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ORIGINAL RESEARCH

Physicians' Understanding of the Role of the Microbiome in Allergies and Asthma: A Questionnaire-Based Study in Saudi Arabia

Suzan AlKhater[1,2]

[1]College of Medicine, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia; [2]Department of Pediatrics, King Fahd Hospital of the University, Al-Khobar, Saudi Arabia

Correspondence: Suzan AlKhater, Department of Pediatrics, King Fahd Hospital of the University, P.O. Box 2208, Al-Khobar, 31952, Saudi Arabia, Tel +966 8966666 # 1812, Email Saalkhater@iau.edu.sa

Purpose: Allergies and asthma are two noncommunicable illnesses of increasing public health concern in Saudi Arabia. Nevertheless, little is known about knowledge of the microbiome and its relationship to asthma and allergy risks among healthcare professionals, such as pediatricians and family medicine practitioners, who are often involved in the care of patients suffering from these illnesses. Therefore, this study aimed to examine knowledge about microbiome science in these healthcare workers in the eastern region of the kingdom, where allergies and asthma are highly prevalent.

Patients and Methods: The study survey consisted of 37 online questions in three topical domains, including microbiome science, dysbiosis, and probiotics, and was distributed to 203 participants in various demographic groups.

Results: The survey analysis revealed that the mean knowledge score was 67.6%. The component scores were highest for the microbiome (75.6%) and lowest for dysbiosis (52.6%). Only 17.7% of the healthcare workers were prescribing probiotic food or drinks for most of their patients with allergies and/or asthma; and 37.8% of the healthcare workers were unaware of the reasons for prescribing pro-/prebiotics. Regression analysis revealed that older age (>45 years old), probiotic prescription experience, and positive beliefs about the importance of nutritional advice were independent predictors of higher microbiome knowledge.

Conclusion: The analysis not only revealed existing gaps in microbiome knowledge among the participants, including those related to the role of the microbiome in allergy and asthma development but also identified predictors of higher microbiome knowledge. These observations provide an impetus for the rational design of continuing medical education curriculum and training to update healthcare professionals with emerging clinical application of microbiome knowledge for the management of microbiome-related illnesses.

Keywords: knowledge, survey, health professionals, allergy, asthma, probiotics

Plain Language Summary

Recent studies have demonstrated the role of the microbiome in the shaping of immune responses that confer protection against allergic diseases. However, little is known about microbiome knowledge and its relation to asthma and allergy risks among healthcare professionals. In this study, we examined microbiome knowledge among pediatricians and family medicine practitioners, in the eastern regions of the Kingdom of Saudi Arabia. Physicians' knowledge was tested in three topical domains, namely, microbiome science, dysbiosis (the imbalance between the microbiota and the loss of microbial diversity in the human body), and probiotics. The results revealed lack in the current knowledge, perceptions and clinical practices in the three areas of microbiome science that are highly relevant to the pathogenesis of allergies and asthma. The findings can be a guide in designing future training programs for the clinical use and application of microbiome knowledge in the management of allergic disorders and asthma.

Introduction

Allergies and asthma are noninfectious disorders that affect more than 250 million people worldwide.[1] Traditionally considered conditions of dysregulated type II inflammatory responses, immunological illnesses might be preventable by

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early-life exposure to environmental stimuli, during which the immune system is trained not to induce allergic reactions.[2,3] In congruence with this long-standing "hygiene hypothesis", recent studies have demonstrated the role of the microbiome, defined as the collection of all microorganisms existing in the different mucosal surfaces of the body, in the shaping of immune responses that confer protection against allergic diseases.[4–7] In this regard, exposure of infants to microbes in breast milk and the maternal reproductive and digestive tracts is instrumental in the early development of their microbiome.[8,9] Loss of these early-life microbial contacts, often caused by antibiotic misuse or cesarean section birth, can trigger an imbalance between the microbiota and a loss of microbial diversity, known as dysbiosis, and immunological aberrations that predispose children to allergies and asthma.[5,10,11] Conversely, restoring this microbial imbalance via therapeutic applications of probiotics, which are nutritional supplements containing health-promoting microbes, has yielded promising results in the management of allergy and asthma symptoms.[12] These promising scientific observations together with clinical evidence may reveal a previously unexplored role of the microbiome in immune-mediated diseases.[13] Importantly, although there is no precise protocol available yet to follow for prescribing probiotics, the encouraging results for their efficacy in treating certain clinical conditions, and allergic disorders in particular, highlight the urgent need to update healthcare providers with training on these rapidly evolving medical topics to improve patient care.

Few studies in the medical literature have assessed healthcare providers' knowledge about microbiome science and its clinical relevance in allergies and asthma. Among these works, probiotic knowledge and practices was most frequently examined, given its direct implication in nutrition in patients with various illnesses for which microbiome restoration has been proven beneficial. Knowledge about probiotics among healthcare providers varies among different regions of the world. For example, two studies from North America revealed that nutritionists, clinicians, and pharmacists had sufficient knowledge about probiotics and their therapeutic utility.[14,15] In contrast, South Asia and the Middle East surveys demonstrated less probiotic knowledge among healthcare workers.[16,17] Furthermore, different healthcare professions appeared to have different levels of knowledge about probiotics. In some studies, pediatricians demonstrated greater knowledge about probiotics than family medicine practitioners.[18,19] However, others showed that mixed knowledge levels existed between these two specialties for various domains within the topic of probiotics.[20] In addition to knowledge about probiotics, knowledge about dysbiosis among physicians has also been examined in some studies in North America and the Middle East; these studies revealed that the majority of the participants had an inadequate understanding of the role of dysbiosis in the development of immune-mediated diseases.[21,22] Notably, only two studies examined healthcare providers' knowledge about the potential therapeutic utility of probiotics in the context of allergic disease development, along with other topics in microbiome science.[19,23] These two surveys, including more than 1000 participants each, demonstrated that most healthcare providers had an adequate understanding of the positive impact of probiotics on allergies. Altogether, these knowledge assessments suggest that while healthcare providers worldwide are aware of the emerging role of the microbiome in health and diseases, their knowledge levels vary among different geographical locations, medical specialties, and different topical domains of microbiome science.

In Saudi Arabia, asthma and allergies have increased in prevalence in recent years.[24,25] Notably, studies in the past three decades reported that approximately 8–25% of children in Saudi Arabia suffered from these conditions, with the highest frequencies in the eastern regions of the kingdom.[26,27] In light of these data and the emerging importance of the microbiome in the pathogenesis of allergies and asthma, it is necessary to ensure that clinicians in the kingdom are updated on the latest advances in these fields.[28] However, no studies thus far have attempted to comprehensively evaluate microbiome knowledge and its clinical applications in healthcare providers, such as pediatricians and family medicine practitioners, who frequently take care of patients, particularly children, with allergies and asthma. Only one study has assessed some aspects of the general microbiome knowledge of healthcare workers in all regions in Saudi Arabia and revealed that most pediatricians have insufficient knowledge about probiotics.[16] Therefore, the current study aimed to evaluate knowledge about microbiome science, with a focus on allergies and asthma. The study was conducted in a cohort of healthcare providers from two specialties, pediatrics and family medicine, in the eastern region of Saudi Arabia.

Materials and Methods

Study Design

This study aimed to evaluate the knowledge and perception of the microbiome, dysbiosis, and the use of probiotic products among pediatricians and family medicine practitioners who are frequently involved in the management of childhood allergies and asthma in hospitals, communities, or primary care settings. Between July and September 2021, an English-based survey was distributed online to faculty members of the College of Medicine at Imam Abdulrahman Bin Faisal University and the major referring hospitals in the region. The survey was distributed via email and social media using snowball sampling, with WhatsApp as the primary platform for communication, and the primary participants were allowed to forward the link to the questionnaire to colleagues in the same professional area (pediatric allergies and asthma) in the region and thereby recruit additional participants. A total of 203 participants were enrolled during this period. All subjects received an explanation about the study's objective and were informed about the anonymous and voluntary nature of the survey. The participants were also informed that submission of their answers was considered informed consent for their participation. Ethical approval was obtained from the Ethics Committee at Imam Abdulrahman Bin Faisal University (study number: IRB-2021-01-243).

Survey Development

The authors developed an online survey consisting of 37 questions based on current literature on microbiome science and a previous study on this topic.[23] The survey took five minutes on average to complete and was based predominantly on multiple-choice questions with an open field to clarify an answer if needed. The first section included demographic questions, while sections 2–5 focused on the participants' knowledge about the microbiome, dysbiosis prevention/management, and probiotics. In each section, the respondents were asked about definitions of and facts about the microbiome, dysbiosis, and probiotics, and the answers were categorized as correct or incorrect. A list of the knowledge questions on microbiome, dysbiosis, and probiotics and their correct answers are shown in Supplementary Table 1. At the end of the last section, the respondents were asked about their main sources of information for microbiome science and if they would like to develop more extensive knowledge on this topic.

Survey Validation

The initial content of the survey was validated with the content validity index (CVI), as per previously published guidelines,[29] by a team of 5 subject matter experts, each of whom had more than 35 years of experience in microbiome science. In brief, experts in the field of asthma, allergies and clinical immunology were asked to rate the items in terms of their relevance to the topics of interest (the microbiome, dysbiosis, and the application of probiotic products) using a 4-point ordinal scale (1: not relevant, 4: highly relevant). The CVI was calculated at both the scale (S-CVI) and item (I-CVI) levels. The I-CVI (ranging from 0 to 1) represented the proportion of experts who agreed on the relevance of each item, while the S-CVI was defined as "the proportion of items on an instrument that achieved a rating of 3 or 4 by the experts". To calculate the I-CVI, the number of those who considered the item relevant (rating of 3 or 4) was divided by the number of experts. The items with I-CVIs above 0.79 were considered appropriate. On the other hand, items with I-CVIs of 0.70–0.79 required revisions, and those with I-CVIs below 0.70 were eliminated. Subsequently, the survey was modified according to the experts' recommendations. To calculate the S-CVI, items with scores of 3 and 4 (relevant) and 2 and 1 (not relevant) were combined. In the universal agreement approach (S-CVI/UA), the number of items considered relevant by all experts or with a CVI equal to 1 was divided by the total number of items. In the average approach (S-CVI/Ave), the sum of the I-CVIs was divided by the total number of items. All CVIs in this study were equal to 1, indicating that the survey content achieved a satisfactory level of content validity.

Data Collection and Statistical Analysis

Categorical variables are presented as frequencies and percentages, while continuous variables are presented as means and standard deviations (SDs). The responses to knowledge questions were coded as one point for a correct answer and zero points for an incorrect or "do not know" answer. The knowledge score was calculated as the sum of responses to 27

questions related to a specific topic (the microbiome, dysbiosis, and probiotics). The score was then converted into a 100-point scale for ease of interpretation and categorized into two groups by knowledge scores: > the median score of 70.4% (high-knowledge group) and ≤ the median score of 70.4% (low-knowledge group). Demographic and professional characteristics and related experience were compared between the two groups. The chi-squared test or Fisher's exact test, as appropriate, was used to compare categorical variables. *t*-tests were used to compare continuous variables. All P values were two-tailed. A p value <0.05 was considered significant. Statistical Package for the Social Sciences software (SPSS Version 27.0. Armonk, NY: IBM Corp) was utilized for statistical analysis.

Results

Participants' Demographic and Professional Characteristics

Table 1 shows the demographic and professional characteristics and related experience stratified by overall knowledge level. The mean age was 41.1±10.7 years, with 31.5% of the healthcare workers aged less than 35 years. Approximately 61.6% of the healthcare workers were female. Slightly more than half (53.2%) of the healthcare workers were pediatricians, while the rest (46.8%) were family medicine physicians. The majority of healthcare workers were consultants (53.7%), followed by specialists (21.7%), residents (22.2%), and others (subspeciality fellows, master's students) (2.5%).

Overall Microbiome Knowledge Among Healthcare Workers

Table 2 shows the responses to the knowledge questions. The 5 question topics that received the most correct answers were as follows: microorganisms living naturally in the intestinal tract (98.5%) and on the skin (97.0%), microorganisms naturally present in some foods (90.1%), microorganisms naturally living in body compartments and their major roles in human health and disease pathogenesis (89.7%), and vertical transmission of microorganisms from mothers to newborns during natural birth (88.7%). The 5 question topics that received the fewest correct answers were as follows: dysbiosis in children born by cesarean section and the increased risk for the development of allergic disorders in early life (29.1%); the importance of cleaning hands with antimicrobial soap to prevent some infections (31.5%); reducing the risk of allergic immune responses via microbial manipulation (34.0%); interactions between microorganisms living in different body compartments, such as between the intestinal and lung microbiomes (36.0%); and the definition of dysbiosis (45.3%). The mean overall knowledge score was 67.6%. The component scores were highest for the microbiome (75.6%), followed by probiotics (69.5%), and lowest for dysbiosis (52.6%).

Overall Probiotic Prescription Experience and Beliefs About Nutritional Advice Among Healthcare Workers

The majority (64.0%) of the healthcare workers prescribed probiotic food or drinks for most of their patients for a variety of causes. However, only 17.7% of the healthcare workers were prescribing probiotic food or drinks for most of their patients with allergies and/or asthma. Yogurt was the most frequently prescribed type of probiotic (67.7%), followed by pharmaceutical tablets (13.8%), naturally fermented products (10.0%), and pharmacy powder (8.5%). The majority (77.3%) of healthcare workers believed that nutritional advice plays an important role in the treatment of allergies or asthma in children. Medical articles/clinical trials were the most frequent sources of information about dysbiosis (45.5%), followed by the internet/social media (32.3%), course instructors (9.1%), colleagues (8.1%), and other sources (5.1%).

Characteristics of the Participants with High Knowledge About the Microbiome

Compared to those with lower overall knowledge scores in Table 1, a higher overall knowledge score was significantly associated with an age older than 45 years (40.6% versus 27.8%, p=0.015), employment as a consultant (62.3% versus 44.3%, p=0.036), the prescription of probiotic food or drinks for most patients (82.1% versus 44.3%, p<0.001), the prescription of probiotic food or drinks for most patients with allergies and/or asthma (25.5% versus 9.3%, p=0.003), the prescription of nonyogurt forms of probiotics, especially pharmacy tablets (40.2% versus 16.3%, p=0.048), and the belief that nutritional advice plays an important role in the treatment of allergies or asthma in children (91.5% versus 61.9%,

Table 1 Demographic and Professional Characteristics and Knowledge About the Microbiome, Dysbiosis, and Probiotics Among Healthcare Workers

Variable	All Participants	Knowledge Score		P value
		High	Low	
Age group				
Mean ± SD (years)	41.1 ± 10.7	42.4 ± 10.1	39.6 ± 11.2	0.060
< 35 years old	64 (31.5%)	24 (22.6%)	40 (41.2%)	**0.015**
35–45 years old	69 (34.0%)	39 (36.8%)	30 (30.9%)	
> 45 years old	70 (34.5%)	43 (40.6%)	27 (27.8%)	
Sex				
Male	78 (38.4%)	40 (37.7%)	38 (39.2%)	0.833
Female	125 (61.6%)	66 (62.3%)	59 (60.8%)	
Specialty				
Pediatrics	108 (53.2%)	54 (50.9%)	54 (55.7%)	0.500
Family Medicine	95 (46.8%)	52 (49.1%)	43 (44.3%)	
Level of training				
Consultant	109 (53.7%)	66 (62.3%)	43 (44.3%)	**0.036**
Specialist	44 (21.7%)	18 (17.0%)	26 (26.8%)	
Resident and others	50 (24.6%)	22 (20.8%)	28 (28.9%)	
Prescription of probiotic food or drinks for most patients				
Yes	130 (64.0%)	87 (82.1%)	43 (44.3%)	**<0.001**
No	73 (36.0%)	19 (17.9%)	54 (55.7%)	
Prescription of probiotic food or drinks for most patients with allergies and/or asthma				
Yes	36 (17.7%)	27 (25.5%)	9 (9.3%)	**0.003**
No	167 (82.3%)	79 (74.5%)	88 (90.7%)	
Forms of probiotics prescribed for patients				
Yogurt	88 (67.7%)	52 (59.8%)	36 (83.7%)	**0.048**
Naturally fermented products	13 (10.0%)	10 (11.5%)	3 (7.0%)	
Pharmacy powder	11 (8.5%)	9 (10.3%)	2 (4.7%)	
Pharmacy tablets	18 (13.8%)	16 (18.4%)	2 (4.7%)	
Believes that nutritional advice plays an important role in allergies and asthma in children				
Strongly agree/agree	157 (77.3%)	97 (91.5%)	60 (61.9%)	**<0.001**
Strongly disagree/disagree	11 (5.4%)	4 (3.8%)	7 (7.2%)	
I do not know	35 (17.2%)	5 (4.7%)	30 (30.9%)	
Sources of information about dysbiosis				
Internet/social media	32 (32.3%)	22 (29.7%)	10 (40.0%)	0.323
Medical article/clinical trials	45 (45.5%)	34 (45.9%)	11 (44.0%)	
Course instructor	9 (9.1%)	9 (12.2%)	0 (0.0%)	
Colleagues	8 (8.1%)	5 (6.8%)	3 (12.0%)	
Others	5 (5.1%)	4 (5.4%)	1 (4.0%)	

Notes: Data are presented as the absolute number (%) of participants who chose a particular survey response and were in specific age, specialty and training groups. Significant P values are shown in bold.

p<0.001). The majority of these findings were observed in the dysbiosis knowledge score and to a lesser extent in the probiotic knowledge score but not in the microbiome knowledge score (Supplementary Table 2). The scores did not differ by sex or specialty (data not shown).

Table 3 shows the results of the multivariate logistic regression analysis for the identification of predictors of higher overall knowledge. Of the characteristics associated with higher overall knowledge shown in Table 1, the following were independent predictors for higher overall knowledge about the microbiome, dysbiosis, and probiotics: age older than 45 years (odds ratio [OR] 2.60, confidence interval [CI] 1.13–5.99, p=0.025), the prescription of probiotic food or drinks for

Table 2 Responses of Healthcare Workers to Individual Knowledge Questions About the Microbiome, Dysbiosis, and Probiotics

Question	Correct	Incorrect	Do Not Know
Microbiome			
1. What is the microbiome?	155 (76.4%)	16 (7.9%)	32 (15.8%)
2. All microorganisms cause diseases in humans*	179 (88.2%)	12 (5.9%)	12 (5.9%)
3. There are microorganisms living naturally in the intestinal tract	200 (98.5%)	0 (0.0%)	3 (1.5%)
4. There are microorganisms living naturally in the respiratory tract	162 (79.8%)	18 (8.9%)	23 (11.3%)
5. There are microorganisms living naturally on the skin	197 (97.0%)	4 (2.0%)	2 (1.0%)
6. Microorganisms naturally living in body compartments play a major role in human health and disease pathogenesis	182 (89.7%)	11 (5.4%)	10 (4.9%)
7. There are microorganisms present in breast milk	119 (58.6%)	26 (12.8%)	58 (28.6%)
8. There are microorganism naturally present in some food we eat	183 (90.1%)	9 (4.4%)	11 (5.4%)
9. Mothers can transfer microorganisms to infants during pregnancy	147 (72.4%)	23 (11.3%)	33 (16.3%)
10. Mothers can vertically transmit microorganisms to their newborn during natural birth	180 (88.7%)	5 (2.5%)	18 (8.9%)
11. Mothers can transmit microorganisms to their infant during breast feeding	153 (75.4%)	13 (6.4%)	37 (18.2%)
12. Interactions occur between microorganisms living in different body compartments, such as between the intestinal and lung microbiomes	73 (36.0%)	32 (15.8%)	98 (48.3%)
13. The diversity among the microbial species of the microbiome varies between individuals and between various body compartments within the same individual	154 (75.9%)	1 (0.5%)	48 (23.6%)
14. Cleaning hands with antimicrobial soap is important to prevent all infections*	64 (31.5%)	126 (62.1%)	13 (6.4%)
Dysbiosis			
15. What is dysbiosis?	92 (45.3%)	30 (14.8%)	81 (39.9%)
16. A strong link exists between microbes living in our body (microbiome) and the development of allergic diseases	134 (66.0%)	4 (2.0%)	65 (32.0%)
17. Changes (microbial dysbiosis) in the respiratory microbiome are associated with the development of bronchial asthma and allergic rhinitis	102 (50.2%)	5 (2.5%)	96 (47.3%)
18. Changes (microbial dysbiosis) in the gastrointestinal microbiome are associated with allergic conditions such as eczema and food allergy	114 (56.2%)	3 (1.5%)	86 (42.4%)
19. Early exposure to environmental flora and fauna can lower the risk of developing allergies	135 (66.5%)	8 (3.9%)	60 (29.6%)
20. Reduced antibiotic use during early infancy or during the perinatal period can lower the risk of dysbiosis development and future allergies and asthma in children	149 (73.4%)	5 (2.5%)	49 (24.1%)
21. Maternal cesarean section causes dysbiosis in the child and increases the risk for the development of allergic disorders during early life	59 (29.1%)	27 (13.3%)	117 (57.6%)
22. Microbial manipulation can reduce the risk of allergic immune responses	69 (34.0%)	19 (9.4%)	115 (56.7%)
Probiotics			
23. What is the definition of a probiotic?	145 (71.4%)	39 (19.2%)	19 (9.4%)
24. It is advisable to avoid consuming any supplement labeled as "bacterial strains" or "probiotics" because they may be harmful*	144 (70.9%)	25 (12.3%)	34 (16.7%)
25. Do you know reasons for prescribing pro-/prebiotics?	115 (56.7%)	12 (5.9%)	76 (37.4%)
26. Which products are good sources of probiotics?	125 (61.6%)	8 (3.9%)	70 (34.5%)
27. Cultured dairy products, such as yogurt, buttermilk, and kefir, are sources of good bacteria	176 (86.7%)	2 (1.0%)	25 (12.3%)

Notes: Data are presented as the absolute number (%) of participants with correct, incorrect, or "do not know" answers to each question. *Negatively stated questions.

most patients (OR=15.96, CI 3.07–82.88, p=0.001), and positive beliefs about nutritional advice in the management of allergies or asthma in children (OR=8.52, CI 2.81–25.86, p<0.001).

Trends of Pro-/Prebiotic Prescriptions and Areas of Concern

As shown in Figure 1, 37.8% of the healthcare workers were not aware of the reasons for prescribing pro-/prebiotics. The most frequent causes of the prescription of pro-/prebiotics were irritable bowel syndrome (17.4%),

Table 3 Multivariate Logistic Regression Model for the Predictors of Higher Overall Microbiome Knowledge Among Healthcare Workers

Variable	Reference	Odds Ratio	95% Confidence Interval		P value
			Lower	Upper	
Age group					
35–45 years old	< 35 years	1.72	0.75	3.91	0.200
> 45 years old	< 35 years	2.60	1.13	5.99	**0.025**
Prescription of probiotic food or drinks for most patients	No prescription	15.96	3.07	82.88	**0.001**
Belief that nutritional advice plays an important role in allergies and asthma in children					
Strongly agree/agree	I do not know	8.52	2.81	25.86	**<0.001**
Strongly disagree/disagree	I do not know	3.32	0.60	18.53	0.171

Notes: Factors that could predict higher knowledge about the topics of the microbiome, dysbiosis, and probiotics were analyzed in a multivariate logistic regression model. The analysis was adjusted for age, training level, prescription of probiotics, forms of probiotics, and belief in nutritional advice. The model R-squared = 0.361. Significant P values are shown in bold.

indigestion (7.5%), diarrhea (7.0%), and allergies (6.0%). The most frequent areas of concern when recommending probiotics were evidence of proven efficacy (33.0%), immunocompromised status in patients (15.0%), and lack of sufficient education (11.5%).

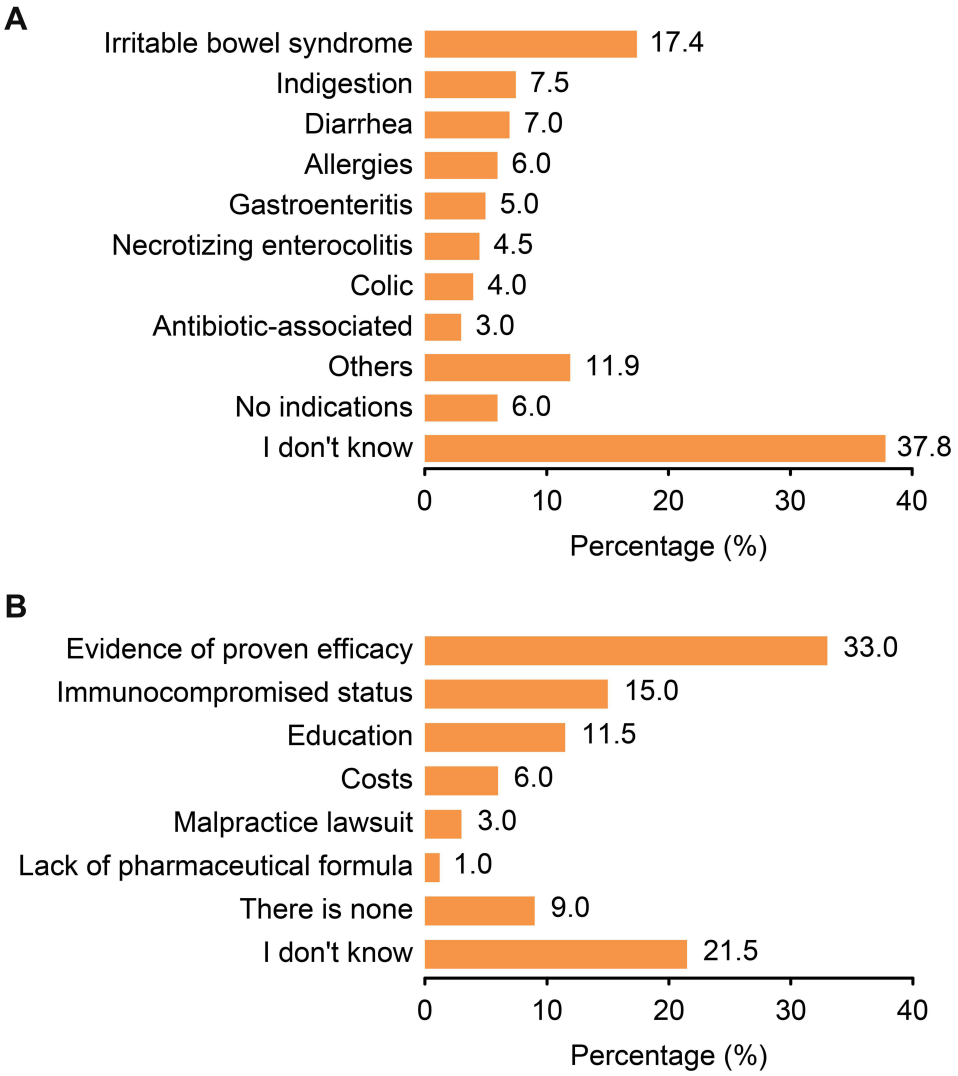

Figure 1 Trends of disease-specific pro-/prebiotic prescriptions and areas of concern with regard to this topic among healthcare workers. (**A**) Reasons for prescribing pro-/prebiotics and (**B**) areas of concern regarding the recommendation of probiotics among healthcare workers.

Methods of Acquiring Microbiome Science Knowledge Among Health Professionals

In addition to knowledge-based questions, the survey also included question on the methods of learning about microbiome science by the participants (Table 1). For the majority of the respondents, the internet/social media and medical articles/clinical trials were the major sources of knowledge about dysbiosis (32.3% and 45.5%, respectively). Other methods included information from course instructors (9.1%) and colleagues (8.1%). There were no significant differences in the percentages of participants with high knowledge vs low knowledge who learned about dysbiosis on the internet and social media (29.7% vs 40%), in medical articles and clinical trials (45.9% vs 44%), or from course instructors (12.2% vs 0%) or colleagues (6.8% vs 12.0%).

Discussion

This survey represents the first comprehensive assessment of microbiome science knowledge with regard to allergies and asthma among physicians in multiple major hospitals with residency training programs across the eastern region of Saudi Arabia. As such, the findings are particularly relevant to the evaluation of knowledge competency among clinicians who have extensive exposure to patients who suffer from these illnesses. Specifically, the analysis revealed existing gaps in microbiome knowledge among the participating physicians and physicians-in-training; these gaps included those related to the role of the microbiome in allergy and asthma development, the efficacy of hygiene procedures in preventing infections, the crosstalk between microbiomes in different body compartments, and topics related to the concept of dysbiosis. Consequently, more than one-third of the participants did not know whether pro-/prebiotics could be prescribed for the treatment of various illnesses. Notably, only 17% of participants reported prescribing probiotic food or drink for most of their patients with allergies and/or asthma. Only 6% of the participants reported that they would consider prescribing microbial therapies to patients with allergic diseases. These findings are consistent with results from another study in Saudi Arabia, where more than 60% of participants were found to have little to no knowledge about probiotics.[16]

Another major finding of this study was the positive association of the practice of therapeutic microbial manipulation and advocacy for nutritional management of allergic disorders with a higher level of microbiome knowledge. Consistent with this finding, recommending probiotics in clinical practice and the belief in the importance of nutritional advice in allergy and asthma management were independent predictors of higher microbiome knowledge. These observations provide an important proof of concept, indicating that additional knowledge about microbiome science would be helpful in guiding clinical practices related to this emerging field. As such, specific modifications to medical training with regard to microbiome knowledge should be recommended to increase the application of this knowledge in clinical medicine. For instance, improved knowledge about the interaction between the gastrointestinal and respiratory microbiomes could serve as a foundational understanding and guide the application of oral probiotics as a treatment potential in the management of allergic disorders of the respiratory tract.[5,30] Similarly, a thorough understanding of how cow's milk formula and cesarean section births result in dysbiosis and increase susceptibility to allergy and asthma development can serve as a scientific rationale for advocating for breast feeding and natural births to reduce the risk of the development of allergic diseases later in life.[31,32] Collectively, these examples demonstrate the important need to further develop continuing medical education curricula to include the most updated information about the role of the microbiome in disease pathogenesis as well as potential therapeutic applications to prevent the development and/or mitigate symptoms of diseases of public health importance in Saudi Arabia, such as allergies and asthma.

Microbiome knowledge competency differed between participants from different professional positions and age groups. In this regard, consultants appeared to have more advanced knowledge than other participants, particularly in the microbiome science and dysbiosis topics. This observation might be explained by the professional schedules of these two groups of survey respondents. In Saudi Arabia, most nonconsultants are physicians-in-training who are engaged in busy residency programs and work night shifts, while consultants represent more senior physicians with established clinical practices. As a result, the latter group could allocate more time in their schedules for other educational activities, such as participation in special seminars, conferences and workshops, to improve their knowledge and learn about updates in the most recent research in the field. Furthermore, participants older than 45 years of age are more experienced

with regard to overall knowledge of the microbiome than those younger than 45 years old. In congruence with this finding, older age predicted a higher microbiome knowledge level in our study. These findings were consistent with the observations of the knowledge gap between consultants and nonconsultants, as participants in the latter positions are often younger than 45 years of age. Collectively, these two observations of the associations between age/professional status and microbiome knowledge provide the rationale for future modifications of residency training curricula and continued medical training; this will allow the timely updating of and adequate provision of microbiome science knowledge among physicians-in-training or those in the early stages of their career.

Learning methods are often correlated with the level of knowledge competency.[33–35] Nevertheless, no studies to date have characterized all potential methods of microbiome knowledge acquisition. In light of the current deficits in the microbiome knowledge of the participants, our study also aimed to identify the common means by which the participants acquired information about microbiome science. This study also revealed that the majority of the participants with knowledge about microbiome science utilized two main channels to obtain information about this topic: medical articles/clinical trials (45.5%) and the internet/social media (32.3%) (Table 1). This observation is particularly relevant for future efforts to update physicians on the latest advances in microbiome science in the context of allergy and asthma prevention and management. For instance, providing clinicians access to medical journals and online databases of clinical trial results could help reduce the existing knowledge gaps. Additionally, other channels of knowledge acquisition, including coursework, appeared to be underutilized. Therefore, rational and need-based continuing medical education and knowledge-based workshops could be implemented to provide additional means for clinicians to improve their microbiome knowledge relevant to their professional activities. Notably, the major areas of concern for the practice of pro-/prebiotic prescription were related to the proven efficacy and effects in immunocompromised patients; updated knowledge about the effectiveness of microbial manipulation for the treatment of various disorders with a particular focus on the impact of these therapies on weakened/defective immune responses should be prioritized.

The current study has some limitations. First, the study participants were primarily recruited from one region of the kingdom. Therefore, it remains unclear whether similar microbiome science knowledge levels exist among physicians with similar demographic characteristics in other regions of Saudi Arabia. Second, the comparison did not take into consideration differences in the medical training curricula of the participants. As a consequence, it is difficult to assess whether the knowledge gaps in specific clinician populations were related to insufficient medical education materials and/or failure to achieve training outcomes. Last, the sample sizes of the subpopulations of participants were relatively small; therefore, the statistical power of the study might be limited by this sampling factor. Taken together, future studies should include a larger sample size and participants from different regions of Saudi Arabia. Additional integration of medical training outcome indexes into the knowledge assessment will also provide a more accurate analysis of knowledge retainment and its subsequent application in clinical practice.

Conclusions

The results of the current survey highlight existing gaps in the current knowledge, perceptions and clinical practices of pediatricians and family medicine practitioners in the eastern region of Saudi Arabia. The three major topics of microbiome science included in the survey are highly relevant to the understanding of the pathogenesis of allergy and asthma as well as clinical strategies for the prevention and management of these illnesses, which have been increasing in prevalence in the kingdom. Advanced age, the prescription of microbial therapies, and positive attitudes about nutritional management of allergic diseases were important predictors of higher microbiome knowledge. The findings also provide useful information about the need to improve specific areas of microbiome knowledge among practitioners in certain medical specialties and demographic subsets of healthcare providers. Furthermore, this study also provides a blueprint for similar efforts to assess medical topics that are relevant to diseases of public health concern in different regions of Saudi Arabia; awareness of the potential knowledge inadequacy among physicians could be promptly identified, and relevant training and education could be supplemented to optimize patient care. The current study was conducted on participants from a specific geographical location. Future studies with a larger sample size, sampled from different geographical locations, will allow for the generalizability of the findings. In addition, future studies are required to explore whether the currently existing knowledge gap is related to insufficient medical material or poor training.

Abbreviation

CVI, Content validity index.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Informed Consent

Ethical approval was obtained from the Ethics Committee at Imam Abdulrahman Bin Faisal University (study number: IRB-2021-01-243).

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