



Awareness of antibiotic resistance: a tool for measurement among human and animal health care professionals in LMICs and UMICs

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Background: Raising awareness of antimicrobial resistance is a cornerstone of action plans to tackle this global One Health challenge. Tools that can reliably assess levels of awareness of antibiotic resistance (ABR) among human or animal healthcare professionals (HCPs) are required to guide and evaluate interventions.

Methods: We designed and tested an ABR awareness scale, a self-administered questionnaire completed by human and animal HCPs trained to prescribe and dispense antibiotics in six countries—Ghana, Nigeria, Tanzania, Vietnam, Thailand and Peru. Questionnaires also elicited demographic, practice, and contextual information. Psychometric analysis for the scale followed Rasch Measurement Theory. Bivariate analysis was carried out to identify factors associated with awareness scores.

Results: Overall, 941 HCPs (625 human and 316 animal) from Ghana, Nigeria, Tanzania, Vietnam, Thailand and Peru were included in the study. The 23-item ABR awareness scale had high-reliability coefficients (0.88 for human and 0.90 for animal HCPs) but performed better within countries than across countries. Median ABR awareness scores were 54.6–63.5 for human HCPs and 55.2–63.8 for animal HCPs (scale of 0–100). Physicians and veterinarians scored higher than other HCPs in every country tested. HCPs in this study reported working in contexts with limited laboratory infrastructures. More than 95% of HCPs were interested in receiving information or training on ABR and antimicrobial stewardship.

Conclusion: HCPs' awareness of ABR can be reliably assessed with this validated 23-item scale within the countries tested. Using the scale alongside context questions and objective measurement of practices is recommended to inform interventions to improve antibiotic use.

Introduction

Antimicrobial resistance (AMR) has been signalled as one of the biggest threats to global health.¹ Despite its importance, there is concern that awareness of AMR is low.² The first objective of

the World Health Organization's Global Action Plan (GAP) on AMR, which operates as a blueprint for national action plans (NAPs) around the world, is to raise awareness about AMR among healthcare professionals (HCPs) and the public.¹ Numerous local, national and international campaigns have been undertaken to

raise awareness of AMR among prescribers and consumers—primarily in humans but also in veterinary medicine.^{2–8}

Previously, a range of knowledge, attitudes and practices surveys have been used to assess AMR awareness among the public and HCPs—including veterinarians—worldwide.^{2,9–18} One challenge for these studies, however, is to create generalizable definitions of what people should know, think and do in relation to the complex topic of AMR. Among HCPs commonalities can be assumed, given medical and veterinary education include standard information on biological mechanisms and antimicrobials, however, variation in curricula and expectations is inevitable across specialities, places and over time.¹⁹ The relevance of different forms of microbial resistance also varies; for example, malaria, tuberculosis, HIV, typhoid and colibacillosis in animals, each has different epidemiological profiles as well as different mechanisms for developing drug resistance. AMR awareness and how to respond to it is also known to emerge through healthcare practice as much as through curriculum learning.²⁰ While apparently simple questions such as ‘have you heard of antimicrobial resistance?’ may represent awareness of an abstract concept, capturing awareness of AMR as it bears relevance and meaning to a health practitioner requires more detailed and carefully designed questioning.

Psychometricians have established techniques for developing and validating scales that can be used to measure complex concepts.^{21–24} Such instruments intend to provide an ‘objective measurement of the skills, knowledge and abilities, as well as the subjective measurement of individuals’ interests, values and attitudes’.²⁵ The process of development and validation of these measurement instruments entails three phases: item development (domains are identified and items generated), scale development (constructs are identified, questions are pretested

and factors extracted) and scale evaluation (dimensionality, validity and reliability tests are performed).²⁶

To aid the design and evaluation of AMR awareness-raising efforts, we developed a scale to quantitatively measure awareness of antibiotic resistance (ABR) among trained HCPs from low- and middle-income countries (LMICs) and upper-middle countries (UMICs). The questionnaires targeted both human and animal HCPs in recognition of AMR as a One Health problem.²⁷ Our focus on LMICs and UMICs recognizes that manifestations of AMR and means to address it may differ from higher resource settings, with implications for what constitutes ‘awareness’, yet these data are urgently needed to inform the implementation of NAPs.

Methods

Study design

This was a multi-step multi-country study involving the design, testing and analysis of a scale to assess human and animal HCPs’ awareness of ABR (Figure 1). The first step involved qualitative research with human and animal HCPs across a range of settings in six LMICs to develop a conceptual framework, described elsewhere.^{20,28} In the questionnaire testing phase, items were then taken to six countries for translation, pretesting and piloting. In-country validation was done by local experts of the target population in each location. This allowed the adaptation of the wording and format of items and the assessment of the content validity and accuracy of translation of the tools to the different field sites. The sample size required for the survey response analysis was estimated to be 385 HCPs for each health sector (95% CI, 5% error, response distribution of 50%). Psychometric analysis was then carried out by two psychometricians, and the resulting scale examined for patterns of demographic and contextual factors that may have shaped ABR awareness scores of HCPs in each country. Data were collected between May

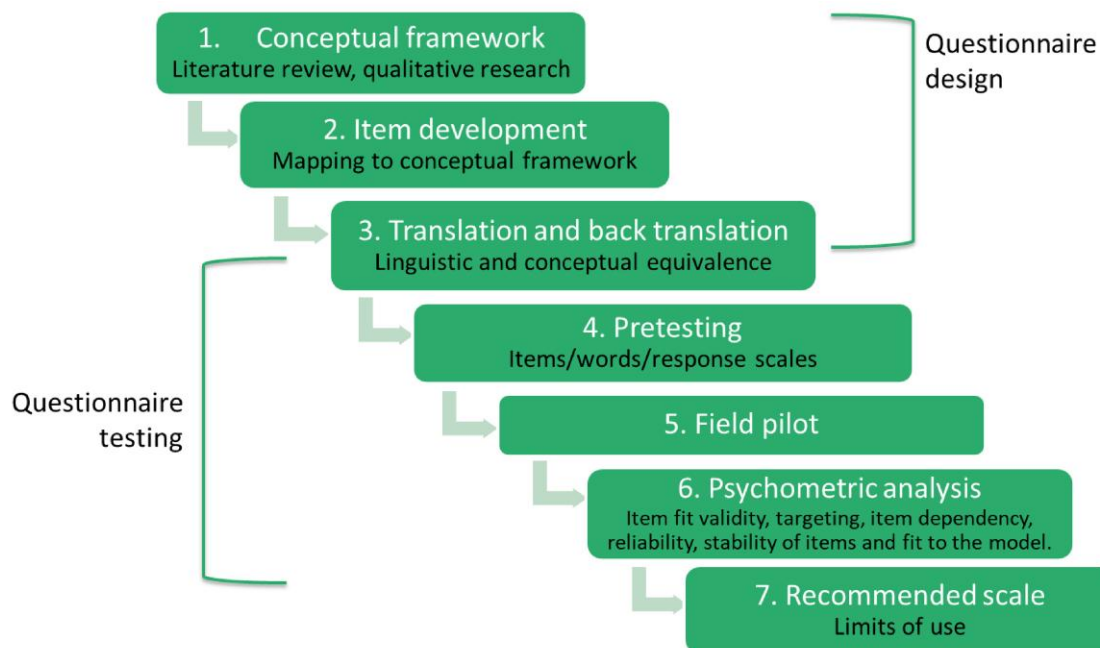


Figure 1. Design and testing the HCP ABR awareness questionnaire. This figure appears in colour in the online version of JAC and in black and white in the print version of JAC.

and September 2018. Additional details on methods can be found in Table S1 (available as Supplementary data at JAC Online).

Participants

Countries selected by building upon existing collaborations with local host institutions and aiming to represent different continents—were Ghana, Nigeria and Tanzania from West and East Africa, Vietnam and Thailand from Southeast Asia, and Peru from South America. From each country, human HCPs (HHCPs), animal HCPs (AHCPs) or both were invited to participate in the study and were eligible to participate if they were registered and/or licensed to prescribe or dispense antibiotics. Participants were mainly recruited from the capital cities of each country where the density of HCPs was highest. Printed, email or phone invitations to participate in the study were circulated at hospitals, private clinics, professional bodies and postgraduate programmes. Participation was confidential. Detailed information about the recruitment process in each country is included in the Supplementary material, p. 3.

Questionnaires and data collection

The questionnaires comprised four modules: demographics, ABR awareness; practice items and context items. ABR awareness-related items used a four-point Likert scale ('strongly agree', 'agree', 'disagree' and 'strongly disagree'). Demographic, practice and contextual variables were multiple choice, Likert or binary formats (Table S1). The practice module was included to capture self-reported prescribing/dispensing practices, and the context module was included to situate the findings within the work settings of respondents.

Questionnaires were forward-back translated from English to local languages (including Swahili, Thai, Vietnamese and Spanish). Questionnaires for self-completion were delivered by email, including a link to the online version (with an Open Data Kit (ODK) platform) or in a paper printed version. The team manually entered completed paper-based questionnaires into the online ODK platform. Datasets were stored in a password-protected local server at the London School of Hygiene and Tropical Medicine (LSHTM) using FilR software.

Data analysis

Data were analysed using quantitative methodologies on SPSS software v.23.0 (IBM Corp., USA).

ABR awareness scale and scores

The ABR awareness module of the questionnaires was validated by applying psychometric techniques based on Rasch Measurement Theory.²⁹ Analysis was performed separately for the human and AHCPs questionnaires, initially for separate countries and then combined across countries. Following psychometric evaluation, items were scored using the estimates from the Rasch model. Scores were produced in a standardized range of 0 to 100.³⁰

Demographic and contextual factors

A descriptive analysis of demographic and context variables was carried out. The structure of the final version of the questionnaires included in the analysis comprised 58 items (Table S2). ABR awareness scores were calculated and compared to participants' demographics and previous

Table 1. Field sites and type of HCPs and total number of participants surveyed for every country

Region	West Africa		East Africa		South America		Southeast Asia		Total					
Country	Ghana		Nigeria		Tanzania		Peru		Vietnam		Thailand			
Site	Volta Region		Abuja		Arusha		Lima ^a		Ho Chi Minh		Bangkok			
Survey language	English		English		English and Kiswahili		Spanish		Vietnamese		Thai			
Delivery format	Paper		Paper		Paper		Online		Paper/ Online		Online			
Number of participants ^b	106 H		112 H		164 H		91 H/139 A		253 H/183 A		43 A			
Human health care professionals ^c /(N%)														
Doctor	48	(46.2)	55	(64.7)	32	(25.4)	53	(63.1)	73	(32.3)	261	(41.8)		
Dentist	2	(1.9)	8	(9.4)	8	(6.3)	30	(35.7)			48	(7.7)		
Nurse	21	(20.2)			56	(44.4)			53	(23.5)	130	(20.8)		
Pharmacist	15	(14.4)	21	(24.7)	14	(11.1)			62	(27.4)	112	(17.9)		
Physician Assistant	18	(17.3)							38	(16.8)	56	(9.0)		
Medical/Clinical Officer					16	(12.7)					16	(2.6)		
No answer			1	(1.2)			1	(1.2)			2	(0.3)		
Animal health care professionals ^c /(N%)														
Veterinarian							119	(100)	69	(44.2)	41	(100)	229	(72.5)
Veterinary Drug seller									18	(11.5)			18	(5.7)
Veterinarian and drug seller									64	(41.0)			64	(20.3)
No answer									5	(3.2)			5	(1.5)

^aInvitations to participate were sent to local participants, however, a snowballing technique was also used and participants from other parts of Thailand and Peru were included in the study.

^bIncluded ALL participants.

^cOnly included participants with no missing values in the 23-item scale and for whom scores were calculated. H: HHCPs. A: AHCPs.

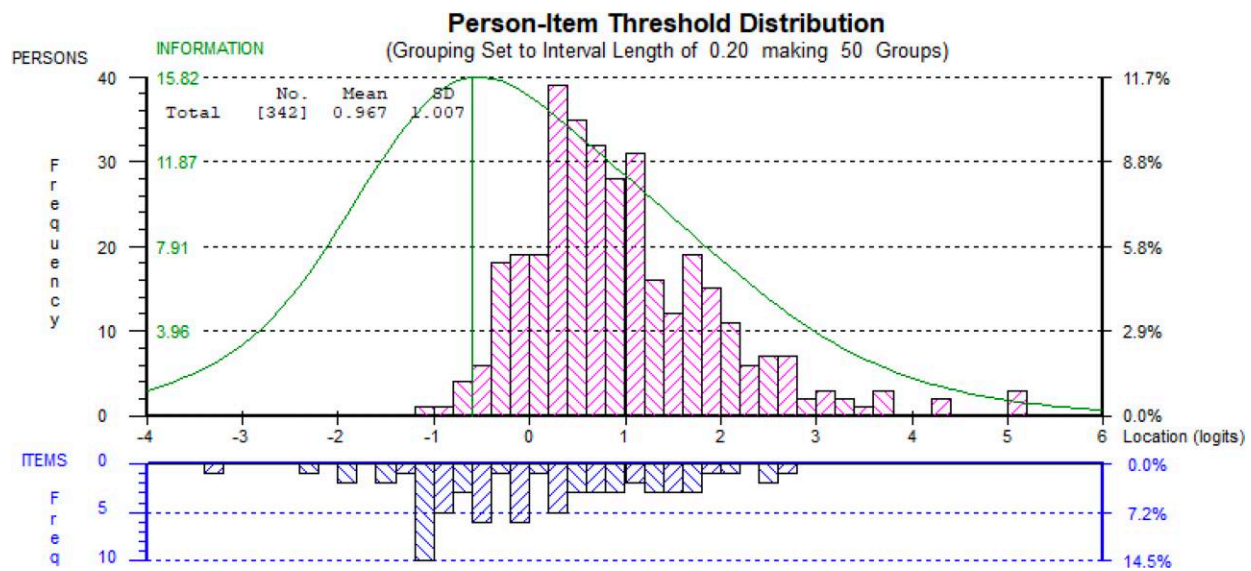


Figure 2. Targeting of human HCP scale (23 items). This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

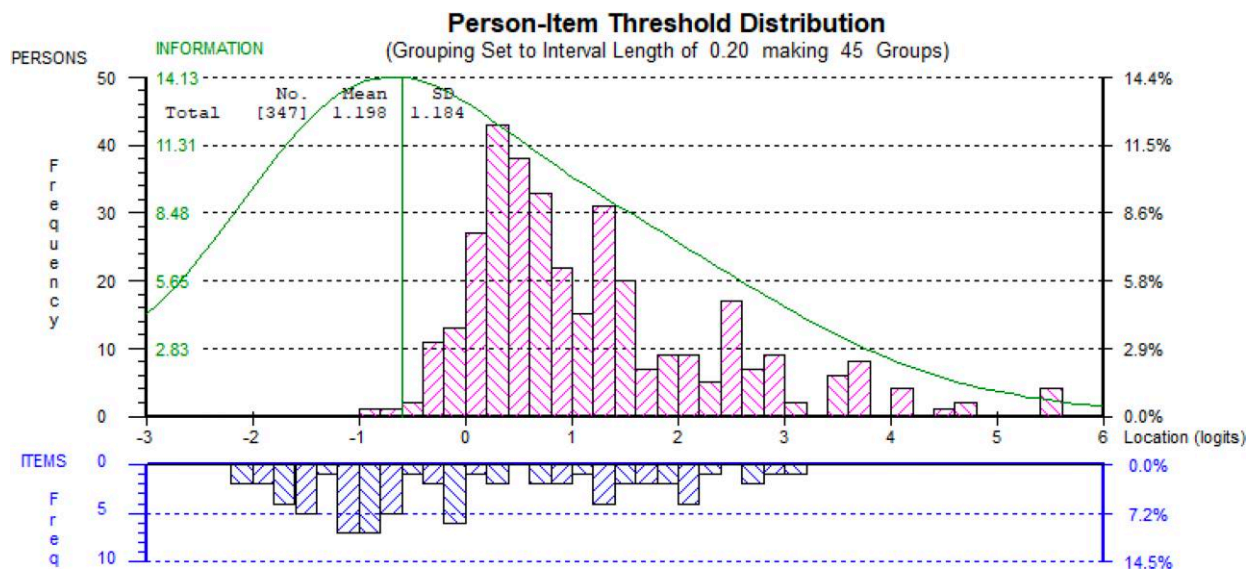


Figure 3. Targeting of animal HCP scale (23 items). This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

training on ABR, where scores were used as the main outcome to analyse any possible relationships with independent variables. Bivariate analysis included *t*-tests, one-way ANOVA with Tukey *post hoc* analysis or with Mann-Whitney *U*-test or Kruskal-Wallis depending on data distribution, at a significance level of 0.05.

A set of variables assessing prescription practices was initially included in the questionnaire. However, most questions were removed from the final analysis because these items performed poorly in relation to the qualitative research, which suggested a normative bias in respondent reporting. The items included in the final version of the questionnaires and analysed here are described in [Supplementary Material](#), Table S3.

Ethical considerations

Consent was requested from participants either on paper or by including the consent form, designed in local language, as the first page of the

online questionnaires. To encourage participation incentives were used in Peru and Vietnam, where participants could enter a prize draw for medical books or a book voucher, respectively, on survey completion through an anonymized link. Ethical approval was granted by the Ethics Committee of the London School of Hygiene and Tropical Medicine (United Kingdom) individually for each study site, reference numbers: 15167 (Ghana), 15053 (Nigeria), 15258 (Peru), 15105 (Tanzania), 15481 (Thailand) and 15255 (Vietnam), and by local ethics committees. Additional information on the local ethical approval is included in the [Supplementary material](#) p. 4.

Results

In total, 1091 participants (726 HHCPs and 365 AHCPs) agreed to participate in the study and filled in the questionnaires (Table 1).

Table 2. Descriptive statistics for participants scores by country

Country	Type of HCP	Valid respondents ^a	Scores mean	Scores SE	Scores median	IQR	Minimum score	Maximum score	95% CI	
									Lower bound	Upper bound
Ghana	Human	104	61.2	0.92	59.7	11.4	40.77	92.01	59.39	63.05
Nigeria	Human	85	59.7	1.15	57.1	13.4	43.97	100	57.40	61.96
Tanzania	Human	126	56.6	0.88	54.6	9.8	35.29	100	54.80	58.29
Vietnam	Human	226	57.5	0.67	55.4	8.3	41.59	100	56.18	58.83
	Animal	156	58.2	0.84	55.2	11.3	40.95	100	56.58	59.91
Thailand	Animal	41	66.1	1.85	63.8	20.4	50.4	92.47	62.37	69.85
Peru	Human	84	65.6	1.33	63.5	17.9	47.03	100	62.99	68.26
	Animal	119	61.2	0.94	57.8	15.1	46	100	59.30	63.04

^aStatistics based on participants with 23 valid answers in the ABR awareness scale. IQR=interquartile range.

Note that while the countries are positioned side by side, it is important to note that scores should be interpreted within-country rather than compared across countries, for example as baseline data within a given country.

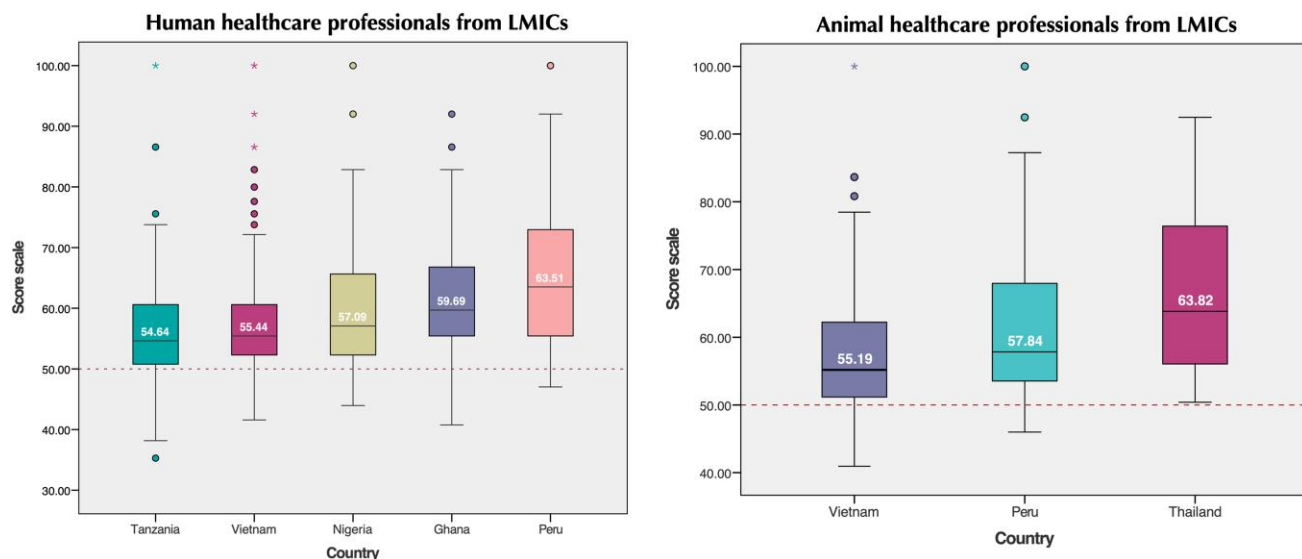


Figure 4. Distribution of scores in the ABR awareness scale by country for HHCPs (left) and AHCPs (right). Due to the presence of outliers, the median is used here as the main statistics reported. Note that while the countries are positioned side by side, it is important to note that scores should be interpreted within-country rather than compared across countries, for example as baseline data within a given country. This figure appears in colour in the online version of JAC and in black and white in the print version of JAC.

Response rates varied across countries from 12% to 88% depending on the country tested, health sector and survey delivery format. For AHCPs the sample size fell short by 20 participants. Only 941 (86.3%) respondents (625 HHCPs and 316 AHCPs) were included in the final analysis as a requirement to score the questionnaires was that participants did not have missing values in any of the 23 items related to the ABR awareness scale.³⁰

Performance of the HCP ABR awareness scale

The ABR awareness module of the questionnaires was reduced in dimension to 23 items, under four domains of ABR knowledge: mechanisms of ABR; antibiotic use (ABU) as a driver of resistance; transmission and infection control of ABR and detecting and

recognizing ABR. The 23-items of the scale were those identified as contributing to the construct of ABR awareness whereas the items removed were those more closely related to practices. The domains identified as relevant for ABR awareness were the same for both versions of the questionnaire. Further details of the item reduction—including item fit validity, targeting, item dependency, reliability and stability of items—are described in detail in a separate report.³⁰

The Rasch analysis to assess and validate the scale was performed on each country’s data. Because not all items worked well in the scale across different languages and settings, questionnaires were validated in English language for HHCPs and in Spanish, Thai and Vietnamese language for AHCPs. The most coherent analysis included questionnaires administered in English

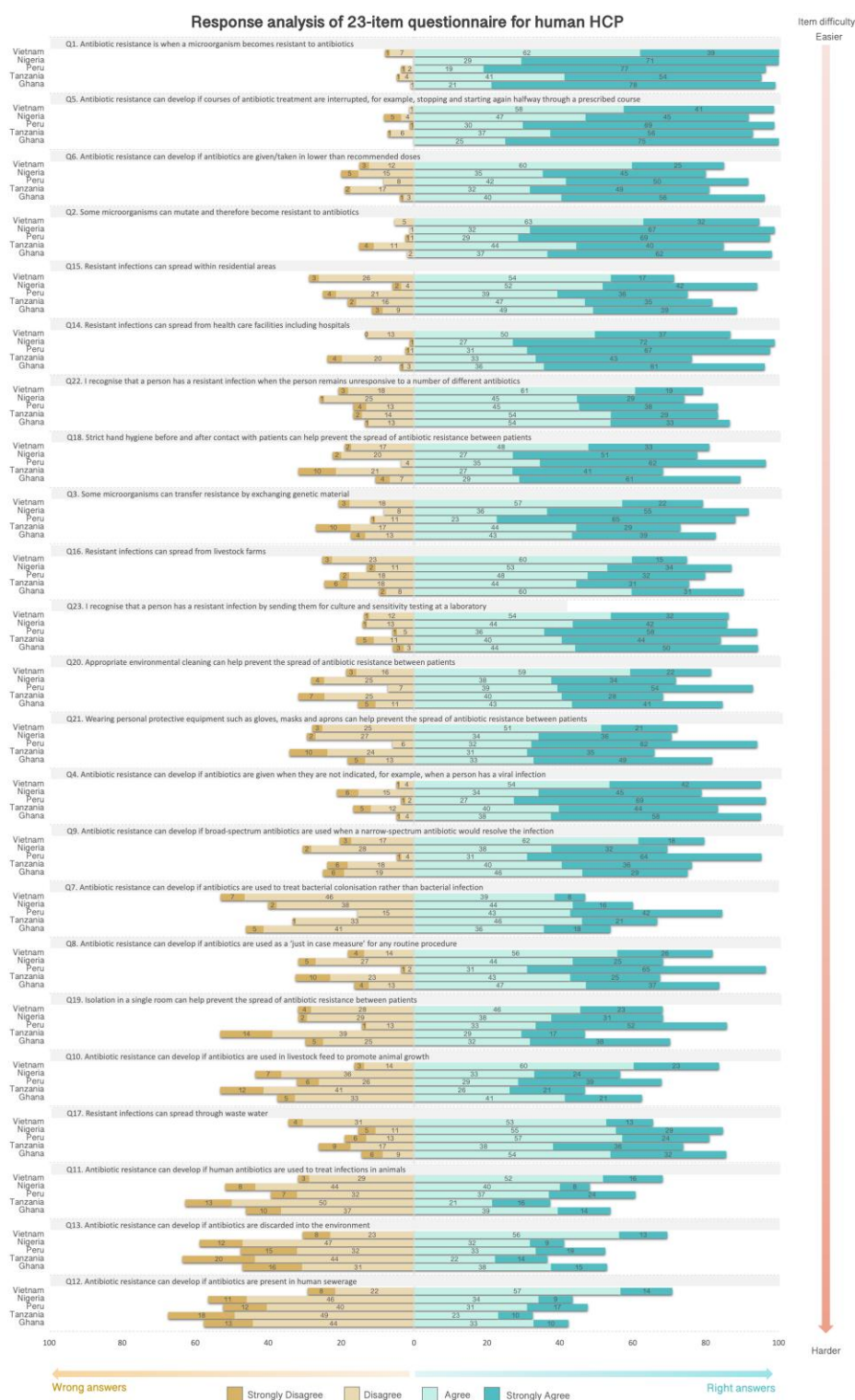


Figure 5. Response analysis of ABR awareness module used to calculate scores (23-item) for HHCPs. Items are ordered by level of difficulty, from easier to harder (vertical arrow on the right). Every bar in the graph represents the percentages of participant responses to every item in the Likert scale. To the right, there are the percentages of participants that 'strongly agree' or 'agree' with the items, and to the left, the percentages of participants that 'strongly disagree' and 'disagree' with the items. S1A (Mechanisms of ABR), S1B (ABU as a driver of ABR), S1C (Transmission and control of ABR infections) and S1D (Detecting/recognizing ABR) are the codes of the location of the items in the conceptual framework. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

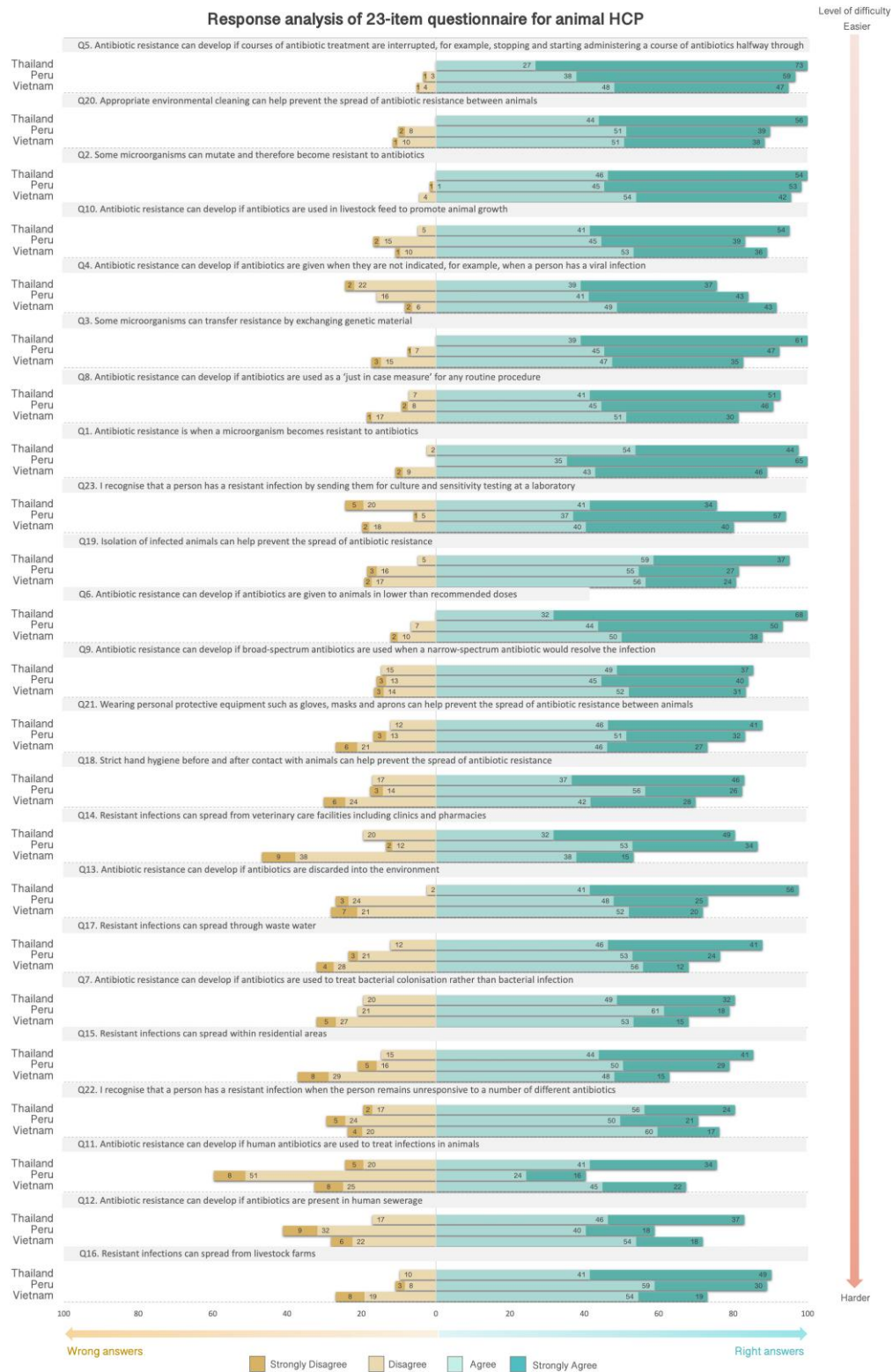


Figure 6. Response analysis of ABR awareness module used to calculate scores (23-item) for AHCPs. Items are ordered by level of difficulty, from easier to harder (vertical arrow on the right). Every bar in the graph represents the percentages of participant responses to every item in the Likert scale. To the right, there are the percentages of participants that ‘strongly agree’ or ‘agree’ with the items, and to the left, the percentages of participants that ‘strongly disagree’ and ‘disagree’ with the items. S1A (Mechanisms of ABR), S1B (ABU as a driver of ABR), S1C (Transmission and control of ABR infections) and S1D (Detecting/recognizing ABR) are the codes of the location of the items in the conceptual framework. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

language over 342 HHCPs from Ghana ($n=106$), Nigeria ($n=112$) and Tanzania ($n=124$), and in Spanish, Thai and Vietnamese language over 348 AHCPs from Peru ($n=122$), Thailand ($n=43$) and Vietnam ($n=183$), respectively. It was not possible to combine the HHCPs and AHCPs data and maintain a coherent analysis (Figures 2 and 3).

Data from neither questionnaire, was a good fit to the Rasch model ($P<0.001$) based on six and five class intervals. However, the reliability coefficients were high (Person Separation Index of 0.88 for HHCPs and 0.90 for AHCPs).³⁰ Questionnaires were recommended to be used for analysis within rather than across countries and in the languages tested until further validation is undertaken. Versions of the developed scale can be found in English, Spanish, Vietnamese and Thai languages in the [Supplementary material](#) (Tables S4.1–S4.4). The output of the Rasch analysis was a scale that was used to calculate participants' scores (Table S5). Items in the questionnaires were located on the scale from easiest to hardest (Tables S6 and S7).

Awareness scores

Results on awareness scores for professionals in each country are presented in Table 2 and distribution of scores in Figure 4. This figure should be considered as within-country scores that can form, for example, a baseline for subsequent surveys rather than interpreted comparatively across countries. Median scores ranged from 54.6 (IQR=9.8) Tanzanian to 63.5 (IQR=17.9) Peruvian HHCPs and 55.4 (IQR=8.3) Vietnamese to 63.8 (IQR=20.4) Thai AHCPs.

Participants' responses to each item of the ABR awareness module mirrored the level of difficulty of the conceptual framework for both HHCPs and AHCPs. Items classified as easier by the Rasch model were those more commonly correctly answered, whereas those classified as more difficult showed more answer variations. The same trends were seen for all countries: however, small variations were observed between health sectors. Figure 5 (HHCPs) and Figure 6 (AHCPs) show the distribution of answers for each item of the ABR awareness module by country. For HHCPs, item 17 (spread of ABR through wastewater) was one of the most difficult items (position 20 in the scale) according to the Rasch model, however, the percentage of wrong answers for this item was smaller compared with other items in the scale around the same location. In Vietnam, item 7 (use of antibiotics to treat bacterial colonization) seemed to be the most difficult one (position 16 in the scale), in Nigeria item 13 (development of ABR if antibiotics are discarded into the environment) (position 22 in the scale), and in Peru, Ghana and Tanzania item 12 (development of ABR if antibiotics were present in human sewerage), as expected according to the prediction model.

Participants' background and awareness scores

The analysis of demographic variables and ABR awareness scores showed statistically significant associations between scores and profession, training level and type of practice for HHCPs in some countries. No associations were seen between scores and gender or age (Table 3). For AHCPs, no associations were seen between scores and demographic variables, except by type of practice in Vietnam where those working in public practices scored

statistically higher ($P=0.002$) than those working in private practices (65.8 versus 58.41) (Table 4).

Profession was statistically significantly associated with scores for Ghanaian (pharmacists 68.71 versus physicians 59.73; $P=0.004$), Tanzania (physicians 60.43 versus pharmacists 61.93; $P=0.003$) and Peruvian HHCPs (physicians 70.42 versus dentists 57.48; $P<0.001$). Likewise, Tanzanian HHCPs with university degrees scored higher (60.12 versus 54.09, respectively; $P=0.002$) than those trained at non-university institutions. Furthermore, Peruvian HHCPs working in tertiary care hospitals (72.5) or in public hospitals (70.9) had statistically significantly higher scores ($P=0.01$) than those in primary (64.2) or secondary care (61.1) and in private practice (61.6).

Training on ABR

Overall, 34.7% of HHCPs said they had attended specific training on AMR or AMS (30.8% Ghana, 35.3% Nigeria, 42.9% Peru, 25.4% Tanzania and 38.5% Vietnam). In Peru and Vietnam, those who indicated that they were taught about ABR as part of their curricula had statistically significantly higher scores ($P<0.001$ for HHCPs and $P=0.043$ for AHCPs, respectively) than those who did not (Table 5). Among AHCPs, fewer received specific ABR training in Peru (25.2%) than in Thailand (78.0%) or Vietnam (55.1%) (Table 6).

Context of antibiotic practice

Factual context factors such as the presence or absence of particular resources, presence of other diseases or receiving information appeared to provide reliable findings, when compared with the qualitative research carried out alongside the development of the questionnaires. Items that provided useful information were re-grouped together in three sections: 'prioritization', 'resources' and 'information'.

AMR prioritization

Across most countries, both HHCPs and AHCPs reported that their medical decisions on prescribing antibiotics were driven by a fear of worse health outcomes (HHCPs: 62.5% Ghana, 75.3% Nigeria, 63.5% Tanzania, 68.1% Vietnam and 39.3% Peru. AHCPs: 68.9% Peru, 58.5% Thailand and 88.5% Vietnam). For example, they were more concerned about the level of hygiene and sanitation than ABR (HHCPs: 60.6% Ghana, 63.5% Nigeria, 60.7% Peru, 48.4% Tanzania and 38.5% Vietnam; AHCPs: 57.1% Peru, 65.9% Thailand and 81.4% Vietnam).

Various disease groups were also considered of higher concern than ABR among HHCPs in Africa. Infectious diseases such as TB, malaria and HIV were frequently considered more important, as well as trauma and accidents. Chronic diseases were considered more important by HHCPs across countries and malnutrition more so in Nigeria than elsewhere. Among AHCPs, more than half were more concerned about chronic diseases in Vietnam, Peru and Thailand. In Vietnam, malnutrition and infectious diseases were also a concern (Table S8).

Resource availability

The 'context' module asked HCPs about availability of relevant resources, receipt of information about ABR and potential ABR concerns. Among both HHCPs and AHCPs, many reported that the

Table 3. Demographic characteristics relationships with ABR awareness scores for human HCPs^d

Variable	Description	Ghana (n=104)						Nigeria (n=85)					
		N (%)	Mean	SE	CI 95%		P value	N (%)	Mean	SE	CI 95%		P value
					Lower	Upper					Lower	Upper	
Profession	Doctor	48 (46.2)	59.7 ^b	1.1	57.6	61.9	0.004 ^c	55 (64.7)	59.27	1.4	56.5	62.0	0.156
	Dentist	2 (1.9)	71.4	20.6	57.2	92.0		8 (9.4)	54.04	3.0	47.0	61.1	
	Nurse	21 (20.2)	60.7	1.8	56.8	64.5		—	—	—	—	—	
	Pharmacist	15 (14.4)	68.7 ^a	2.9	62.4	75.0		21 (24.7)	62.37	2.6	57.0	67.8	
	Physician Assistant	18 (17.3)	58.5 ^b	2.0	54.2	62.7		—	—	—	—	—	
	Medical Officer	—	—	—	—	—		—	—	—	—	—	
Gender	Male	66 (63.5)	61.5	1.1	59.4	63.6	0.809	45 (52.9)	61.42	1.7	57.9	64.9	0.106
	Female	37 (35.6)	60.8	1.8	57.1	64.4		40 (47.1)	57.71	1.4	54.9	60.5	
Age	18 to 25	10 (9.6)	62.2	2.7	56.0	68.3	0.329	8 (9.4)	57.28	2.4	51.7	62.9	0.711
	26 to 35	52 (50.0)	62.3	1.3	59.7	65.0		52 (61.2)	59.92	1.6	56.7	63.2	
	36 to 45	16 (15.4)	61.4	2.6	55.9	66.9		18 (21.2)	61.22	2.3	56.3	66.1	
	46 to 55	13 (12.5)	56.4	2.7	50.6	62.2		7 (8.2)	56.64	2.7	50.0	63.3	
	> 55	9 (8.7)	58.9	2.9	52.3	65.7		—	—	—	—	—	
Training level	Non-University	—	—	—	—	—	NC	—	—	—	—	—	0.741
	University	104 (100)	61.2	0.9	59.4	63.0		29 (34.1)	60.07	2.1	55.7	64.5	
	Specialist	—	—	—	—	—		55 (64.7)	59.27	1.4	56.5	62.0	
	Postgraduate (MSc, PhD)	—	—	—	—	—		—	—	—	—	—	
Type of care ^e	Primary Care	32 (30.8)	59.4	1.33	56.7	62.1	0.05	—	—	—	—	—	NC
	Secondary Care	54 (51.9)	63.3	1.47	60.4	66.3		—	—	—	—	—	
	Tertiary Care	18 (17.3)	58.1	1.44	55	61.1		85 (100)	59.7	1.14	57.4	62	
Type of Practice	Public practice	78 (75)	60.5	1.09	58.3	62.7	0.24	85 (100)	59.7	1.14	57.4	62	NC
	Private practice	11 (10.6)	61.2	1.93	56.9	65.5		—	—	—	—	—	
	Public and Private practice	15 (14.4)	65	2.46	59.7	70.3		—	—	—	—	—	

SE: Standard error, CI: Confidence interval, NC: Not calculated.

^{a,b}Different letters in different rows indicate statistical differences between groups.

^cStatistical differences ($P < 0.05$). All P values were calculated with ANOVA and Tukey *post hoc* comparison test. All significant values are two-tailed.

^dIncludes only participants without missing values in the 23-item scale who replied to the question, therefore differences in numbers of participants across calculations may vary accordingly.

^e18 participants from Tanzania did not indicate the level of care of their working centres.

Note that while the countries are positioned side by side, it is important to note that scores should be interpreted within-country rather than compared across countries, for example as baseline data within a given country.

Tanzania (n=126)						Peru (n=84)						Vietnam (n=226)					
N (%)	Mean	SE	CI 95%		P value	N (%)	Mean	SE	CI 95%		P value	N (%)	Mean	SE	CI 95%		P value
			Lower	Upper					Lower	Upper					Lower	Upper	
32 (25.4)	60.4 ^a	2.1	56.2	64.7	0.003 ^c	53 (63.1)	70.4 ^a	1.6	67.2	73.7	0.000 ^c	73 (32.3)	57.9	1.1	55.7	60.2	0.912
8 (6.3)	54.1	2.7	47.7	60.5		30 (35.7)	57.5 ^b	1.4	54.6	60.4		—	—	—	—		
56 (44.4)	54.7	0.9	52.9	56.4	—	—	—	—	—	—	—	53 (23.5)	57.1	1.5	54.1	60.0	—
14 (11.1)	61.9 ^a	3.9	53.6	70.3	—	—	—	—	—	—	—	62 (27.4)	56.9	1.3	54.4	59.6	—
—	—	—	—	—	—	—	—	—	—	—	—	38 (16.8)	58.0	1.7	54.7	61.4	—
16 (12.7)	51.9 ^b	1.9	47.9	56.0	—	—	—	—	—	—	—	—	—	—	—	—	—
57 (45.2)	57.7	1.4	54.9	60.5	0.223	42 (50.0)	68.2	1.9	64.3	72.0	0.055	73 (32.3)	57.1	1.0	55.2	59.1	0.701
69 (54.8)	55.6	1.1	53.3	57.8	—	42 (50.0)	63.1	1.8	59.5	66.7	—	153 (67.7)	57.7	0.9	55.9	59.4	—
16 (12.7)	55.9	2.1	51.6	60.3	0.364	14 (16.7)	61.4	1.9	57.2	65.6	0.067	16 (7.1)	61.2	2.5	55.9	66.4	0.119
53 (42.1)	58.6	1.6	55.4	61.9	—	39 (46.4)	66.3	2.1	62.1	70.5	—	93 (41.2)	57.3	1.1	55.1	59.5	—
27 (21.4)	54.9	1.6	51.7	58.3	—	22 (26.2)	63.5	2.4	58.5	68.5	—	43 (19)	55.7	1.4	52.9	58.4	—
12 (9.5)	53.3	1.6	49.8	56.7	—	3 (3.6)	67.7	7.0	37.8	97.7	—	52 (23)	57.7	1.3	55.2	60.2	—
10 (7.9)	56.8	2.8	50.4	63.1	—	6 (7.1)	77.8	5.7	63.1	92.6	—	5 (2.2)	66.1	5.6	50.7	81.6	—
72 (57.1)	54.1 ^b	1.1	52.0	56.2	0.001 ^c	—	—	—	—	—	0.776	95 (42)	58.3	1.2	55.8	60.7	0.588
47 (37.3)	60.1 ^a	1.5	57.1	63.2		38 (45.2)	66.4	2.1	62.2	70.5		107 (47.3)	56.8	0.9	55.1	58.5	
—	—	—	—	—	—	21 (25)	65.3	3.0	59.0	71.7	—	—	—	—	—	—	—
1 (0.8)	70.7	—	—	—	—	21 (25)	63.9	2.1	59.5	68.5	—	18 (8)	57.7	1.8	54.0	61.5	—
33 (26.2)	55.9	2.07	51.7	60.1	0.95	41 (48.8)	64.2 ^b	1.73	60.7	67.7	0.01 ^c	141 (62.4)	57.8	0.9	56	59.6	0.65
57 (45.2)	56.5	1.16	54.2	58.8	—	19 (22.6)	61.1 ^b	2.69	55.4	66.7	—	83 (36.7)	57.2	0.99	55.2	59.1	—
14 (11.1)	56.7	2.54	51.2	62.1	—	20 (23.8)	72.5 ^a	2.96	66.3	78.7	—	—	—	—	—	—	—
79 (62.7)	55.7	0.84	54.1	57.4	0.09	31 (36.9)	70.9 ^a	2.45	66	76	0.01 ^c	191 (84.5)	57.5	0.77	56	59	0.98
32 (25.4)	56.7	1.76	53.2	60.3	—	35 (41.7)	61.6 ^b	1.73	58.1	65.1	—	20 (8.8)	57.9	0.86	56.1	59.7	—
12 (9.5)	62.4	5.48	50.4	74.5	—	13 (15.5)	63.8	2.85	57.6	70	—	12 (5.3)	57.9	2.71	51.9	63.8	—

Table 4. Demographic characteristics relationships with ABR awareness scores for AHCPs^d

Variable	Description	N (%)	Thailand (n = 41)					Peru (n = 119)					Vietnam (n = 156)						
			Score mean	CI 95%		SE	P value	N (%)	Score mean	CI 95%		SE	P value	N (%)	Score mean	CI 95%		SE	P value
				Lower	Upper					Lower	Upper					Lower	Upper		
Profession	Veterinarian	41 (100)	66.4	1.9	62.6	70.2	NC	119 (100)	61.2	1.0	59.3	63.1	NC	69 (44.2)	60.2	1.4	57.5	63.0	0.077
	Veterinary drug seller	—	—	—	—	—	—	—	—	—	—	—	—	18 (11.5)	54.3	1.6	51.0	57.6	—
Gender	Veterinarian and drug seller	—	—	—	—	—	—	—	—	—	—	—	—	64 (41.0)	57.5	1.3	54.9	60.1	—
	Male	18 (43.9)	66.8	2.3	61.8	71.7	0.53	65 (54.6)	60.7	1.1	58.5	62.9	0.534	115 (73.7)	58.7	1.0	56.6	60.7	0.409
Age	Female	2 (48.8)	67.0	3.1	60.6	73.5	—	53 (44.5)	61.9	1.6	58.6	65.1	—	41 (26.3)	57.1	1.4	54.2	60.0	—
	18 to 25	3 (7.3)	70.5	6.7	41.7	99.3	0.42	1 (0.8)	76.4	—	—	—	0.126	4 (2.6)	53.8	2.8	44.9	62.7	0.265
	26 to 35	16 (39.0)	67.3	3.1	60.7	73.8	—	43 (36.1)	62.8	1.4	59.9	65.6	—	27 (17.3)	60.2	2.4	55.3	65.1	—
	36 to 45	14 (34.1)	67.4	3.4	60.1	74.7	—	37 (31.1)	61.8	2.1	57.6	65.9	—	54 (34.6)	58.0	1.4	55.2	60.8	—
	46 to 55	7 (17.1)	58.2	3.3	50.3	66.2	—	21 (17.6)	60.1	1.7	56.6	63.7	—	47 (30.1)	57.3	1.5	54.2	60.4	—
Training level	> 55	1 (2.4)	71.4	—	—	—	—	16 (13.4)	56.3	2.3	51.3	61.2	—	14 (9.0)	63.5	2.8	57.4	69.6	—
	Non-University	ND	—	—	—	—	—	48 (40.3)	60.9	1.3	58.3	63.5	0.619	66 (42.3)	56.3	1.2	53.9	58.6	0.071
	University	ND	—	—	—	—	—	28 (23.5)	60.5	2.0	56.3	64.6	—	79 (50.6)	59.3	1.3	56.8	61.8	—
	Specialist	ND	—	—	—	—	—	40 (33.6)	62.7	1.8	59.0	66.4	—	—	—	—	—	—	—
Year prescribing/dispensing ^e	Postgraduate (MSc, PhD)	ND	—	—	—	—	—	—	—	—	—	—	—	8 (5.1)	63.9	3.7	55.2	72.7	—
	0 a 5	14 (34.1)	66.2	3.3	59.1	73.4	0.938	41 (34.5)	61.9	1.5	58.9	65.0	0.801	10 (6.4)	55.5	3.5	47.6	63.4	0.405
	6 a 10	8 (19.5)	67.5	3.9	58.3	76.6	—	33 (27.7)	62.3	2.2	57.7	66.8	—	20 (12.8)	58.3	1.8	54.4	62.1	—
	11 a 20	14 (34.1)	66.1	3.6	58.4	73.9	—	24 (20.2)	60.4	1.5	57.2	63.6	—	27 (17.3)	60.0	2.1	55.6	64.3	—
	21 a 30	4 (9.8)	61.7	5.1	45.4	78.0	—	7 (5.9)	56.3	3.7	47.2	65.3	—	24 (15.4)	55.8	1.6	52.5	59.1	—
	31 a 40	1 (2.4)	71.4	—	—	—	—	3 (2.5)	62.7	9.7	20.7	104.6	—	2 (1.3)	51.4	4.7	-7.9	110.7	—
Type of Practice	40+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Public practice	12 (29.3)	72.1	3.9	63.6	80.6	0.07	20 (16.8)	64.7	2.6	59.3	70.0	0.233	29 (18.6)	64.12 ^a	2.4	59.3	69.0	0.002 ^c
	Private practice	21 (51.2)	62.4	2.2	57.7	67.0	—	63 (52.9)	60.1	1.2	57.8	62.5	—	89 (57.1)	56.27 ^b	1.0	54.3	58.2	—
Practice	Public and Private practice	8 (19.5)	67.0	3.9	57.9	76.1	—	35 (29.4)	61.2	1.9	57.4	65.1	—	36 (23.1)	58.5	1.7	55.0	62.0	—

SE: Standard error, CI: Confidence interval, NR: Not relevant, NC: Not calculated.

^{a,b}Different letters in different rows indicate statistical differences between groups.

^cStatistical differences ($P < 0.05$). All P values were calculated with ANOVA with Tukey post hoc comparison test. All significant values are two-tailed.

^dIncludes only participants without missing values in the 23-item scale who replied to the question; therefore, differences in the number of participants across calculations may vary accordingly.

^e11 and 73 participants from Peru and Vietnam, respectively, did not indicate the number of years prescribing/dispensing.

Note that while the countries are positioned side by side, it is important to note that scores should be interpreted within-country rather than compared across countries, for example, as baseline data within a given country.

Table 5. Relationships between previous ABR training for HHCPs and awareness scores by country^b

Items	Ghana			Nigeria			Peru			Tanzania			Vietnam		
	N	%	Score mean	N	%	Score mean	N	%	Score mean	N	%	Score mean	N	%	Score mean
I was taught everything I needed to know about Antibiotic Resistance as part of my training curriculum	64	61.5	61.7	54	63.5	61.3	46	54.8	69.4	99	78.6	56.9	169	74.8	57.9
The information and training I currently receive on Antibiotic Resistance are adequate for my day-to-day practice	40	38.5	60.4	25	29.4	57.1	38	45.2	61	26	20.6	54.8	56	24.8	57.9
I have attended specific training on Antibiotic Resistance and/or Antibiotic Stewardship	67	64.4	61.8	42	49.4	60.2	54	64.3	68.1	92	73	57.2	128	56.6	57.3
	37	35.6	60.1	37	43.5	59.8	30	35.7	61.1	33	26.2	54.4	97	42.9	57.8
	32	30.8	62	30	35.3	62.3	36	42.9	68.7	32	25.4	57.2	87	38.5	58.2
	72	69.2	60.9	49	57.6	58.6	48	57.1	63.3	92	73	56.3	138	61.1	57.1

^aStatistical differences ($P < 0.05$). All significant values are two-tailed.

^bIncludes only participants without missing values in the 23-item scale who replied to the question; therefore, differences in the number of participants across calculations may vary accordingly.

Note that while the countries are positioned side by side, it is important to note that scores should be interpreted within-country rather than compared across countries, for example, as baseline data within a given country.

availability of laboratory services affected their decisions to prescribe/dispense antibiotics. Indeed, those who had nearby facilities where they could send their samples for culture and sensitivity testing tended to score higher in the scale than those without nearby facilities. However, the capacity of facilities to provide culture and sensitivity testing was often considered insufficient, although this varied between countries. Confidence in the equipment and staff availability at laboratories was lower for AHCPs than HHCPs, and lower in Vietnam than other settings. While in most countries over 80% participants did report having access to running water and over 88% had electricity at their workplace, only around two-thirds reported having access to the best antibiotic to treat particular infections at their workplace (Table S9).

Access to information about ABR

Around two-thirds of respondents felt the information received on ABR was not adequate to inform their day-to-day practice, especially among Peruvian AHCPs than elsewhere. In Vietnam and Thailand, access to local data on ABR was reported to be adequate by most respondents. However, in general, most participants felt they had inadequate access to local ABR patterns, with less than one-third reporting having access to them. In most settings, respondents reported that nobody at their workplace was monitoring ABR, except by AHCPs in Thailand. Among those AHCPs who reported workplace ABR monitoring their score was higher than those who do not.

Many respondents were aware of ABR campaigns, which was associated with a slightly higher awareness score among HHCPs but not AHCPs. Most participants across countries were interested in receiving more information about ABR, either online or at work, and indicated a willingness to participate in further training on ABR.

Overall, two-thirds of participants reported being exposed to advertising about antibiotics. Most respondents had sometimes or often received information and samples about antibiotics from medical representatives. Across both sectors, those who had often received samples from medical representatives scored higher in ABR awareness than others, suggesting that this could be a source of information about antibiotics (Table S10).

Discussion

ABR awareness raising is a cornerstone of the WHO GAP and, therefore, of many NAPs. Previous studies have attempted to develop surveys to measure factors associated with ABU among HCPs and the general public,^{31,32} however, these studies had specific target populations, and a full development and validation process of the tools had not been followed.³² In this study, two ABR awareness questionnaires were developed and validated to provide scores as a measurement of level of ABR awareness among HHCPs and AHCPs.

The development of a validated scale was a complex process that raised the question of whether ABR awareness is a single coherent and measurable construct. The similarities in biomedical training around the world, however, provided a platform for the development of the linear scale. We did not objectively measure HCPs' prescribing practices and therefore the relationship between practice and awareness remains to be tested, and it is possible that better ABR awareness does not correlate with better

Table 6. Relationships between previous ABR training for AHCPs and awareness scores by country^b

Items		Peru				Thailand				Vietnam			
		N	%	Score mean	P value	N	%	Score mean	P value	N	%	Score mean	P value
I was taught everything I needed to know about Antibiotic Resistance as part of my training curriculum	Agree	55	46.2	59.6	0.116	35	85.4	66.64	0.943	122	78.2	59.06	0.043 ^a
	Disagree	64	53.8	62.51		4	9.8	67.1		31	19.9	54.75	
The information and training I currently receive on Antibiotic Resistance are adequate for my day-to-day practice	Agree	46	38.7	61.78	0.475	27	65.9	66.07	0.632	86	55.1	58.26	0.979
	Disagree	72	60.5	60.41		12	29.3	68.08		69	44.2	58.22	
I have attended specific training on Antibiotic Resistance and/or Antibiotic Stewardship	Yes	30	25.2	64	0.08	32	78	65.2	0.095	86	55.1	59.3	0.177
	No	89	74.8	60.2		7	17.1	73.5		69	44.2	57	

^aStatistical differences ($P < 0.05$). All significant values are two-tailed.

^bIncludes only participants without missing values in the 23-item scale who replied to the question; therefore, differences in the number of participants across calculations may vary accordingly.

Note that while the countries are positioned side by side, it is important to note that scores should be interpreted within-country rather than compared across countries, for example, as baseline data within a given country.

antibiotic prescription.³³ However, as good ABR awareness levels have been signalled as a prerequisite for the success of behavioural change activities regarding ABU,^{34,35} it was crucial to design a tool that enables such a measurement. Moreover, context-specific factors could influence antibiotic prescription/dispensing as much as awareness, highlighting the importance of their documentation as part of awareness surveys.

Validation of ABR awareness questionnaires

The developed scale comprises items in four domains of ABR knowledge, and these are similar for both human and AHCPs. This suggests that many of the concepts relevant to ABR awareness are shared by HCPs regardless of their background, and the minor differences might be related to the nature of their patients. Data misfits and challenges with some of the Rasch Measurement Theory criteria were seen during the validation process, although the questionnaires showed to be highly reliable and performed well enough to be used within the countries tested, and scores were recommended to be analysed as groups instead of individuals. Additionally, results obtained from respondents suggest that the level of item difficulty of the conceptual framework of ABR awareness questionnaire fitted well the Rasch model.

Even though the questionnaires were validated to produce ABR awareness scores in this study, it is recommended that, for optimal assessments across countries, these tools undergo further rounds of testing in different scenarios before using them as a globally standardized scale. Additionally, when implementing these versions of the questionnaires, the wording of the items should remain unchanged unless the rewording is validated.

ABR awareness scores

The results indicate that the levels of ABR awareness among HHCPs and AHCPs was reasonable but not high (median scores of 54.6 to 63.5 for HHCPs, and 55.4 to 63.8 for AHCPs) on a

0–100 scale. Scores for both health sectors were below the 75th percentile, which indicates that there are topics regarding ABR that remain unknown. In general, some variation in knowledge of ABR-related topics was observed in different countries, however, topics related to use of antibiotics in animals as a driver of ABR, and the spread of antibiotics residues and ABR through the environment, were incorrectly answered across many HCPs, regardless of their background. Interestingly, the item related to the potential of ABR development when human antibiotics are used in animals was one of the most unknown topics in all countries tested and both health sectors. Overall, while bacterial mechanisms of ABR and ABU in humans are reasonable well-known topics, ABU in animals and the impact of this in disseminating ABR in the environment are fairly unknown topics, indicating potential gaps in the training curricula of HCPs and highlighting the importance of applying a One Health approach when designing training programmes.

Previous studies have reported better than expected levels of awareness about ABR among HCPs and the public in different countries.^{2,20} Studies conducted in Peru,³⁶ Ghana³⁷ and Nigeria³⁸ documented high awareness levels among physicians in some cities of these countries. However, methodologies used, questions asked, types of participant and topics included varied from the ones used in this study, making comparisons difficult.

The heterogeneity in awareness between different types of HCPs was unsurprising, considering that professions such as medicine and veterinary medicine that involve more years of study, responsibilities and wider scope of actions, are likely to have more content in their training curricula regarding diagnostic and treatment of diseases than other health professions. Nonetheless, all participants were prescribers/dispensers, and the findings indicate that preservice training about antibiotics and resistance may need to be enhanced particularly for nurses, pharmacists and veterinary drug sellers. Differences in scores between different types of HCPs

also suggests that professionals' backgrounds should be considered when planning AMR awareness campaigns, as diversity in the gaps of their knowledge could lead to information being absorbed differently.

Medical practices

Despite previous experiences with ABR cases, high awareness scores were not necessarily a good indicator of good practices when prescribing or dispensing antibiotics, as HCPs with high scores also reported agreeing with practices that could contribute to the development of ABR. We suggest that actual prescribing practices are captured through more reliable methods than self-reporting, such as point prevalence surveys or direct observation. Such objective practice measurement can then be compared with ABR awareness of individual practitioners.

Context of antibiotic practices

The working environments captured by the survey indicate additional factors that should be considered in understanding antibiotic practices, beyond AMR awareness. Many HCPs were working in facilities without laboratory testing facilities, and many reported a lack of confidence in the facilities they could access. Most HHCPs and AHCPs showed interest in receiving more information and participating in training about ABR. Access to information about ABR was statistically linked to scores, professionals being trained and/or having access to information scored significantly better. Taken together with the finding that participants from both health sectors reported fears of worse health outcomes if antibiotics were not prescribed, it is critical to ensure that HCPs are equipped with evidence about the likelihood common illnesses will benefit from antibiotic treatment—such as through the WHO's Antibiotic Book,³⁹ as well as information about sensitivity profiles of common pathogens of patients and animals in their care to guide choice of antibiotics.

Most participants did report access to running water and electricity in their workplace, suggesting a relatively privileged study sample given limited progress on WASH⁴⁰ in health facilities in the study countries. Future awareness assessment efforts should aim for as representative a sample as possible from across different settings within a given country.

These findings suggest that there is not a single contextual variable shaping medical practices but rather a set that may be informing the 'mindlines' (internalized and collectively reinforced tacit guidelines) of HCPs and the practices that have become common sensical.⁴¹ Beyond improving access to information and the context of practice, addressing ABR as a complex problem will need to extend to wider determinants of infection and resistance including medical, infrastructural, social, economic and political dimensions.⁴²

Some survey biases, such as non-response, social desirability and observer bias, were minimized by anonymization and the self-completion nature of the survey. Adjustments made to the inclusion criteria of some HCPs at each field site may have affected the results as the variability, and undefined lines between HCP roles between countries make drawing conclusions for this population difficult.

Conclusions

In this study, we developed a scale that provides a measurement of levels of ABR awareness at a group level, within countries and across HCPs from human and animal health sectors. This tool could be used to direct and track interventions to improve AMR awareness and to ascertain the success of these interventions, enabling cost-effectiveness evaluations. When combined with a module collecting information on contextual factors, and reliable data on prescribing practices, the tool could support the understanding of the ABR problem and the design of HCP-oriented interventions.

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Transparency declarations

None to declare.

Supplementary data

Tables S1 to S10 is available as [Supplementary data](#) at JAC online.

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