is to vaccinate children before the period when they are at the highest risk of infectious diseases.	−1.28	1.01	0.97
14. Even if a high percentage of the population is vaccinated, infectious diseases can still spread, and the risk of an epidemic does not decrease.	0.70	1.14	1.20
15. Some vaccines, such as varicella (chickenpox) and BCG, require booster doses to maintain protection.	0.43	1.13	1.26
16. Despite the existence of different types of vaccines (live, attenuated, inactivated), the fundamental principle of vaccines is to stimulate the immune system.	−0.99	0.91	0.80
17. Despite different types of vaccines (live, attenuated, inactivated), the fundamental principle of vaccines is to stimulate the immune system.	−1.90	0.89	0.80
18. Vaccines weaken the immune system.	−0.58	0.94	0.86
19. Maintaining proper nutrition and good overall health is more effective in preventing infectious diseases than vaccines.	0.63	0.98	0.96
20. A child with complaints like ear infections, runny nose, or undergoing antibiotic treatment can still receive vaccines	2.10	1.04	1.21
21. The hepatitis B vaccine also protects against liver cancer.	0.82	1.12	1.17
22. Since breast milk is more protective than vaccines, there is no need to vaccinate infants who are breastfed.	−0.97	0.96	0.88
23. The number of children paralyzed due to polio worldwide has almost disappeared since 1988 through vaccination programs.	0.20	0.92	0.87
24. Vaccines must be stored in a cold place between + 2 to + 8 degrees Celsius until administered to a child.	0.34	0.98	0.94
25. Delaying vaccination increases the risk of serious illness.	−0.46	1.00	0.96
26. The childhood vaccine schedule provides information about which vaccines should be administered in which month.	−1.97	0.80	0.64
27. Mumps infection can lead to severe conditions such as hearing loss, meningitis, and infertility.	−0.22	1.00	1.01
28. Diseases protected by vaccines can be treated with antibiotics.	1.04	0.95	1.19

alpha value of the test is 0.8213, and the Cronbach's alpha value is 0.84, with other reliability analyses that are very close to this value (Table 4).

Educational level, childbearing status, previous information about vaccines, and trust in vaccines were significant variables for VKT. On the other hand, income perception does not affect the knowledge test. Being informed about vaccines increases the score of the knowledge test by 3.8-point, confidence in vaccines by 3.3-point, having graduated from university by 2.7-poin, and having children by 2.0-point higher. These variables explain 29% of the variance in the VKT score (Table 5).

Discussion

One of the most pressing issues today is the rise in vaccine hesitancy and refusal, which has long been on the agenda of policymakers and healthcare professionals at the international and national levels. Despite the

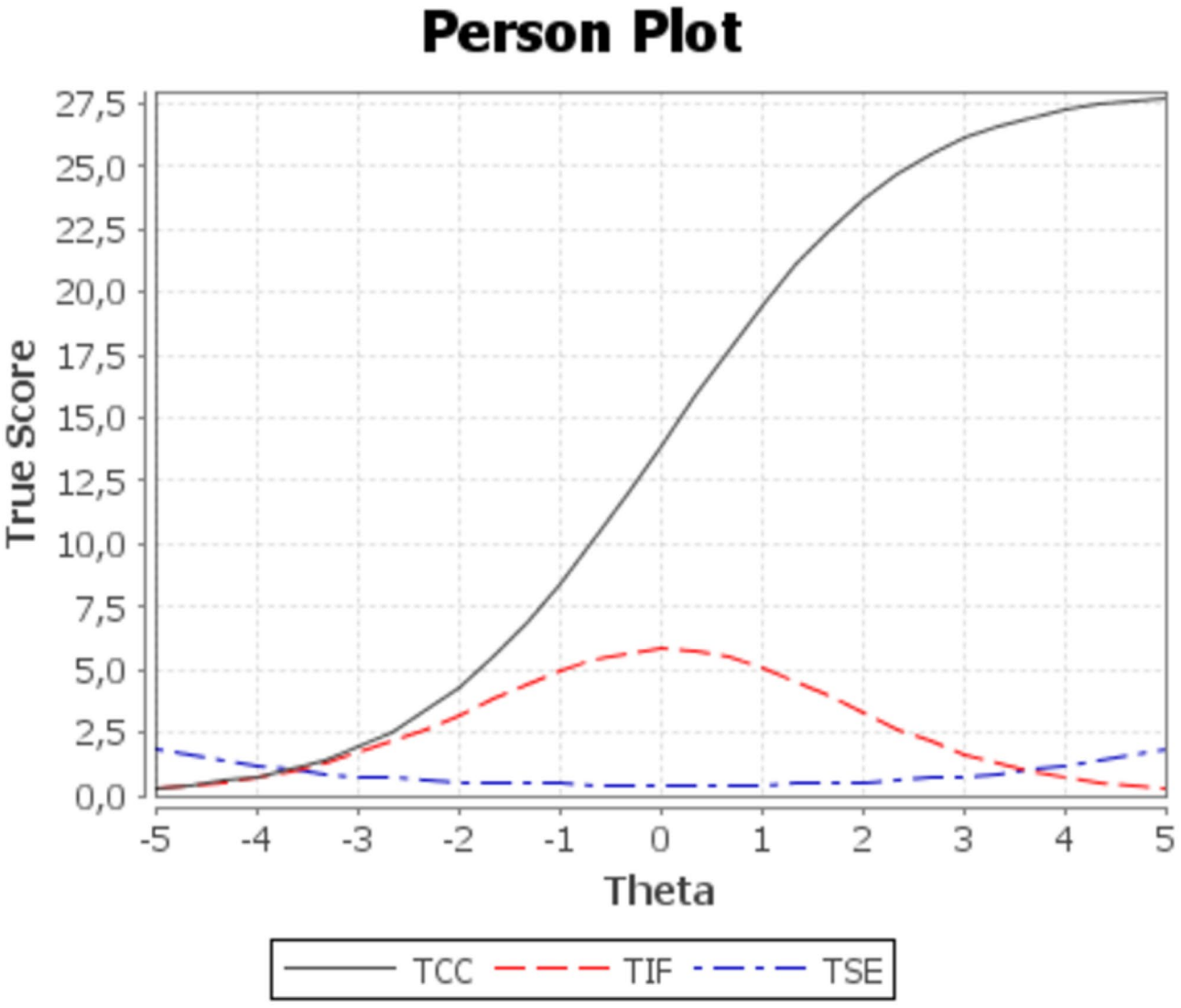

Fig. 1 Person plot for vaccine knowledge test

Table 3 Scale quality statistic for vaccine knowledge test

Statistic	Items	Persons
Separation Index	7.9461	2.2638
Number of Strata	10.9281	3.3517
Reliability	0.9844	0.8367

numerous positive health outcomes achieved through vaccines, vaccine hesitancy has emerged [2, 15]. The reasons for this and how to address vaccine hesitancy have often been discussed in various platforms and articles. Among the individual-level reasons, particular attention has been paid to the impact of psychosocial processes, demonstrating the influence of vaccine knowledge and

Table 4 Descriptive and reliability results of the vaccine knowledge test (28 items)

Method	Estimate	95% Confidence Interval	SEM
Guttman's L2	0.8517	(0.8300 –0.8718)	2.2349
Coefficient Alpha	0.8480	(0.8258–0.8686)	2.2622
Feldt-Gilmer	0.8493	(0.8273–0.8697)	2.2528
Feldt-Brennan	0.8490	(0.8270–0.8695)	2.2547
Raju's Beta	0.8480	(0.8258–0.8686)	2.2622
Mean: 14.5 ± 5.7 Median: 14.0 (IQR = 7.0)	Skewness: -0.058 Kurtosis: 0.146	KR-21: 0.8213	

Table 5 Determinants of vaccine knowledge test

	B	S.E.	Beta	t	Sig.	Tolerance	VIF
Education (1: University)	2.717	0.530	0.229	5.131	0.000	0.902	1.108
Income (1: Perception of high income)	0.346	0.630	0.025	0.549	0.583	0.894	1.119
Having a child (1: Yes)	2.025	0.610	0.145	3.321	0.001	0.941	1.063
Informed about the vaccine (1: Yes)	3.764	0.537	0.314	7.012	0.000	0.896	1.116
Trust in the vaccine (1: Yes)	3.297	0.502	0.280	6.568	0.000	0.989	1.011
	R: 0.538		R^2:0.290		F: 32.255		p: 0.001

attitudes on vaccine hesitancy. There are many scales in the literature to measure vaccine attitudes and vaccine knowledge, each with its strengths and weaknesses [9, 11, 20–22, 24–28]. However, there is a need for a structured approach that can either nurture or change attitudes by focusing on knowledge. A measurement tool that assesses vaccine knowledge may help describe and analyze vaccine behavior in detail. Therefore, this study includes the methodological evaluation of the Vaccine Knowledge Test, developed explicitly for childhood vaccines.

Creating an item pool and establishing content validity are the most important stages in knowledge testing. The literature, health professionals and service users contributed to the item pool to ensure the necessary diversity to establish the content of this study. The quality and shortcomings of the content were then checked using the specification table, expert opinion, and pilot implementation processes. During the development of the specification table, topics were reviewed on the Vaccine Knowledge Project website, which the University of Oxford established to provide an independent source of information on vaccines and infectious diseases [29]. In addition, numerous official vaccine information websites were also evaluated [30, 31]. The item pool was designed to include questions that could assess each cognitive level within the Bloom taxonomy. For this reason, the questions were adapted based on the targeted cognitive domain. Topics, objectives, and outcomes that should be included in a vaccine knowledge test were listed, and based on this list, a draft form was obtained, taking into account the cognitive levels specified in the Bloom Taxonomy (knowledge, comprehension, application, analysis, and evaluation) for each item. Bloom's Taxonomy, which categorizes learning objectives at different levels, is a guide to identifying and developing appropriate questions for cognitive levels. Bloom's Taxonomy makes a significant contribution to improving the quality of tests [37].

For the final form, the extent to which each item met the expectations was assessed by three experts in the field of assessment and evaluation. At this stage, appropriate wording adjustments were made to the items to ensure alignment with the intended cognitive domains. A content validity index (CVI) was calculated for this final form based on the expert opinions (eight experts). It is recommended that the CVI for each item should be greater than 0.80, and items with scores below this threshold should be removed from the measurement tool [38]. For this vaccine knowledge test, item 31 ('Getting childhood vaccines is a legal requirement') was removed from the item pool because it had a CVI of 0.25, below the threshold recommended in the literature. The experts gave this item a low score, reasoning that there may not be a single valid, correct answer to this item due to the different nature of legal procedures and public health practices in different countries. The remaining items had CVI values between 0.88 and 1, with an overall CVI value of 0.95 for the entire item pool. The use of numerous reference sources and ways in the construction and finalisation of the item pool, and the collection of expert opinions in a way that could assess the quality of the measurement of both the content and the cognitive abilities of the knowledge test, strengthened the measurement tool in many ways.

The validity analysis of the VKT was examined using classical test theory and item response theory. According to classical theory, considering the difficulty of the items in the VKT, items 8, 21, and 23 were difficult. When the discriminating indices were examined, it was found that two items had very weak discriminating power (8 and 23), five items had good discriminating power (14, 15, 18, 21, 22 and 28) and twenty-two items had excellent discriminating power (1, 2, 3, 4, 5, 6, 7, 9, 16, 17, 20, 24, 25, 26, 27, 29 and 30). When item difficulty values were considered along with item discriminative indices, items 8 and 23 were removed from the knowledge test. Item 21 ("A child with complaints such as ear infection, runny nose, or receiving antibiotic treatment on the day of vaccination can still receive vaccines") was a difficult item. However, it was retained in the knowledge test because it had good discriminative power and addressed a significant public health issue. Knowing individuals' responses to this item is important for healthcare professionals because the information in this item can be a reason for missed vaccination opportunities. When the average item difficulty (0.498) and item discrimination (0.447) values of the VKT are examined, it can be interpreted that the test is a moderately difficult knowledge test with very good discriminative ability.

Rasch analysis was used to assess the fit and construct validity of the items in the VKT. Rasch techniques have changed the way tests and surveys are created and used. The Rasch model was developed to overcome the limitations of classical test theory and has been updated and refined over time [39]. In Rasch analysis, item fit is examined using WMS (infit) and UMS (outfit) values. WMS and UMS values above 2.00 may distort the properties of the measurement tool and reduce its quality. Values in the range of 0.5 to 1.5 are considered efficient/appropriate for the measurement tool, while values below 0.50 are considered less efficient but do not lower the quality of the tool. In addition, the ideal range for WMS and UMS scores is often cited in the literature as being between 0.50 and 1.50 [40]. When the items in the VKT were examined, it was found that each item's WMS and UMS values fell within the range of 0.50 to 1.50. Based on these values, it can be concluded that the items in the VKT have a good fit, which means that the items are well adapted to the abilities of the individuals and that the problem of outlier responses is under control.

Furthermore, the analysis results showed a reliability coefficient of 0.83 and a separation index 2.2638. In the literature, a separation index of 2 or higher is considered acceptable [40, 41] values suggest that the VKT can reliably discriminate between individuals with different levels of knowledge or skills (low and high). In addition, the person plot (Fig. 1) shows that knowledge can be obtained from a wide range of ability levels using this knowledge test. Considering all this information, the items in the VKT are a good fit. The VKT consists of a single dimension and can effectively differentiate individuals with different levels of vaccine knowledge. To assess the internal consistency of the VKT, various reliability coefficients were obtained, including Kuder-Richardson (20 and 21), Guttman's L2, Coefficient Alpha, Feldt-Gilmer, Feldt-Brennan, and Raju's Beta. The internal consistency was found to be 85% for all these analyses. An internal consistency value above 0.80 can be interpreted as an additional indicator that the measurement tool has high-reliability characteristics [42].

Knowledge can be acquired in various ways, such as education, observation, or experience. Therefore, it is expected that the results of a knowledge test would differ based on these variables. When the determinants of VKT were examined, it was found that variables such as having received information about vaccines, believing that vaccines are safe, having a university education, and having children were significant determinants of vaccine knowledge. This is consistent with existing literature suggesting that higher levels of education [10, 43], having five or more children [44], having received vaccine education [43] and higher vaccine literacy [45] have a positive effect on vaccine knowledge. The multiple regression analysis also showed that the VKT can effectively assess different levels of knowledge based on individual characteristics.

Limitations

The VKT is essential to the literature because it is a structured scale of vaccine knowledge that has undergone validity and reliability testing. However, limitations of this study include the lack of another valid and reliable measure of vaccine knowledge, making it difficult to compare results with a similar scale. The use of convenience sampling in research can be seen as a limitation. Since the ability to distinguish participants according to the level of knowledge expected from a knowledge test was evaluated in this study, participants were also included among healthcare professionals who did not have children during the vaccination period or who had better knowledge about vaccination than the general public. The effect of these groups was evaluated with multiple regression analysis in the study. It was clearly shown how much change in the knowledge test was caused by having knowledge about vaccination and having children. We would like to bring this situation to the attention of researchers and healthcare professionals in the use of the knowledge test. Another limitation is the need to assess the validity and reliability of the VKT in different geographical regions and languages. Nevertheless, international practices and literature have been considered in developing the VKT, and the questions are of universal relevance.

Implications for health policy, research, and practice

The knowledge test developed reflects universal vaccine knowledge in the items it contains. This test has psychometric results that make it possible to categorise individuals according to their need for knowledge about vaccination. Researchers and health professionals can easily administer this knowledge test. It will assist researchers in assessing vaccine knowledge, investigating the relationship between vaccine knowledge and vaccine confidence, evaluating the effectiveness of vaccine education interventions, and various other interventions related to vaccine knowledge and attitudes. Nurses, midwives and pharmacists can use this test to help guide and evaluate vaccine education and training.

Conclusion

The psychometric evaluation results indicate that the VKT is a valid and reliable measurement tool with ideal properties in measurement capability.

Abbreviations

VKT	Vaccine Knowledge Test
WHO	World Health Organization
CVI	Content Validity Index
KR	Kuder Richardson

Supplementary Information

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Supplementary Material 1.

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Declaration of AI and AI-Assisted Technologies in the Writing Process
During the preparation of this work, the authors used Grammarly in order to improve language and readability. We declared that no producer contribution was received.

Authors' contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Deniz S. YORULMAZ DEMIR and Deniz KOCOGLU-TANYER. The first draft of the manuscript was written by Deniz S. YORULMAZ DEMIR and Deniz KOCOGLU-TANYER. Supervision and consultancy was carried out by Deniz KOCOGLU-TANYER. All authors read and approved the final manuscript.

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Data availability
Data that support the findings of this article are available from the relevant author (D-KT) upon reasonable request.

Declarations

Ethics approval and consent to participate
Prior to the research, ethical committee approval (Approval Committee: Republıc of Turkey, Artvin Çoruh Unıversıty Rectorate, Scientific Research and Publication Ethics Committee, number: E-18457941-050.99-68849, date: 01.11.2022) and institutional approval (Artvin Provincial Health Directorate, number: E-17720518-514.03.02-207936246, date: 25.01.2023) were obtained. Participants were informed about the research topic during the study, and their consent was obtained. All participants were 18 years of age or older; informed consent was obtained without any potential for coercion. This research was conducted by the tenets of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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