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Drug allergy knowledge, attitude, and practice: A survey among doctors and pharmacists in public health facilities of Sabah, Malaysia

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ABSTRACT

Background: Given the deficits in allergists and testing capacity, the diagnosis of drug allergy is largely dependent on the clinician's and pharmacist's judgment. The ability to recognize drug allergies and respond appropriately is crucial to patient safety. Currently, there is a void in the evidence that limits the ability to recommend comprehensive and swift improvements on this front.

Objective: This study thus aimed to evaluate the knowledge, attitude, and practice toward drug allergy among doctors and pharmacists working in public healthcare facilities in Sabah, Malaysia.

Methods: This cross-sectional study was conducted in 24 hospitals and 11 clinics in Sabah. A validated Drug Allergy Knowledge, Attitude, and Practice Questionnaire was adapted from a published study and developed on an online survey platform. The questionnaire was distributed to all listed eligible respondents via email and personal messenger service.

Results: A total of 549 doctors and pharmacists responded, with an overall response rate of 18.2%. The total mean knowledge, attitude, and practice scores were 8.3 (SD, 1.98), 18.9 (SD, 2.55), and 17.3 (SD, 4.4), respectively. It was found that pharmacists performed significantly poorer than both medical officers (mean score difference = –0.5; $P = 0.006$) and specialists (mean score difference = –0.9; $P = 0.020$) in the knowledge domain. As the time in service doubles, the knowledge score increases significantly by 0.3 ($P = 0.015$).

Conclusion: Knowledge, attitude, and practice on drug allergy among doctors and pharmacists in Sabah were poor. It is thus timely for advanced educational programs on drug allergy to be formalized and implemented.

Keywords: Adverse drug reaction; allergy; drug allergy; healthcare; hypersensitivity; knowledge

1. Introduction

Drug allergy is an adverse immune-mediated reaction to medicines that occurs in susceptible individuals. This hypersensitivity reaction is mediated by either specific antibodies or T lymphocytes, which lead to the release of inflammatory mediators [1, 2]. The reactions can range from mild to moderate symptoms such as skin rash, itchiness, cramps, and joint pains to more severe and life-threatening conditions such as anaphylaxis, Stevens–Johnson syndrome, and drug reaction with eosinophilia and systemic symptoms [3, 4]. The epidemiological risk factors for drug allergy are not completely understood and may be influenced by geographical differences in drug prescriptions and genetic markers [3].

The true prevalence of drug allergy is unknown, and the reported prevalence in the literature is highly variable. A population survey in South Australia has reported that 22.2% of the adults were allergic to some drugs [5]. Meanwhile, a study among hospitalized patients in Hong Kong has found that 13.5% had drug allergy labels [6]. In comparison, a study in India among inpatients and outpatients has stated that the prevalence of drug allergy labels was 5.6% [7]. Among children, a nationwide survey in Korea has revealed that the prevalence of drug allergy could be as high as 4.6% [8]. Looking at a specific drug class, it was estimated that the prevalence of beta-lactam antibiotic allergy in hospitalized patients from mainland China, Hong Kong, and Japan ranges from 4% to 5.6% [9].

Definitive diagnosis of drug allergy is crucial, as misdiagnosis may result in the use of less appropriate or more expensive drugs [10]. According to various international guidelines, the gold standard for diagnosing drug allergy is by using a combination of tests which include detailed clinical history, skin tests, in vitro testing, and oral provocation test. Adherence to the

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guidelines is challenging, however, due to the lack of allergists, dermatologists, test kits, investigational facilities, and training [11, 12]. It was reported that the number of allergists per population in Malaysia was only around 1 in 25 million [13]. There are also constraints on the number of dermatologists in public healthcare facilities in the country, particularly in Sabah [14].

In Sabah, the diagnosis of drug allergy is largely dependent on the World Health Organization-Uppsala Monitoring Centre System and clinicians' experiences. The system grades the likelihood of a drug to cause any observed adverse reactions from unlikely to certain based on the patient's allergy history, the timing of drug intake, the amount of drug taken, the timing of the occurrence of the reactions, the action taken on the suspected drug, the nature of the reactions, and the responses after dechallenge and/or rechallenge [15]. The system is currently incorporated into the national adverse drug reaction reporting form used in all public healthcare facilities. This practice may result in many false positives of true drug allergy as it was estimated that drug allergy constitute less than 20% of adverse drug reaction cases [16].

The reliance on healthcare professionals such as medical doctors and pharmacists who are not specifically trained in identifying drug allergy raises the question of whether they are well-equipped with the necessary knowledge and skills to detect and manage it. Currently, there is still a lack of studies exploring the knowledge, attitude, and practices on drug allergy among healthcare providers in Malaysia. Many studies were focusing instead on adverse events in general [17]. Without this information, it is challenging for the stakeholders to make necessary improvements.

Internationally, several studies have tried to explore the same question. Wang et al. [18] have reported low levels of knowledge on drug allergy among doctors, nurses, and medical students in China. Similar findings were found in a study from Turkey, where only 28.3% of current medical interns and residents were satisfied with their drug allergy knowledge, with those not having any formal lessons on drug allergy scoring the lowest [19]. Even in developed countries and teaching hospitals, the gap in knowledge remains, especially in terms of the management of patients with penicillin allergies [20].

Looking into the international evidence and how the findings can be used to advocate and facilitate focus on improving present practices, the current study aimed to evaluate the knowledge, attitude, and practice toward drug allergy among doctors and pharmacists in public health facilities in Sabah, Malaysia.

2. Methods

2.1. Ethics

Ethical approval for this study (NMRR-22-00090-LTL) was provided by the Malaysian Medical Research and Ethics Committee, National Institutes of Health, Ministry of Health, Shah Alam, Selangor, Malaysia (Chairperson Dr. Hjh. Salina Abdul Aziz) on March 10, 2022. A statement of consent was put before the first page of the online survey questions. Only those respondents who agreed to the consent statement were allowed to continue and included in the study.

This was a cross-sectional, multi-center, self-administered questionnaire study among doctors (specialists and medical officers) and fully registered pharmacists who are working in public healthcare facilities (24 hospitals and 11 district clinics) in Sabah. The survey was conducted between May and June 2022. Using the sample size calculator for estimating mean with finite population correction [21], the minimum sample size needed was given a standard deviation of 2.05 for the knowledge score [18], a precision of 2.5, and a 5% drop-out rate was 382 respondents. To ensure adequate representation from all study sites, a minimum number of respondents was assigned to each study site according to the number of doctors and pharmacists at each study site.

2.2. Research tools

The questionnaire used in this study was adapted from the study by Wang et al. [18] with permission [18]. It consists of 4 sections: (1) socio-demographic, including 4 general questions; (ii) 6 questions on the practices, including practice patterns of taking allergy history, performing skin tests, and receiving advanced education on drug hypersensitivity reactions, rated using a 5-point Likert scale (1, never; 2, occasionally; 3, sometimes; 4, often; and 5, always); (3) 14 multiple choice questions on knowledge of the respondents on drug allergy, including mechanism, clinical manifestations, diagnosis, and management of drug hypersensitivity reactions, where each correct answer was given 1 mark and 0 otherwise; and (iv) 5 questions on the attitude of the respondents towards drug allergy, including attitude towards the need of taking an allergic history, performing skin test, and receiving advanced education of drug hypersensitivity reactions, rated using a 5-point Likert scale (1, strongly disagree; 2, disagree, 3, uncertain; 4, agree; and 5, strongly agree). The practice section was required to be completed before the knowledge and attitude sections to avoid leading answers. All questions are in English. To ensure the relevancy and appropriateness of the questionnaire, face validation was carried out among 3 doctors and 3 pharmacists.

2.3. Data collection

The questionnaire was constructed in an online Google Forms format. A data collector was appointed at each study site to recruit the respondents and promote the study. All data collectors were briefed before data collection. Although the sample size calculated was 382, the questionnaire was distributed to all doctors and pharmacists registered in the public healthcare facilities in Sabah identified from the name list provided by the State Health Department. This was in anticipation of a lower response rate of online surveys, which typically ranged from 0.4% to 83% [22]. The survey forms were shared via both their official email address and their personal messenger service, WhatsApp. Reminder messages were sent out 2 weeks after the initial invitation to encourage participation.

2.4. Data analysis

The data were analyzed using R version 4.2.0. Appropriate descriptive statistics were used to summarize the data. Internal consistency reliability for each questionnaire was assessed using Cronbach's alpha (also called Kuder–Richardson 20 for tests with binary outcomes). Pairwise correlations between the scores were studied using Pearson's correlation. The association between 2 categorical variables was analyzed using Fisher's exact test. Factors associated with the knowledge score were determined via multiple linear regression. The selection of variables to be included in the final model was based on stepwise Akaike Information Criteria. All possible 2-way interactions and

Table 1.
Demographics of respondents (n = 549)

Variable	Median (IQR)	n (%)
Time in service (years)	5 (4)a	
Occupation		
Specialist		36 (06.6)
Medical officer		254 (46.3)
Pharmacist		259 (47.2)
Workplace		
Hospital		425 (77.4)
Clinic		124 (22.6)
Division		
West Coast		207 (37.7)
Interior		131 (23.9)
Tawau		111 (20.2)
Sandakan		57 (10.4)
Kudat		43 (07.8)

[a]Skewed to the right.

multicollinearity were checked before the preliminary model was finalized. The final model fit was assessed by performing residual diagnostics. A *P* value less than 0.05 was considered statistically significant.

3. Results

3.1. Sample characteristics

A total of 549 doctors and pharmacists responded, which represented 18.2% of the total number of doctors and pharmacists in Sabah. There was about equal participation by doctors (52.8%) and pharmacists (47.2%) in the survey. The majority of the doctors were from the medical department (87.9%), followed by others (7.2%), surgical (2.8%), and family medicine (2.1%). Meanwhile, most pharmacists were working in the outpatient department (40.9%), followed by others (25.5%), clinical pharmacists (15.8%), and the inpatient department (15.8%). The respondents' time in service ranged from 0.8 to 30.1 years. Other characteristics of the respondents are summarized in Table 1.

3.2. General questions

The responses to the 4 general questions are shown in Table 2. There was no significant difference between doctors and pharmacists in their responses to the question, "Have you seen an allergy card from Ministry of Health Malaysia?" (P = 0.072) and the question, "Do you think knowledge of drug allergy is important in your practice?" (P = 0.126). Most of the pharmacists (98.5%) have issued an allergy card to a patient before. Similarly, most of the doctors (85.5%) have referred patients to a pharmacist for an allergy card application before.

3.3. Knowledge

The Kruder–Richardson 20 value for the knowledge questionnaire was 0.35 (95% CI, 0.27–0.43). The responses to the knowledge questionnaire are shown in Table 3. Item A4 had the highest percentage of correct answers (93.3%) and item A11 had the lowest percentage of correct answers (20.9%). The overall mean knowledge score was 8.3 (SD, 1.98). The mean knowledge score for specialists, medical officers, and pharmacists was 9.2 (SD, 2.01), 8.5 (SD, 1.87), and 8.0 (SD, 2.04), respectively. Occupation and time in service were significantly

Table 2.
Responses to the general questions

	Yes n (%)	No n (%)	OR (95% confidence interval)	*P* value
(i) "Have you seen an allergy card from MOH Malaysia?" (Answered by all respondents)				
Doctors (n = 290)	283 (97.6)	7 (2.4)	6.4 (0.8, 288.3)	0.072
Pharmacists (n = 259)	258 (99.6)	1 (0.4)		
(ii) "Have you ever issued an allergy card to a patient before?" (Answered by pharmacists only)				
Pharmacists (n = 259)	255 (98.5)	4 (1.5)	-	-
(iii) "Have you ever referred to a pharmacist for an allergy card application before?" (Answered by doctors only)				
Doctors (n = 290)	248 (85.5)	42 (14.5)	-	-
(iv) "Do you think knowledge of drug allergy is important in your practice?" (Answered by all respondents)				
Doctors (n = 290)	286 (98.6)	4 (1.4)	Inf (0.6, Inf)	0.126
Pharmacists (n = 259)	259 (100.0)	0 (0.0)		

1. Allergy card can be issued by pharmacists only.
2. Doctors need to refer to pharmacists for every allergy card application.
3. Fisher's exact test was used for statistical analysis. Odds ratio (OR) is the odds of answering "No" to the question in doctors vs the odds of answering "No" to the question in pharmacists.
4. Inf means the OR is indeterminate as the consequence of a cell with zero value.
5. Wide 95% Confidence interval is the consequence of sparse data in the 2 × 2 table.
MOH, Ministry of Health.

Table 3.
Knowledge of respondents on drug allergy (n = 549)

Item	Choice A	Choice B	Choice C	Choice D
A1	376 (68.5)	40 (07.3)	23 (04.2)	110 (20.0)
A2	163 (29.7)	8 (01.5)	134 (24.4)	244 (44.4)
A3	382 (69.6)	27 (04.9)	125 (22.8)	15 (02.7)
A4	512 (93.3)	16 (02.9)	8 (01.5)	13 (02.4)
A5	506 (92.2)	23 (04.2)	14 (02.6)	6 (01.1)
A6	92 (16.8)	454 (82.7)	3 (00.5)	0 (00.0)
A7	50 (09.1)	204 (37.2)	111 (20.2)	184 (33.5)
A8	198 (36.1)	83 (15.1)	208 (37.9)	60 (10.9)
A9	282 (51.4)	45 (08.2)	158 (28.8)	64 (11.7)
A10	103 (18.8)	147 (26.8)	295 (53.7)	4 (00.7)
A11	115 (20.9)	307 (55.9)	88 (16.0)	39 (07.1)
A12	388 (70.7)	113 (20.6)	28 (05.1)	20 (03.6)
A13	58 (10.6)	39 (07.1)	186 (33.9)	266 (48.5)
A14	4 (00.7)	56 (10.2)	53 (09.7)	436 (79.4)

Values are presented as n (%). Correct answers are bolded. See the supplementary file for the questionnaire Supplementary Material, http://links.lww.com/PA9/A12.

associated with knowledge scores, as shown in Table 4. As the time in service doubles, the knowledge score increases by 0.3 (P = 0.015). It was also found that pharmacists performed significantly poorer than both medical officers (mean score difference = –0.5; P = 0.006) and specialists (mean score difference = –0.9; P = 0.020). There was no significant difference between medical officers and specialists.

3.4. Attitude

The Cronbach's alpha value for the attitude questionnaire was 0.53 (95% CI, 0.47–0.59). The responses to the attitude questionnaire are shown in Table 5. The overall mean attitude score was 18.9 (SD, 2.55). The mean attitude scores for specialists, medical officers, and pharmacists were 19.5 (SD, 2.25), 19.2 (SD, 2.48), and 18.5 (SD, 2.62), respectively. There was no significant correlation between attitude and knowledge score (Pearson's ρ = 0.044; P = 0.300).

Table 4.

Factors associated with knowledge score (n = 549)

	Simple linear regression			Multiple linear regression		
Variable	***b* (95% Confidence interval)**	***t*-stat. (*df*)**	***P* value**	***b* (95% Confidence interval)**	***t*-stat. (*df*)**	***P* value**
Log_2 (time in service [years])	0.335 (0.138–0.533)	3.330 (547)	<0.001	0.266 (0.052–0.480)	2.437 (545)	0.015
Occupation: Pharmacist	−0.465 (−0.805 to −0.125)	−2.686 (546)	0.007	−0.475 (−0.814 to −0.137)	−2.757 (545)	0.006
Occupation: Specialist	0.762 (0.076–1.448)	2.182 (546)	0.030	0.400 (−0.343 to 1.142)	1.057 (545)	0.291
Workplace: Clinic	−0.308 (−0.705 to 0.090)	−1.520 (547)	0.129			
Division: Kudat	−0.001 (−0.686 to 0.683)	−0.004 (544)	0.997			
Division: Sandakan	−0.069 (−0.687 to 0.549)	−0.219 (544)	0.827			
Division: Tawau	−0.492 (−0.994 to 0.010)	−1.924 (544)	0.055			
Division: West Coast	0.015 (−0.419 to 0.450)	0.067 (544)	0.946			

Variable selection was made using stepwise Akaike Information Criteria (AIC). Adjusted $R^2 = 0.034$. Reference level for occupation is medical officer. Reference level for workplace is hospital. Reference level for division is interior. The model fitted well. Model assumptions were met. There were neither multicollinearity nor interactions between variables.

Table 5.

Attitude of respondents on drug allergy (n = 549)

Item	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
B1	Do you think HCPs should receive advanced knowledge and training of DHRs?				
	21 (03.8)	0 (00.0)	3 (00.5)	172 (31.3)	353 (64.3)
B2	Do you think *in vivo* or *in vitro* test of drug is very important before drug administration?				
	6 (01.1)	24 (04.4)	218 (39.7)	198 (36.1)	103 (18.8)
B3	Are you satisfied with your knowledge of DHRs?				
	35 (06.4)	186 (33.9)	240 (43.7)	80 (14.6)	8 (01.5)
B4	Do you think drug allergy has an adverse impact on patient's quality of life?				
	7 (01.3)	10 (01.8)	21 (03.8)	259 (47.2)	252 (45.9)
B5	Do you think drug allergy always occur in your daily practice?				
	12 (02.2)	82 (14.9)	100 (18.2)	266 (48.5)	89 (16.2)

Values are presented as n (%).

DHR, drug hypersensitivity reaction; HCP, healthcare practitioner.

Table 6.

Practice of respondents on drug allergy (n = 549)

Item	Never	Occasionally	Sometimes	Often	Always
C1	Do you take the patient's history of drug allergy before the drug administration?				
	8 (01.5)	33 (06.0)	78 (14.2)	149 (27.1)	281 (51.2)
C2	Do you take the patient's allergy history before drug administration?				
	14 (02.6)	47 (08.6)	78 (14.2)	150 (27.3)	260 (47.4)
C3	Do you evaluate the drug skin test result timely and accurately?				
	389 (70.9)	52 (09.5)	51 (09.3)	40 (07.3)	17 (03.1)
C4	Do you perform positive control and negative control during drug skin test?				
	461 (84.0)	27 (04.9)	31 (05.6)	14 (02.6)	16 (02.9)
C5	Do you recognize and manage DHRs timely when it occur?				
	82 (14.9)	80 (14.6)	106 (19.3)	151 (27.5)	130 (23.7)
C6	Do you participate in continuous medical education regarding drug allergy?				
	93 (16.9)	146 (26.6)	174 (31.7)	91 (16.6)	45 (08.2)

Values are presented as n (%).

DHR, drug hypersensitivity reaction.

3.5. Practice

The Cronbach's alpha value for the practice questionnaire was 0.74 (95% CI, 0.70–0.77). The responses to the practice questionnaire are shown in Table 6. The overall mean practice score was 17.3 (SD, 4.4). The mean practice scores for specialists, medical officers, and pharmacists were 20.2 (SD, 4.20), 18.7 (SD, 3.86), and 15.5 (SD, 4.18), respectively. There was no significant correlation between practice and knowledge scores (Pearson's $\rho = 0.074$; $P = 0.082$). However, there was a significant positive but weak correlation between practice and attitude score (Pearson's $\rho = 0.280$; $P < 0.001$).

4. Discussion

The mean knowledge score among our respondents was quite poor. The scores, if converted to percentage, ranged only from 57.1% among the pharmacists to 65.7% among the specialists. Overall, most of the respondents failed to correctly identify factors that were related to drug allergy, as shown by the very low proportion of correct answers (29.7%) on Item A2. Furthermore, less than 60% of respondents have managed to accurately answer questions related to drug allergy tests as asked by Items A7– to A11. Given the over-reliance on the World Health Organization-Uppsala Monitoring Centre system and their own clinical judgment in diagnosing drug allergy, the results were not surprising. The unavailability of allergy tests in our public healthcare facilities and inadequate training may explain the low scores. The level of knowledge among the respondents in this study was comparable to that of Wang et al. [18] which reported a mean knowledge score of 8.71 (SD, 2.05) among the doctors surveyed [18] versus 8.3 (SD, 1.98) in this study. In their study, the lack of knowledge was also shown to reflect the lack of drug provocation tests carried out in public health facilities in China [18].

The diagnosis of drug hypersensitivity reactions is often difficult without the availability of experts and relevant tests, causing many reactions to be misdiagnosed [3,10–12]. Doctors and pharmacists usually rely on past observations from different patients encountered over the years to identify drug allergies. As the pathophysiology of hypersensitivity reactions is not part of formal training modules during housemanship, the skills can only be developed through experiential learning. This is reflected by the higher knowledge scores among those with longer years in service. Nevertheless, the rarity of events and variability in the clinical pictures limits the range of information that can be gained through experiences. An add-on and continuous learning module are thus essential to ensure the current gaps can be filled.

Interestingly, our results demonstrated that doctors had a higher level of knowledge about drug allergies than pharmacists. This is contrary to the findings by Staicu et al. [20] which reported that pharmacists were shown to have a better understanding of allergy and antibiotic cross-reactivities. This may be explained by the fact that doctors in our public facilities are often the first point of referral by patients and thus are more involved in the identification of potential allergic reactions. According to the Guideline for Detecting Drug Allergy by the Pharmaceutical Services Division, Ministry of Health Malaysia, allergic reactions must be verified by a doctor before a pharmacist can issue an allergy card to a patient [23]. Another possible explanation is that the clinical pharmacists, who work the closest with the patients in the wards and hence more likely to encounter patients with allergic reactions, made up only about 15% of the pharmacists who responded.

The general mean attitude score of 18.9 (SD, 2.55) in our study appeared to be lower than the scores reported by Wang et al. [18], which was 21.21 (SD, 2.27) for chief physicians and 20.72 (SD, 2.17) for attending doctors [18]. Albeit scoring low, the doctors and pharmacists showed a positive attitude in terms of being aware of their limitations and highlighting the importance of receiving proper training. Furthermore, 93.1% of our respondents reiterated that drug allergy can adversely impact the patient's quality of life. This was consistent with the literature that the majority of the respondents agreed that healthcare professionals should receive advanced knowledge and training in drug hypersensitivity reactions [18, 24], and nearly half of them were not satisfied with their current knowledge level [18, 24]. The findings by Zaruhi et al. [24], for example, stated that 82.7% of the healthcare professionals surveyed were not satisfied with their knowledge. They also recommended targeted multidisciplinary education for staff involved in managing drug allergies [24]. These findings can be interpreted as there is a strong acceptance of any education and training program that will be implemented in the future.

In terms of practice, the overall mean practice score was 17.3 (SD, 4.40). On the percentage scale, this was equivalent to 47.1%. It is quite alarming to note that only about half of the respondents managed to always take the patient's history of allergy. Excluding the pharmacists, the proportions of respondents who answered "Always" to questions C1 and C2 only improved slightly to 63% and 61%, respectively. Similar findings were reported by Ercan et al. [25] where only half of the respondents questioned their patients about drug allergies before prescribing a drug. This may reflect the low awareness among the respondents of the importance of investigating a patient's history of allergy. Furthermore, more than 70% of the respondents failed to properly perform and evaluate drug skin tests. The over-reliance on expert opinion by the attending doctors based solely on the patient's history may explain the observation. It was also found that less than a quarter of the respondents were able to always recognize and manage drug hypersensitivity reactions in a timely manner. Compared with the original study by Wang et al. [18], the practice profile of the respondents from this study is much poorer (mean practice score of 23.24 vs 17.3).

Indirectly, this study reveals a practice gap in drug allergy management in Sabah. The pharmacist's role should not be just limited to issuing allergy cards on doctors' requests. In the case of penicillin allergies, for instance, recent studies support the role of a pharmacist-led penicillin allergy de-labeling program, which can fill the unmet need for allergy specialists in delivering this service [26]. There is mounting evidence that pharmacist-led oral challenge or penicillin skin testing is safe and accurate and contributes to better antimicrobial selection without the need for recourse to specialized allergy/immunology assessment [27]. This practice gap and its corresponding opportunity for service expansion are also applicable to pharmacists in other Asian countries, as discussed by Jantarathaneewat et al. [28] The addition of penicillin allergy de-labeling initiative into the existing clinical pharmacist-driven Antimicrobial Stewardship Program interventions is the way forward for clinical pharmacists in Asia [28].

Our study has some limitations. Although the study had over 500 respondents, they only formed about 18.2% of the medical officers and pharmacists working in the public healthcare facilities in Sabah. Selection bias may be present as the characteristics of those who chose to participate may be different from those who did not respond. The generalizability of the study results is thus questionable. Nevertheless, our findings were found to be consistent with past studies [18-20, 24, 25]. In addition, the reliability of the questionnaire was mediocre. All but the practice dimension had a reliability coefficient of less than 0.7. This, however, does not totally invalidate the usefulness of this questionnaire, as the individual questions can still give valuable information on the phenomena studied. Finally, only 4 variables: time in service, occupation, workplace, and division were included in the regression analysis of the factors associated with the knowledge score. The final model, which consists of time in service and occupation, only explains 3.4% of the total variation in the knowledge score (adjusted R^2 value = 0.034). This indicates that one or more relevant variables have been inadvertently left out from our study. This is known as omitted variable bias, and it may cause our model to misestimate the effects of occupation and time in service on the knowledge score.

To conclude, it was found that knowledge, attitude, and practice on drug allergy among doctors and pharmacists in Sabah were poor. Despite showing low knowledge scores, most respondents were aware of their shortcomings and demonstrated a positive attitude toward the importance of drug allergy on patients' quality of life. Their acceptance of advanced educational training in drug hypersensitivity reactions was very encouraging. Aside from implementing strategies to fill this knowledge gap, future studies can also explore the effectiveness of such strategies and factors that may influence the outcomes.

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Conflicts of interest

The authors have no financial conflicts of interest.

Author contributions

Conception and design: Melinda See Kee Kwan, Sze Ling Tan, Sivaraj Raman, Hoo Seng Tan, James Yau Hon Voo. Analysis and interpretation of the data: Thamron Keowmani. Drafting of the article: Melinda See Kee Kwan, Thamron Keowmani, Sze Ling Tan, Nur'Ain binti Madi, Diyanah Khan binti Zainullah Faidin, Khamisah binti Itim, Mohd Ridzuan bin Zakaria. Critical revision of the article for important intellectual content: Melinda See Kee Kwan, Thamron Keowmani. Final approval of the article: Melinda See Kee Kwan, Thamron Keowmani, Sze Ling Tan, Sor Leng Goh, James Yau Hon Voo, Hoo Seng Tan, Mohd Ridzuan bin Zakaria, Sivaraj Raman, Jackie Chit Khong Ho, Diyanah Khan binti Zainullah Faidin, Nur'Ain binti Madi, Khamisah binti Itim. Provision of study materials or patients: Jackie Chit Khong Ho, Melinda See Kee Kwan, Sor Leng Goh, Khamisah binti Itim, Diyanah Khan binti Zainullah Faidin, Mohd Ridzuan bin Zakaria. Statistical expertise: Thamron Keowmani.

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