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RESEARCH ARTICLE

Testing and validation of the questionnaire for evaluating the chemical composition of bottled water in relation to public health

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ABSTRACT

Introduction. In the context of increasing global consumption of bottled water, assessing its chemical composition and impact on public health becomes essential. Although perceived as a safe alternative, bottled water exhibits variability in its chemical composition, and advanced filtration methods can remove essential minerals. Consumers opt for bottled water due to its taste and convenience, yet awareness of associated risks remains limited. This study proposes the development and validation of a questionnaire to evaluate public perceptions of bottled water quality and its health impact, providing a valuable tool for public education and regulatory policies.

Material and methods. The questionnaire was developed to analyze consumer attitudes and behaviors regarding bottled water. Structured into four sections (socio-demographic data, consumption habits, perceptions of quality, and health impact), it underwent multiple validation stages. A panel of experts assessed the relevance of the questions, and a pilot study was conducted with a sample of 32 adults (aged 24-62) to evaluate validity and internal consistency using the Cronbach's alpha coefficient. Final validation was based on the feedback collected and statistical analysis performed using SPSS Statistics 27.

Results. S-CVI/Ave and S-CVI/UA are indicators of questionnaire content validity, calculated based on item validity scores and the percentage of agreement among evaluators. The S-CVI/Ave and S-CVI/UA values exceeded the minimum standard of 0.80, while the I-CVI index ranged between 0.83 and 1.00, demonstrating excellent item validity. Following respondent feedback, 18 questions were revised, and 6 were removed, resulting in a second version with 61 items. The validity sample comprised 84.4% women and 15.6% men, aged 24 to 62 years. Most respondents considered the questions clear and easy to understand, although suggestions were made to improve clarity and avoid redundancy. Internal consistency was confirmed through the Cronbach's alpha coefficient, which was acceptable for most domains, except one, where the coefficient was below 0.70 but was retained due to the validity of the questions.

Conclusions. The questionnaire for assessing bottled water consumption was successfully validated, demonstrating content validity and internal consistency. Face validity ensured the clarity of the questions.

Keywords: bottled water, water mineralization, questionnaire, validation, pre-testing.

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Key messages

What is not yet known on the issue addressed in the submitted manuscript

The impact of the chemical composition of bottled water, particularly its mineralization indices, on public health remains insufficiently explored. Moreover, there is no validated tool designed to assess this relationship comprehensively.

The research hypothesis

The questionnaire developed to evaluate the population's perception

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of bottled water quality, particularly its chemical composition, is a valid and reliable tool for collecting relevant data to analyze the relationship between consumer perceptions and public health impact.

The novelty added by manuscript to the already published scientific literature

The study presents the development and validation of a novel questionnaire for assessing the chemical composition of bottled water and its potential health impacts, marking a significant contribution to scientific literature. This tool is particularly innovative for the Republic of Moldova, as it represents the first standardized method tailored to evaluate the relationship between water quality and public health in the region.

Introduction

In the context of growing concerns about the impact of bottled water on public health, assessing its chemical composition has become essential to ensuring safe consumption. Bottled water is often perceived as a safer alternative to tap water; however, the variability in its chemical composition, including the presence of potentially hazardous substances, can affect the long-term health of the population [1]. Although numerous studies have focused on the physicochemical analysis of bottled water, tools for evaluating consumer perceptions and raising awareness about the associated risks remain limited.

The increasing consumption of bottled water can be attributed to greater public awareness of its perceived health benefits. This trend initially emerged in Western Europe, followed by the United States and Asian countries. Global bottled water consumption reached 329.33 billion liters in 2015 [2]. The technological process of bottled water production includes reverse osmosis, nanofiltration, or ultrafiltration, wherein water passes through membranes measuring 0.0001, 0.001, and 0.01 μm, respectively, before being packaged. However, these filtration methods often remove essential minerals along with impurities. The World Health Organization has emphasized that consumers primarily choose bottled water for its taste and convenience, but safety and potential health benefits should be fundamental priorities [3]. As bottled water becomes increasingly popular, the Codex Alimentarius Commission of the WHO (2011) established an international framework for regulating bottled water.

Recent studies have shown that in blind taste tests, consumers were unable to distinguish between tap water and bottled water. Nevertheless, more consumers choose bottled water over tap water [4]. Despite adverse reports regarding bottled water, much of the research focuses on exceeding limits rather than evaluating baseline thresholds. Establishing ideal global limits based solely on human health could lead to overestimation or underestimation, given regional variations in daily water consumption [5].

The aim of this study is to develop, test, and validate a questionnaire to assess the population's perception of bottled water quality, particularly regarding its chemical composition, and to establish the interrelationship between these perceptions and public health. The validation of the questionnaire will not only provide an effective data collection tool but also offer valuable insights into public education and regulatory policies for bottled water.

Material and methods

Stage 1. Development and design of the questionnaire and questionnaire validation

The questionnaire titled "Assessment of the chemical composition of bottled water and its impact on population health" was designed to be comprehensive, explicit, simple, and easy to understand.

The development process involved creating a detailed research tool capable of thoroughly investigating the attitudes, behaviors, and perceptions of the population regarding the consumption of bottled still water. The goal was to produce a well-structured material, organized into distinct sections, each targeting an essential aspect of the subject: from preferences and purchasing habits to perceptions of quality and health impacts.

The development process began with defining objectives, focusing on addressing key questions about bottled water consumption. These included identifying the factors influencing purchasing decisions, assessing consumers' awareness of the chemical composition and quality of bottled water, examining perceptions of product safety and sustainability, and evaluating the health impacts of consumption.

The questionnaire was structured with a clear organization, comprising four major components. The first part is dedicated to gathering general information about respondents, including socio-demographic characteristics. The second part examines consumption habits and brand preferences, as well as points of purchase. The third section explores perceptions of bottled water quality, trust in producers, and perceived risks. The final section addresses the connection between still water consumption and health, focusing on reported positive and negative influences as well as medical recommendations.

Specifically, a series of socio-demographic questions targeted biological gender, age, place of residence, profession, education level, family size, and average household income.

These questions focused on drinking water consumption and health conditions that might affect hydration and overall health, aiming to evaluate the respondent's profile. Detailed habits regarding the consumption of drinking water or beverages were recorded, requesting quantitative information about the volume in liters or the number of bottles consumed daily.

The questionnaire items were designed to allow the collection of both quantitative and qualitative data. The first version of the questionnaire was based on expert opinions and a bibliographic review focused on similar previously developed questionnaires. To minimize measurement errors, the questions were short, closed-ended, and crafted to be concise and easy to understand. Additionally, predefined response options were provided, drawing on previous studies and consultations with domain experts, offering detailed choices to better clarify the questionnaire's purpose.

To ensure the validity and relevance of the instrument, the questionnaire was tested on a sample of 32 respondents, allowing the identification and correction of any ambiguities or redundancies.

In July-August 2024, 32 adult individuals (5 men and 27 women) recruited from the general population of the Republic of Moldova, aged between 24 and 62 years, participated in the study. The questionnaire was applied online via the Google Forms platform, and the link was distributed through open social networks. The participants were informed about the study objectives and provided their consent to participate. The collected data were kept confidential, and the study was approved by the Research Ethics Committee of the *Nicolae Testemițanu* State University of Medicine and Pharmacy, approval number 1, dated 09.10.2023.

Stage 2. Content validity

This phase aimed to ensure that the set of items accurately measures the expected construct of interest. Content validity assesses how well the items of a questionnaire reflect the concept or domain it aims to evaluate. It is a qualitative measure based on expert judgment. An independent panel of 4 experts participated in this initial stage, including 2 hygiene physicians, a specialist in social medicine and biostatistics, and a sociologist. Each expert received a copy of the first version of the questionnaire via email and was asked to assess the relevance and clarity of the items using two 4-point Likert scales. Content validity is a current and widely used method for assessing the quality of a questionnaire, especially in the early stages of development [6-8].

A content validity index (CVI) was calculated for each domain:

- S-CVI/Ave – scale level, using the average method; acceptable limit >0.80 [8].
- S-CVI/UA – scale level, using the universal agreement method; acceptable limit >0.80 [9].

Additionally, a CVI was calculated for each individual item (I-CVI; acceptable limit >0.83), along with the modified kappa concordance index (κ*):

- 0.75-1.00 – excellent
- 0.60-0.74 – good
- 0.40-0.59 – acceptable
- <0.40 – poor
- acceptable limit >0.60 [7, 10].

The experts were also given the opportunity to provide additional comments and suggestions for each item of the questionnaire. Following this stage, the second version of the questionnaire was developed. Researchers in the Republic of Moldova have extensive experience and have validated questionnaires both at the national level and through the evaluation of study feasibility and the Cronbach's alpha coefficient.

Stage 3. Apparent validity and internal consistency

A quantitative and qualitative study was conducted to analyze the items, aiming to assess their suitability for inclusion in the questionnaire through face validity and internal consistency. The questionnaire, distributed online, was completed by 32 adults, constituting a convenience sample with a wide age range and diverse preferences and practices regarding bottled water consumption.

Data were collected in July-August 2024. Participants completed the second version of the questionnaire and were provided with an open space to offer additional feedback regarding ease of completion, clarity, and suggestions for improvement. For face validity, frequencies were calculated, and open-ended narrative responses regarding opinions and/or instrument improvements were analyzed [11]. Internal consistency was determined using Cronbach's alpha coefficient for each dimension (acceptable limit >0.70) [12]. As a result of this stage, the third version of the questionnaire was developed.

Statistical analysis

The results were presented in terms of central tendency values, relative values, and absolute data. Additionally, Cronbach's alpha coefficient was used to determine internal consistency. Statistical analyses were performed using SPSS Statistics 27 (SPSS, Inc., Chicago, IL, USA).

Results

Stage 1. Development of the questionnaire and questionnaire validation

The first version of the questionnaire included 67 questions, structured into four parts: "General information", "Information about bottled drinking water consumption", "Public perception of bottled still water quality", and "Bottled still water and health". The main areas of interest were: "Information about bottled drinking water consumption", "Public perception of bottled still water quality", and "Bottled still water and health". The questions in the first domain had pre-established, clear, and concise response options. The questions in the second domain also had pre-established answers, with a minimum of 2 response options and a maximum of 20. For some questions (7 in total), multiple responses were allowed. The third domain of the questionnaire included questions with response options ranging from 2 to 15. Two questions allowed multiple responses. The maximum number of responses in the fourth section

was 7, with no multiple-response questions. Respondents were asked to freely express their opinions and knowledge regarding their perceptions of bottled still water, its consumption, water quality, and its impact on health.

Stage 2. Content validity

S-CVI/Ave represents the content validity index at the scale level, calculated as the average of the validity scores for all items, while S-CVI/UA indicates the percentage of items that received complete agreement between evaluators. S-CVI demonstrates content validity in terms of both relevance and clarity (Table 1). S-CVI/Ave ranged from 0.84 to 0.90 for the domains, exceeding the minimum standard of 0.80. S-CVI/UA ranged from 0.82 to 0.89 for the domains, surpassing the minimum standard of 0.80 for relevance and clarity in all domains.

The I-CVI values (Table 2) for the relevance criterion ranged from 0.83 to 1.00, and the κ* indices fell within the "excellent" category (κ* 0.75–1.00). Regarding clarity, the I-CVI values ranged from 0.83 to 1.00, and the κ* indices also fell within the "excellent" category (κ* 0.75–1.00).

Based on the evaluations and comments, modifications were made to 18 questions, including the removal of 6 questions. As a result, the second version of the questionnaire included 61 items.

Table 1. S-CVI/AVE and S-CVI/UA for the three domains of interest in the questionnaire

Domains of the questionnaire	S-CVI/Ave		S-CVI/UA	
	Relevance	Clarity	Relevance	Clarity
Information about bottled drinking water consumption	0.88	0.86	0.84	0.86
Public perception of bottled still water quality	0.86	0.84	0.82	0.82
Bottled still water and health	0.90	0.88	0.89	0.87

Note:
S-CVI/Ave – scale level, using the average method; acceptable limit >0.80;
S-CVI/UA – scale level, using the universal agreement method; acceptable limit >0.80.

Table 2. I-CVI and Kappa* for relevance and clarity of the questionnaire domains

Domains of the questionnaire	I-CVI [a] Relevance				K* for Relevance [b]				I-CVI [a] Clarity				K* for Clarity [b]			
	1.00	0.83	0.67	0.5	Excellent	Good	Acceptable	Poor	1.00	0.83	0.67	0.5	Excellent	Good	Acceptable	Poor
Information about bottled drinking water consumption	85.5	14.5	0	0	100	0	0	0	86.0	14.0	0	0	100	0	0	0
Public perception of bottled still water quality	84.3	15.7	0	0	100	0	0	0	83.2	16.8	0	0	100	0	0	0
Bottled still water and health	89.9	10.1	0	0	100	0	0	0	87.5	12.5	0	0	100	0	0	0

Note:
κ* represents the modified kappa concordance index;
[a] I-CVI indicates the content validity index at the item level;
[b] κ* 0,75-1,00: excellent, κ* 0,60-0,74: good, κ* 0,40-0,59: acceptable, and κ* <0,40: poor

Stage 3. Face validity and internal consistency

The structure of respondents who participated in the face validity phase was 84.4% women and 15.6% men, with ages ranging from 24 to 62 years (40.03±11.74). Of them, 84% were from urban areas, and 16% were from rural areas. Additionally, 96.9% had higher education, and 3.1% had specialized secondary education.

The questionnaire included three open-ended questions, to which respondents provided qualitative answers (Table 3).

Respondents were asked an open-ended question regarding the clarity and understanding of the questions in the questionnaire. Most respondents considered the questions clear and easy to understand, expressing themselves with phrases such as "Everything was clear", "All were clear", or "There are none", indicating the absence of significant issues related to content comprehension. Some participants noted that the questionnaire was lengthy, highlighting the risk that respondents might become bored and abandon it. Additionally, a few responses pointed out specific questions that were perceived as unclear or difficult to understand, such as questions 6, 10, 23, 36, 45, and 51. Furthermore, some responses highlighted the redundancy of certain questions, with one observation noting that some questions seemed to have the same meaning, while another remark pointed to a sequencing issue between questions 50 and 51, suggesting the need for conditional display logic.

Table 3. Results of the responses (n=32) to the three open-ended questions in the questionnaire during the apparent validity phase

	n (%)		
	Yes	Non	Excluded from analysis
1. Please indicate the question numbers of any unclear or difficult-to-understand questions in this questionnaire.	23 (71.9%)	5 (15.6%)	4 (12.5%)
2. Please indicate the question numbers of the clear questions.	24 (75.0%)	4 (12.5%)	4 (12.5%)
3. Please suggest ways to improve the unclear/difficult-to-understand questions in this questionnaire.	23 (71.9%)	5 (15.6%)	4 (12.5%)

Note: n (%) - relative values, and absolute data.

The analysis of responses regarding the questions considered clear in the questionnaire highlighted that most respondents found all the questions clear, using phrases such as "All," "Everything was clear," or "All are clear." One participant noted that some questions practically repeat, especially those referring to changes in health status after starting to consume bottled water. Additionally, question 57 was flagged as redundant in relation to question 60. One participant suggested adding filters to the questionnaire to tailor the questions to specific situations, stating: "Most are clear, but there should be some filters. For example, I consume 5 liters of water over 1.5-2 months...". Some respondents identified specific questions as clear, such as questions 35, 2, and 1, or provided general answers like "Basically all."

From the responses provided by the participants regarding ways to improve unclear or difficult-to-understand questions in the questionnaire, most considered the questions to be clear, offering answers such as "There are none", "They are quite clear", or "Everything is clear", suggesting that the questionnaire is, by and large, well-designed and accessible. However, some respondents provided valuable suggestions for improvements. A frequent observation was related to the repetitiveness of certain questions, such as those concerning changes in health status or questions about organoleptic qualities. For example, one participant mentioned that it was unclear whether the questions referred separately to characteristics such as transparency and taste or to all of them simultaneously. This issue was addressed by clarifying the wording and avoiding redundancy. Additionally, some responses emphasized the need for further explanations for technical or less familiar terms, so that the respondents could better understand the content of the questions. Furthermore, the introduction of filters or conditional logic in the questionnaire was recommended to adapt the questions to the specific situations of the participants, making the questionnaire more personalized and effective. Some participants also suggested adding the option "I don't know/I'm not sure" for all questions, which would allow for the collection of more authentic and less forced responses.

Some of the responses were ambiguous or incomplete, using expressions such as "I don't know", "I couldn't notify", or "-", which indicates either a lack of clear observations or difficulties in understanding the open-ended question posed. These responses were excluded from the analysis.

Internal consistency was demonstrated through the Cronbach's alpha coefficient parameters (Table 4). The Cronbach's alpha coefficient for the entire questionnaire was 0.717 (excluding the nine questions in the "general information" section), and for two domains, the coefficients were also higher than the minimum acceptable value of 0.70 (ranging between 0.702 and 0.815), with the exception of the "Information about bottled drinking water consumption" domain (Cronbach's alpha coefficient = 0.634). We decided to retain this domain because the questions related to it reflect subsequent domains, based on literature data and expert experience. Therefore, no changes were made to the questionnaire.

Table 4. Cronbach's alpha coefficient for each domain and for the entire questionnaire (internal consistency)

Domains of the questionnaire	Cronbach's alpha	
	value	n
Information about bottled drinking water consumption	0.634	21
Public perception of bottled still water quality	0.815	12
Bottled still water and health	0.702	19
The questionnaire in its entirety with all domains	0.717	52

Note: Cronbach's alpha (α) measures the internal consistency of a test, reflecting how well items in a set are related. Values above 0.70 are typically acceptable, while those over 0.90 suggest excellent reliability. Named after psychologist Lee Cronbach, it is widely used to assess test reliability.

Discussions

This study developed a questionnaire to assess the chemical composition of bottled drinking water in relation to public health. The questionnaire was developed through a detailed process that included stages of validity evaluation and content adjustment. Its validation was carried out using the S-CVI and I-CVI validity indices, which demonstrated excellent agreement regarding the relevance and clarity of the questions. Additionally, internal consistency was confirmed through Cronbach's alpha coefficient, with values exceeding the acceptable threshold for most of the domains investigated. Subsequent revisions allowed for the elimination of redundant questions and the improvement of item formulations, ensuring the relevance and accessibility of key topics: bottled drinking water consumption, perceptions of its quality, and health effects.

In particular, the most important result of the study was the creation of a questionnaire that can be used to assess public perception regarding the consumption of bottled drinking water, as well as its potential benefits and risks.

Our study highlights several key findings regarding the development and validation of the questionnaire used to evaluate perceptions and consumption of bottled drinking water. Its structure, the relevance of the questions, their clarity, as well as data on apparent validity and internal consistency, indicate the effectiveness of the research tool employed.

The questionnaire, structured into four domains–three of which are thematic and essential–was adapted based on suggestions provided by respondents and experts. The modifications resulted in a reduction in the number of questions from 67 to 61, while maintaining the relevance of the data collected. This process reflects best practices found in the literature, which emphasize the need for flexible and adaptable tools [13, 14].

The S-CVI/Ave and S-CVI/UA indicators, which exceeded the minimum standard of 0.80 for the three thematic domains of importance, confirm the quality of the questions in terms of both clarity and relevance. These results align with methodologies presented by other researchers, who have emphasized the importance of quantitative assessment of content validity [15]. Additionally, the I-CVI index and the modified kappa coefficient indicate excellent

agreement among evaluators, supporting the robustness of this process.

The respondent profile, predominantly consisting of individuals with higher education and from urban areas, ensured the gathering of diverse perspectives on the investigated topic. Their feedback revealed that the questions were generally well-formulated, although a few aspects were identified that required adjustments. The observations provided facilitated the optimization of the questionnaire, similar to the results presented in other significant studies [16, 17].

The Cronbach's alpha coefficient, with values above the minimum threshold of 0.70 for most domains, confirms the internal consistency of the questionnaire [18, 19]. The exception observed in one domain (0.634) did not, however, affect its use due to its importance within the overall framework of the study. This aspect is supported by similar analyses in the literature [20-22].

Among the identified limitations is the possibility that responses may be influenced by participants' subjectivity and the complexity of the questionnaire. To avoid situations that could jeopardize the survey process and data collection, the developed tool will be applied in a more diversified setting, including respondents from rural areas, for a more extensive validation.

Conclusions

The developed questionnaire for assessing bottled water consumption and public perception has proven to be a valid and effective tool. Content validity and internal consistency were confirmed, and the face validity process ensured the clarity of the questions.

Competing interests

None declared.

Authors' contributions

All authors contributed equally to the drafting and writing of the manuscript. The authors read and approved the final version of the manuscript.

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Ethics approval

The study protocol was approved by the Research Ethics Committee of *Nicolae Testemițanu* State University of Medicine and Pharmacy (Protocol No. 01 of 09.10.2023).

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