Understanding antimicrobial resistance from the perspective of public policy: a multinational knowledge, attitude, and practice survey to determine global awareness

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Abstract

Background

Minimizing the effect of antimicrobial resistance (AMR) requires an adequate policy response that relies on good governance and coordination. We have previously demonstrated a knowledge gap on infectious diseases within the general public, but equivalent data from a policy context are still lacking. The aim of this study is to have a better comprehension of how AMR is understood and perceived among policy makers and stakeholders in tackling AMR on a global level.

Methods

A digital survey was designed to capture the knowledge, attitude, and practices (KAP) towards AMR. A self-reporting questionnaire was distributed to politicians, policy advisors and relevant stakeholders, and survey responses were collected between November 2020 and March 2021.

Results

A total of 351 individuals participated in this study with 80% from high-income countries (HIC) and 20% from low- and middle-income countries (LMIC). Fifteen different countries were represented, and the majority of participants were from the Netherlands, Spain and Myanmar. Overall, participants had sufficient knowledge regarding AMR and reported the importance of political willingness in tackling AMR. More than half (65%) of participants from LMIC reported antibiotics misuse, and almost half (48%) claimed to be unaware of this health problem. Politicians and stakeholders from LMIC demonstrated a higher knowledge on AMR but showed poor perception and attitude toward antimicrobial use compared to those from HIC regions. HIC participants emphasized the role of the veterinary sector in particular, as well as the environmental dissemination of antibiotics and drug residues. The lack of funding resources was especially reported by participants from LMIC.

Conclusion

Inter-regional differences in KAP regarding AMR exist among politicians, policy advisors and relevant stakeholders. Overall, participants demonstrated to have a sufficient level of knowledge and awareness of AMR. This study characterizes a multi-national policymaker and stakeholder mapping that can be used to propose further policy implementation on various governance levels.

Background

Antimicrobial resistance (AMR) is a pressing global health threat that is sometimes referred to as the “silent tsunami” or the next pandemic (Microbiology Society, 2020). The misuse of antibiotics for the prophylactic treatment of COVID-19 patients during the SARS-CoV-2 pandemic accelerated this threat (Hsu, 2020). Moreover, the COVID-19 has highlighted that adequate policy responses, good governance and coordination mitigate the public health burden, suggesting that political efforts can have the same effect on AMR. The World Health Organization (WHO) endorsed its Global Action Plan on Antimicrobial Resistance (GAP-AMR) in 2015 (World Health Organization, 2015), providing countries with a framework for the development of a National Action Plan on AMR (NAP-AMR). A total of 78 countries have developed and implemented such a plan since 2015, and generally, national plans were closely aligned with the five strategic

objectives of the GAP-AMR (Mendelson & Matsoso, 2015). The overall objective of the GAP-AMR was to promote a multidisciplinary approach, focusing on the inclusion of politicians, stakeholders, and scientists in tackling AMR together. In 2021, a United Nations (UN) General High-Level Interactive Dialogue on AMR called for a One Health integrative approach in AMR surveillance and implementations, research and development (R&D), budget planning and evaluation of AMR in the context of COVID-19 (United Nations, 2021). The rapid development of initiatives and growing awareness for AMR by multilateral organizations underlines that tackling AMR requires active involvement of governance and stakeholders in a multidisciplinary context. Moreover, the interest in AMR from the scientific field has expanded significantly over a decade (Lu et al., 2020).

Previous scientific findings along with call-to-action reports from multilateral organizations suggest that political willingness and interest are the required driving forces for a successful strategy in tackling the growing AMR crisis. The knowledge, attitude, and perception (KAP) towards AMR from stakeholders, politicians and policymakers are therefore good indicators to assess the willingness to tackle AMR. Beliefs in the cause, magnitude and severity of the public health issue are affected by the knowledge and perception of the particular topic, and consequently affect governmental responses. Poor knowledge, awareness, or perception of politicians and stakeholders toward particular public health crises can hinder the progress in controlling an epidemic, as previously seen in delayed national responses to the HIV/AIDS epidemic (Oliver, 2006) or current COVID-19 pandemic (Adolph et al., 2021). A previous study in Singapore has shown that low levels of awareness of AMR among policy makers and stakeholders can compromise the progress of AMR initiatives regardless of resources. Their qualitative findings suggested that promoting awareness among policymakers and stakeholders is of critical importance to reduce the burden of AMR. (Singh et al., 2019).

The awareness of AMR from the perspective of national policymakers and stakeholders have not been fully explored yet, particularly on a global level. We have previously demonstrated a knowledge gap on infectious diseases within the general public (van Wijk et al., 2020), but a similar analysis from a policy context has not been done before. The optimal strategy for AMR control requires a multisectoral approach, embodied by the One Health concept. It is therefore critical to determine the KAP towards antibiotic consumption and resistance among focal persons from government and non-government sectors. Therefore, the current study aimed to capture these key indicators on a global level, covering both political and personal KAP levels. In the present study, we further investigated the variation in KAP status and AMR policy progress between high-income countries (HIC) and low-and middle-income countries (LMIC). These findings from politicians, policy makers and stakeholders are important in improving the political agenda toward AMR, but also highlight knowledge and awareness gaps that need to be addressed. Their insight on AMR policy across contexts will be helpful to formulate an evidence-based policy framework and innovation.

Methods

Design of survey

A digital survey was developed to assess the knowledge, awareness and perception (KAP) towards antimicrobial resistance of politicians and stakeholders on a global level (Supplementary file 1). An informed consent page was included to inform the participant with the objective of the study and to obtain the consent. The first section of the survey collected the sociodemographic characteristics of the participants such as gender, age, nationality, country of residence, level of education and field of expertise. Occupational position, level of governance, political view and political party affiliation (if applicable) were asked to capture the political background of every participant. Followed by demographic questions, the survey questionnaire consisted of five sections: 1) sociodemographic information, 2) statements (n = 7) that evaluated the knowledge of antimicrobial resistance, 3) statements (n = 5) that captured the attitude towards antimicrobial consumption, 4) statements (n = 14) that determined the political involvement, and 5) a

series of open-ended questions that capture the constraints and challenges, as well as achievements and on-going progress of political interventions aimed at combating AMR. A five-point Likert scale was provided as answer options to all close-ended statements. The survey was particularly aimed at citizens from the Netherlands, Spain, and Myanmar and was therefore translated into Dutch, Spanish, and Burmese. A translated survey version in French was also available for francophone countries.

Participant recruitment

Mailing lists were compiled of parliament members and governmental staff in Australia, Belgium, Canada, Curaçao, Israel, Morocco, the Netherlands, Nigeria, Spain, Singapore, and Surinam. Since Myanmar lacks an e-government system, Burmese individuals were recruited via convenience sampling, covering both politicians from various governance levels and stakeholders. Similarly with Spain, contact persons were reached to forward the survey invitations within their organisation and/or network. AMR ambassadors in Mexico, Nigeria and India from the AMR Insight network (<https://www.amr-insights.eu/>) were considered as relevant stakeholders and invited to participate in this study. A detailed overview of the number of invites sent per country can be found in supplementary file 2.

Data collection and transformation

Self-administered questionnaires were distributed to invited participants and each response was recorded using the online platform SurveyPlanet. Participants were recruited between November 2020 and March 2021. Participants were classified as working for a governmental or a non-governmental institution based on their job description. Participants that reported an expertise in human health and/or life sciences were considered as having a scientific expertise, whereas all other self-reported competences were assigned to 'other expertise'. Countries were classified as low-and-middle income (LMIC) or high-income (HIC) countries based on the 2021 World Bank classification (World Bank, 2021).

Scoring system

A scoring system was adapted based on a five-point Likert scale: strongly disagree and disagree (-0.5), neither agree nor disagree (0), agree and strongly agree (+ 1). Prior to scoring, the answer options were reversed for negative direct statements, ensuring that good answers were given a positive score (i.e. when strongly disagree was the right answer). The knowledge score was based on 7 statements, personal perception, and attitude scores on 6 statements, and knowledge, perception, and attitude score on political efforts and plans was based on 13 statements. The weighted cumulative scores were normalized to a maximum score of 10. Scores greater or equal to 7 were considered as good scores, whereas scores greater or equal to 5 were considered as a fair score.

Statistical analysis

R-studio version 1.1.447 was used for visualization and statistical analysis of all data. Fisher's exact test was performed to compare the proportion differences in demographics characteristics between LMIC and HIC. A univariate and multivariate logistic regression was used to determine the relationship between the good and fair score and participants' demographic background.

Ethical statement

Participants were asked to read the following description prior to starting the questionnaire: "This survey is intended to get insight into the awareness of politicians, decision-makers and other related professions as well as the current state of action plans that target antibiotic resistance. [...] This survey is completely voluntary and you can withdraw your consent at any time point. Please proceed if you have read this informed consent and agree to participate". Participation was completely voluntary and anonymous, and had no risk involved. The participant's data were kept

confidential and protected with a unique study-ID number. All participants read the description and gave informed consent to agree to participate. Only research personnel had access to data collected in this study.

Results

Participant characteristics

A total of 351 individuals participated in this study, with the vast majority (80.1%, n = 281) living in high-income countries (HIC) and the remaining 19.9% (n = 70) from low- and middle-income countries (LMIC). Among the participants, 51.9% (n = 182) were female, 46.4% (n = 163) were male and 1.7% (n = 6) did not enclose their gender. Half of the study sample (51.0%, n = 179) was between 40 and 60 years-of-age, 26.8% (n = 94) were younger than 40, and 22.2% (n = 78) were older than 60. Regarding occupational background, the vast majority (86.3%, n = 303) held positions at the government, while 12.8% (n = 45) worked for non-governmental organizations. Regarding participants working at a governmental body, 52.1% (n = 183) were working at a municipal or regional level, 18.2% (n = 64) held positions on provincial levels, and 7.1% (n = 25) were working on a national level. Educational backgrounds were mostly master/doctoral degrees (44.7%, n = 157), followed by bachelor (40.7%, n = 143), and lower levels of education (14.0%, n = 49). Regarding field of expertise, 46.4% (n = 163) had a scientific background (i.e. human health or life sciences), whereas the other half (53.6%, n = 188) had an expertise in other backgrounds. Most participants were living in suburban areas (62.7%, n = 220). Demographic characteristics except gender were significantly different between HIC and LMIC subsets ($p < 0.05$). A detailed demographic characteristics of participants is shown in Table 1.

[Table 1: Sociodemographic description and political features of all participants, and stratified for low-and-middle income and high-income countries. Differences between subsets were analyzed by Fisher exact tests.]

Representatives from 15 different countries participated. Most participants were coming from the Netherlands (48.7%, n = 171), followed by Spain (27.6%, n = 97) and Myanmar (9.7%, n = 34). All represented countries are shown in Fig. 1.

[Figure 1: Spatial plot of all countries represented in current multinational study: the Netherlands (48.7%, n = 171), Spain (27.6%, n = 97), Myanmar (9.7%, n = 34), India (3.1%, n = 11), Nigeria (2.6%, n = 9), Mexico (1.7%, n = 6), Morocco (1.4%, n = 5), Australia (1.1%, n = 4), Brasil (1.1%, n = 4), Belgium (0.9%, n = 3), Canada (0.9%, n = 3), Curaçao (0.3%, n = 1), Guatemala (0.3%, n = 1), Panama (0.3%, n = 1) and Singapore (0.3%, n = 1)]

Overall knowledge, attitude and perception scores

Cumulative scores were calculated for: 1) personal knowledge, 2) personal attitude and perception, and 3) political knowledge, attitude and perception. The mean and median scores of personal attitude and perception from all participants were 6.99 and 7.50 out of 10, respectively. Both the mean and median scores on personal attitude and perception were significantly different between HIC (mean of 7.31, median of 7.50) and LMIC (mean of 5.70, median of 5.83) participants ($p < 0.001$). For the knowledge score, a statistically significant difference was only observed for the median score ($p < 0.05$), but not for the mean score. The median score was significantly higher for LMIC participants (7.31) compared to HIC participants (5.70). The political KAP scores were similar between HIC and LMIC participants. Spearman correlation showed that personal knowledge and personal attitude and perception were inversely correlated (Table 2).

Table 2: Cumulative median and mean scores per assessment for all participants, and stratified for high-income country (HIC) and low- and middle-income (LMIC) country participants. Spearman correlation results are shown for the comparison of knowledge and personal attitude and perception scores.

Knowledge assessment

Only a small proportion (30.2%) of participants knew that antibiotic resistance will account for more deaths than cancer in the next 30 years. The level of knowledge of this AMR burden was higher in participants from LMIC (48.6%) than those from HIC (25.6%) ($p < 0.001$). More than half of all participants (67.2%) answered correctly that antibiotics cannot be used for viral infections. Most participants (81.8%) were well-informed that antibiotics misuse and abuse in animal husbandry can negatively affect human health, which again differed significantly between LMIC participants (92.9%) and HIC participants (79.0%) ($p < 0.05$). The vast majority of participants (78.9%) were aware that emerging resistant organisms from other countries or continents can become a problem in their own country. Less participants (69.8%) knew that it is not easy to discover and produce new antibiotics. The role of hygiene in tackling AMR was acknowledged by half (54.4%) of all participants with higher scores seen in LMIC participants (75.7%) than HIC participants (49.1%) ($p < 0.001$).

[Figure 2: Barplot on knowledge among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. The correct answer option (yes/no) is shown behind each statement. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$]

Univariate and multivariate logistic regressions were performed to identify which demographic factors are main determinants for the difference in knowledge levels between participants. Education level was significantly associated with both good and fair knowledge scores ($p < 0.05$). The proportion of getting good scores declined as the education level decreased (54.8% of master/doctoral, 41.3% of bachelor, 22.5% in lower education graduates). Upon multivariate analysis, the association between education level and good and fair score remained significant but only between master/PhD holders and high school graduates (79.6% vs 38.8% for fair score, respectively). Another associated factor for good and fair knowledge scores was a scientific field of expertise. Furthermore, good knowledge scores were significantly associated with age (< 40 years vs. 40–60 years) and country of nationality (Spanish vs. Dutch).

[Table 3: Univariate (odds ratio, OR) and multivariate analysis (adjusted odds ratio, aOR) of good and fair knowledge and demographic variables.]

Perception and attitude assessment

To assess the personal perception and attitude towards antimicrobial consumption and resistance, the perception and attitude questionnaire assessed the behavior about antibiotics use and familiarity with AMR as a public health concern. The results indicated that 38.3% of LMIC participants consumed antibiotics quite often (i.e. at least once every three years) compared to a significant lower proportion of 8.8% among HIC participants ($p < 0.001$). Regarding the completion of an antibiotic treatment, 78.8% of LMIC participants reported that they always finish their treatment whereas this perception and practice was significantly higher among HIC participants with 95.2% reporting to always finish their antibiotic treatment ($p < 0.001$). Furthermore, only 5.5% of all participants did not believe that antibiotic resistance can become a health emergency issue, and this perception was more prevalent among LMIC participants (10.5% of LMIC participants shared this view). This difference in proportion was not statistically significant between LMIC and HIC participants. Regarding the actors that should be held responsible for tackling AMR, 30.9% of LMIC participants reported that hospitals, veterinary clinics, and pharmaceutical industries are responsible for AMR and should solve the problem on their own. From the HIC perspective, only 10.9% shared this view and the difference was statistically significant ($p < 0.001$) between the two subsets. Lastly, 75% reported that the current COVID-19 pandemic increased their awareness of public health and the role of government in outbreak prevention and preparedness.

[Figure 3: Barplot on good personal attitude and perception among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.]

Of all participants, 41.6% and 83.8% had a good and fair personal attitude and perception, respectively. Upon univariate and multivariate analysis several factors were found to be associated with a good and fair attitude and perception (Table 4). Similarly as described for good and fair knowledge scores, higher levels of education and scientific field of expertise were associated with a better attitude and perception. Additionally, LMIC participants were less likely to have a good or fair perception and attitude with an adjusted OR of 0.33 (95% CI 0.14–0.75) for a good score compared to HIC participants.

[Table 4: Univariate (odds ratio, OR) and multivariate analysis (adjusted odds ratio, aOR) of good and fair personal attitude and perception and demographic variables]

Political activity and involvement

To capture the comprehension of the current political effort and plan in tackling AMR, the questionnaire assessed the participants' knowledge and awareness about the current state of political involvement and engagement related to main pillars in fighting against AMR. Only 26.7% of HIC participants reported that a national action plan on antimicrobial resistance (NAP-AMR) has been implemented, whereas 46.9% of LMIC participants were aware of the implementation of a NAP-AMR in their country. This difference was statistically significant ($p < 0.01$). More than half (53.1%) of LMIC participants reported that AMR is gaining more popularity in policies and regulations in the country, compared to a smaller proportion (39.2%) of HIC participants. More than half of HIC participants (56.1%) reported that AMR interventions both address human and animal health, which was statistically different from LMIC participants (40.3%) ($p < 0.05$). In accordance, more LMIC participants (51%) reported that AMR plans mainly focus on human health and not on the contribution of livestock. A significantly smaller proportion (33.9%) of HIC participants agreed with this statement ($p < 0.05$). More HIC participants (34.7%) than LMIC participants (19.7%) reported that hospitals in their regions have taken actions to control AMR. On the contrary, almost half of LMIC participants (47.6%) indicated that hospitals are willing to take action, but lack funding to do so. The proportion that highlighted this financial restraint was only 39.3% among HIC participants ($p < 0.05$). When the participants were inquired about the national budget and funding for AMR, not even half (35.6%) of all participants reported that the funding and resources had increased in recent years and would be increasing more in the future. Nearly everyone (80.1%) was well aware of the fact that a One Health approach should be integrated in monitoring AMR in their country, and more interventions should integrate this interdisciplinary vision. This awareness was, however, more pronounced among LMIC individuals (87.8%) compared to HIC individuals (72.8%) ($p < 0.05$).

[Figure 4: Barplot on first part of statements assessing the political knowledge, attitude and perception (KAP) among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.]

[Figure 5: Barplot on second part of statements assessing the political knowledge, attitude and perception (KAP) among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.]

None of the sociodemographic and occupational variables were associated with overall political KAP scores (Supplementary file 3). The last section of the survey contained four open questions to get a better understanding of the current strategies and interventions that address AMR within the participant's governmental level. It aimed to identify the challenges in designing and implementing new AMR strategies. Representatives from all countries addressed the need of sufficient financial resources, promoting awareness and educating the general public on the involved risks, and tightening of the regulations and prescription behaviours to make antibiotics less easily accessible (Supplementary file). Participants from the Netherlands in particular highlighted the need of a coherent international

approach rather than a national strategy to mitigate the AMR burden. Many Dutch participants also emphasized on the need for more research on the environmental transmission, especially the contribution of livestock and the transmission via wastewater. Participants from Myanmar unanimously reported that the lack of knowledge and awareness of AMR among the general public, and politicians and healthcare workers should be the main focus area to address AMR, whereas there was less mention of the environmental aspects in spread and control of AMR. One Burmese representative said that “implementing policies on AMR (example, an act to reduce antibiotics in animal feed) will be complicated; it could have an effect on markets and economies of farmers”. Various participants from Spain reported that surveillance programs have been developed to better monitor the presence of antibiotic resistant organisms and residues in food products.

In terms of interventions in place, most participants mentioned national and provincial interventions and action plans, and participants working for local authorities mainly mentioned that AMR is not being addressed on a regional level. As an example, one Spanish participant reported that “at the municipal level, we do not have direct powers on how to influence this issue”. This was in accordance with the funding source for AMR interventions, as the majority of financial resources were national in all countries.

Discussion

The current study findings captured both personal and political knowledge, attitude and perception (KAP) of politicians and relevant stakeholders towards antimicrobial resistance (AMR) in low- and middle-income countries (LMIC) and high-income countries (HIC). Since 86.3% of the participants worked for the government, our sample had a good representation of civil workers and political key players from different levels of government. Previously, policy research and KAP assessment had been performed in individual countries and comparative work had not been accomplished with the inclusion of politicians, policy makers and stakeholders before. Current results indicated that there was a significant variation in KAP levels between participants from LMIC and HIC. While LMIC participants displayed poor attitude and practice, they demonstrated to have a better knowledge on AMR than HIC participants. As an example, LMIC individuals self-reported to consume antibiotics more regularly, and did not often finish their treatments. On the other hand, participants from HIC had higher scores on attitude and practice, while their knowledge levels were significantly lower than participants from LMICs. This difference in knowledge might be due to a sampling bias that occurred, and the proportion of stakeholders was higher in the LMIC (80%) subset compared to the HIC subset (20%). The poor attitude toward antimicrobial use (AMU) among LMIC participants might be due to easy access to antibiotics and less restricted regulatory process on antimicrobial consumption in LMIC compared to HIC. Given how AMR was perceived differently in LMIC and HIC, multivariate analyses were performed to further explore explanatory factors for these differences. Notably, a scientific field of expertise and master/doctoral levels of education were the main determinants for good knowledge of AMR. These findings were similar to another study from Japan that also showed that higher education levels yielded higher knowledge scores about AMU and AMR among the general public (Kamata et al., 2018). Another study from Poland again showed that low levels of education were associated with poor public knowledge, behaviour and attitudes toward antimicrobial use (Mazińska et al., 2017). In line with these previous findings, our results highlighted that the level of education was a strong predictor for personal knowledge on AMR and AMU regardless of age, gender and country of origin. However, country of origin, education, and field expertise, were all significantly associated with a good attitude and perception on antimicrobials. Even after adjusting for other factors including education and field of expertise, country of origin (i.e. HIC or LMIC) remained significantly associated with a good perception and behaviour, suggesting that the country's economic status played an important role in shaping the perception and attitude towards antimicrobials. This finding again supported the hypothesis that the country's regulations on antimicrobials were the main determinants for prudent use of antimicrobials on an individual level, regardless of knowledge, education and field of expertise.

These quantitative findings were reflected by the open-ended question responses which led to a better understanding of current regulations and the perspectives of politicians and stakeholders. HIC stakeholders and politicians emphasized the need for a more holistic approach integrating One Health activities. There was a particular mention of addressing AMR in the field of animal husbandry, food safety, and wastewater management among HIC participants. Participants from LMIC emphasized more on capacity building and awareness campaigns. Interestingly, many participants working at a local governmental level mentioned that local authorities were not able to mitigate AMR. Notably, all participants unanimously agreed that main challenges to mitigate AMR burden included the promotion of knowledge and awareness of the general public and stakeholders. There was a consensus on stronger regulations for antimicrobial use in all sectors among all stakeholders and civil workers. Overall, these results provided novel insights that regional politicians demonstrated a lack of belief in regional interventions that could help mitigate the AMR burden even though municipal or regional level interventions were proved successful previously (Katwyk et al., 2019). One representative from a LMIC shared an interesting perspective that antibiotic regulations were not feasible since it would have a big impact on the economy of the country. The rapid emergence of AMR challenges the treatment of infections with resistant strains, leaving last-resort therapeutics as the last treatment option. Antimicrobial consumption data from Vietnam previously showed that purchase of last-resort drugs accounted for a relatively high proportion of health budgets (Dat et al., 2020). According to these survey responses, LMIC politicians and stakeholders might not be aware of the financial burden AMR might cause in the near future, which should therefore be implemented more in awareness and knowledge campaigns.

Although the data analysed were highly relevant, it is important to take into account that this study showed some limitations. There was a clear difference in demographics between the HIC and LMIC subsets, with LMIC participants mostly being stakeholders from non-government organizations with limited civil workers. This sociodemographic variation might explain why the earlier observed difference between LMIC and HIC knowledge scores did not hold during further analyses. Less politicians involvement from LMIC in this study also highlighted the challenge in obtaining information from political keyplayers and policy makers in LMIC. Lack of access to politicians in LMIC regarding their knowledge, attitude and perception about AMR was the main limitation factor in this study. Furthermore, this study design imposed two major biases. The first one was sampling bias for LMIC participants since they were recruited via convenience. The second bias was self-desirability bias associated with self-reporting of perception and attitude toward AMU and AMR for all participants. However, the current study provides new and insightful data from the perspective of the politicians and stakeholders worldwide. As the present work shows the differences in KAP about AMR among politicians, policy makers, and stakeholders from LMIC and HIC, future work should perform the situational analysis of NAP-AMR to measure the progress of national action plans in these countries with AMR focal-person interviews.

Conclusion

Overall, the current study shows how AMR is socially constructed in LMIC and HIC, and different challenges that the politicians, policy makers and stakeholders face in mitigating AMR burden. Although both LMIC and HIC shows sufficient knowledge levels on AMR in this study, the perception and attitude towards antimicrobial use is associated with the country of origin (i.e. LMIC or HIC). This study identifies that awareness interventions targeting politicians and stakeholders are lacking and more political actions are required to combat the AMR crisis.

Abbreviations

AMU Antimicrobial use

AMR Antimicrobial resistance

GAP-AMR Global Action Plan on Antimicrobial Resistance

KAP Knowledge, attitude and perception

LMIC Low-and middle-income countries

NAP-AMR National action plan on antimicrobial resistance

HIC High-income countries

R&D Research and development

UN United Nations

WHO World Health Organization

Declarations

Consent to participate

All participants gave informed consent prior to participation. After consultation with the ethical committee of Hospital Clinic in Barcelona, IRB approval was not required for this study.

Availability of data and materials

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

Competing interests

No authors declare competing interests.

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Author’s contributions

SYN: conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft preparation, writing – review and editing, visualization

MVW: conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft preparation, writing – review and editing, visualization

JV: writing – review and editing, supervision, funding acquisition

CB: Conceptualization, methodology, validation, investigation, resources, data curation, Writing – review and editing, supervision, project administration, funding acquisition

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Tables

Table 1: Sociodemographic description and political features of all participants, and stratified for low-and-middle income and high-income countries. Differences between subsets were analyzed by Fisher exact tests.]

	Complete dataset	HIC	LMIC	Fisher exact
Total	351	80.1% (281)	19.9% (70)	
Gender				
Female	51.9% (182)	40.8% (15)	45.7% (32)	0.252
Male	46.4% (163)	44.5% (125)	54.3% (38)	
Unknown	1.7% (6)	2.1% (6)	0.0% (0)	
Age				
Mean ± standard deviation	49.3 ± 13.3	52.2 ± 12.0	37.8 ± 12.3	
Median [IQR]	52.0 [21.5 - 62.5]	55 [46.5 - 63.5]	33 [23.3 - 42.8]	
Age group				
< 40	26.8% (94)	16.4% (46)	68.6% (49)	< 0,001 ***
40 - 60	51.0% (179)	57.3% (161)	25.7% (18)	
> 60	22.2% (78)	26.3% (74)	5.7% (4)	
Position duration				
< 1 year	7.7% (27)	8.2% (23)	5.7% (4)	< 0,001 ***
1 - 3 years	30.2% (106)	33.5% (94)	17.1% (12)	
3 - 5 years	17.1% (60)	12.5% (35)	35.7% (25)	
5 - 10 years	19.7% (69)	19.2% (54)	21.4% (15)	
> 10 years	25.4% (89)	26.7% (75)	20.0% (14)	
Educational background				
Master / PhD	44.7% (157)	39.5% (111)	65.7% (46)	< 0,001 ***
Bachelor	40.7% (143)	42.7% (120)	32.9% (23)	
Lower levels	14.0% (49)	17.1% (48)	1.4% (1)	
Unknown	0.6% (2)	0.7% (2)	0.0% (0)	
Expertise				
Scientific background	46.4% (163)	42.7% (120)	61.4% (43)	0,008 **
Other expertise backgrounds	53.6% (188)	57.3% (161)	38.6% (27)	
Living condition				
(Suburban	62.7% (220)	54.1% (152)	97.1% (68)	< 0,001 ***
Rural	37.0% (130)	45.6% (128)	2.9% (2)	
Unknown	0.3% (1)	0.4% (1)	0.0% (0)	
Role				
Government	86.3% (303)	97.2% (273)	42.9% (30)	< 0,001 ***

Non-government	12.8% (45)	2.1% (6)	55.7% (39)	
Unknown	0.9% (3)	0.7% (2)	1.4% (1)	
Role (detailed)				
Municipal and regional	52.1% (183)	64.1% (180)	4.3% (3)	< 0,001 ***
Province	64 (18.2% (64)	22.4% (63)	1.4% (1)	
National	7.1% (25)	4.6% (13)	17.1% (12)	
Non-government and unknown	22.5% (79)	8.9% (25)	77.1% (54)	

Table 2: Cumulative median and mean scores per assessment for all participants, and stratified for high-income country (HIC) and low- and middle-income (LMIC) country participants. Spearman correlation results are shown for the comparison of knowledge and personal attitude and perception scores.

	All participants	HIC	LMIC	significance ^a
Personal knowledge				
Means $\pm$ standard deviation	5.95 $\pm$ 2.82	5.81 $\pm$ 2.79	6.43 [3.57]	0.053
Median [inter quartile range]	6.43 [3.57]	6.55 $\pm$ 2.87	7.14 [3.57]	0.044 *
Personal attitude & perception				
Means $\pm$ standard deviation	6.99 $\pm$ 2.55	7.31 $\pm$ 2.38	5.70 $\pm$ 2.80	< 0.001 ***
Median [inter quartile range]	7.50 [2.50]	7.50 [2.50]	5.83 [4.58]	< 0.001 ***
Political KAP				
Means $\pm$ standard deviation	2.88 $\pm$ 2.21	2.84 $\pm$ 2.16	3.04 $\pm$ 2.14	0.529
Median [inter quartile range]	2.31 [3.08]	2.31 [3.08]	2.69 [3.37]	0.676
Spearman correlation				
Knowledge vs. personal AP	0.47 ***	0.48 ***	0.61 ***	

^a Significance is determined by the two-sample t-tests for the comparison between the means, and by Mann-Whitney U tests for the comparison of the median. Significance as *** at $p < 0.001$, ** at $p < 0.01$, and * $p < 0.05$.

Table 3: Univariate (odds ratio, OR) and multivariate analysis (adjusted odds ratio, aOR) of good and fair knowledge and demographic variables.

Variable	N	Good score ^A N (%)	OR 95% CI	Sig	aOR 95% CI	Sig	Fair score A N (%)	OR 95% CI	Sig	aOR 95% CI	Sig
	351	156 (41.3%)	-	-			74.1% (260)	-	-		
Gender^B											
Female	182	44.0% (88)	ref		ref		72.5% (132)	ref		ref	
Male	163	44.2% (72)	1.01 [0.66 - 1.54]	0,968	1.06 [0.66 - 1.69]	0.805	69.9% (114)	0.88 [0.55 - 1.41]	0.596	0.96 [0.57 - 1.64]	0.892
Age group^B											
< 40	94	41.5% (39)	ref		ref		71.3% (67)	ref		ref	
40 - 60	179	49.2% (88)	1.36 [0.82 - 2.26]	0,228	2.12 [1.11 - 4.04]	0,023	77.1% (138)	1.36 [0.77 - 2.39]	0.292	1.76 [0.85 - 3.64]	0.125
> 60	78	37.2% (29)	0.83 [0.45 - 1.55]	0,565	2.03 [0.91 - 4.52]	0,080	60.3% (47)	0.61 [0.32 - 1.15]	0.129	1.68 [0.70 - 4.01]	0.243
Country class^B											
HIC	281	42.4% (119)	ref		ref		70.5% (198)	ref		ref	
LMIC	70	52.9% (37)	1.53 [0.90 - 2.58]	0,115	1.97 [0.84 - 4.62]	0,117	77.1% (54)	1.41 [0.77 - 2.61]	0.268	1.47 [0.52 - 4.10]	0.467
Nationality^C											
The Netherlands	171	43.3% (73)	ref		ref		64.9% (111)	ref		ref	
Spain	97	39.2% (38)	0.84 [0.51 - 1.40]	0,513	0.44 [0.23 - 0.86]	0,017	78.4% (76)	1.96 [1.10 - 3.48]	0.023	1.07 [0.51 - 2.25]	0.856
Myanmar	34	26.5% (9)	0.47 [0.21 - 1.07]	0,073	0.65 [0.22 - 1.92]	0,432	64.7% (22)	0.99 [0.46 - 2.14]	0.982	1.39 [0.42 - 4.64]	0.593
Duration^B											
< 3 years	133	45.1% (60)	ref				71.4% (95)	ref		ref	

3 - 10 years	129	44.2% (57)	0.96 [0.59 - 1.57]	0,880	0.86 [0.50 - 1.48]	0,593	72.1% (93)	1.03 [0.60 - 1.77]	0.905	0.90 [0.48 - 1.67]	0.728
> 10 years	89	43.8% (39)	0.95 [0.44 - 1.63]	0,849	0.66 [0.35 - 1.21]	0,178	71.9% (64)	1.02 [0.56 - 1.86]	0.938	0.65 [0.32 - 1.33]	0.239
Education ^B											
Master / PhD	157	54.8% (86)	ref		ref		79.6% (125)	ref		ref	
Bachelor	143	41.3% (59)	0.58 [0.37 - 0.92]	0,020	0.61 [0.37 - 0.99]	0,045	75.5% (108)	0.79 [0.46 - 1.36]	0.396	0.86 [0.48 - 1.53]	0.597
Lower levels	49	22.5% (11)	0.24 [0.11 - 0.50]	<0.001	0.25 [0.11 - 0.57]	<0.001	38.8% (19)	0.16 [0.08 - 0.32]	<0.001	0.16 [0.07 - 0.37]	<0.001
Expertise ^B											
Scientific	163	55.2% (90)	ref		ref		83.4% (136)	ref		ref	
Other	188	35.1% (66)	0.44 [0.29 - 0.67]	<0.001	0.49 [0.31 - 0.79]	0.004	61.7% (116)	0.32 [0.19 - 0.53]	<0.001	0.34 [0.19 - 0.56]	<0.001
Living condition ^B											
(Sub)urban	220	48.2% (106)	ref		ref		75.9% (167)	ref		ref	
Rural	130	37.7% (49)	0.65 [0.42 - 1.01]	0,057	0.79 [0.47 - 1.31]	0,357	64.6% (84)	0.58 [0.36 - 0.93]	0,024	0.73 [0.41 - 1.30]	0.287
Occupation ^B											
Government	303	143.9% (113)	ref				71.6% (217)	ref		ref	
Non- government	45	44.4% (20)	1.02 [0.54 - 1.92]	0,945	0.56 [0.23 - 1.34]	0.190	71.1% (32)	0.98 [0.49 - 1.95]	0.944	0.52 [0.18 - 1.46]	0.213
Detailed occup. ^D											
Municipal/ regional	183	38.3% (70)	ref				66.1% (121)	ref		ref	
Province	64	50.0% (32)	1.61 [0.91	0,102	1.27 [0.69	0.441	76.6% (49)	1.67 [0.87	0,123	1.28 [0.62	0.504

			- 2.86]		- 2.36]			- 3.22]		- 2.68]	
National	25	56.0% (14)	2.05 [0.88 4.78]	0,095	1.50 [0.57 3.95]	0,409	80.0% (20)	2.05 [0.73 5.72]	0,171	1.28 [0.40 4.12]	0.680
Non government	79	50.6% (40)	1.66 [0.97 2.82]	0,063	1.10 [0.51 2.39]	0,804	78.5% (62)	1.87 [1.01 3.47]	0,047	1.27 [0.47 3.44]	0.644

^A Missing and unknown was not shown in the table, and total count does therefore not always equal 351.

^B Multivariate analysis based on gender, age group, time at current role (duration), country class (HIC or LMIC), living condition, education, field of expertise and occupation (government or non-government)

^C Similar as for B, excluding country class (HIC or LMIC)

^D Similar as for B, excluding occupation (government or non-government)

Table 4: Univariate (odds ratio, OR) and multivariate analysis (adjusted odds ratio, aOR) of good and fair personal attitude and perception and demographic variables

Variable	N	Good AP ^A N (%)	OR 95% CI	Sig	aOR 95% CI	Sig	Fair AP ^A N (%)	OR 95% CI	Sig	aOR 95% CI	Sig
	351	41.6% (146)	-	-			83.8% (294)	-	-		
Gender ^B											
Female	182	62.1% (113)	ref		ref		81.3% (148)	ref		ref	
Male	163	55.2% (90)	0.75 [0.49 - 1.16]	0.196	0.76 [0.47 - 1.21]	0.246	85.9% (140)	1.40 [0.78 - 2.49]	0.255	1.57 [0.80 - 3.09]	0.194
Age group ^B											
< 40	94	45.7% (43)	ref		ref		71.3% (67)	ref		ref	
40 - 60	179	64.8% (116)	2.18 [1.31 - 3.63]	0.003	1.48 [0.78 - 2.78]	0.227	90.5% (162)	3.84 [1.96 - 7.51]	<0.001	2.38 [0.96 - 5.90]	0.062
> 60	78	59.0% (46)	1.70 [0.93 - 3.13]	0.085	1.85 [0.84 - 4.11]	0.129	83.3% (65)	2.01 [0.96 - 4.24]	0.065	2.46 [0.78 - 7.76]	0.125
Country class ^B											
HIC	281	63.0% (177)	ref		ref		88.3% (248)	ref		ref	
LMIC	70	40.0% (28)	0.39 [0.23 - 0.67]	<0.001	0.33 [0.14 - 0.75]	0.009	65.7% (46)	0.26 [0.14 - 0.47]	<0.001	0.19 [0.06 - 0.60]	0.005
Nationality ^C											
The Netherlands	171	56.7% (97)	ref		ref		85.4% (146)	ref		ref	
Spain	97	72.2% (70)	1.98 [1.16 - 3.38]	0.013	1.77 [0.90 - 3.45]	0.100	92.8% (90)	2.20 [0.91 - 5.30]	0.078	1.87 [0.63 - 5.58]	0.259
Myanmar	34	14.7% (5)	0.13 [0.05 - 0.36]	<0.001	0.15 [0.05 - 0.52]	0.003	38.2% (13)	0.11 [0.05 - 0.24]	<0.001	0.15 [0.04 - 0.57]	0.005
Duration ^B											
< 3 years	133	60.2% (80)	ref		ref		82.7% (110)	ref		ref	
3 - 10 years	129	55.8%	0.84	0.477	1.06	0.832	83.7%	1.08	0.826	1.82	0.148

		(72)	[0.51 - 1.37]		[0.61 - 1.84]		(108)	[0.56 - 2.06]		[0.81 - 4.09]	
> 10 years	89	59.6% (53)	0.98 [0.56 - 1.69]	0.929	0.71 [0.38 - 1.33]	0.288	85.4% (76)	1.22 [0.58 - 2.56]	0.595	0.89 [0.36 - 2.19]	0.800
Education ^B											
Master / PhD	157	61.2% (96)	ref		ref		88.5% (139)	ref		ref	
Bachelor	143	59.4% (85)	0.93 [0.32 - 1.16]	0.763	0.85 [0.51 - 1.43]	0.547	82.5% (118)	0.61 [0.32 - 1.18]	0.140	0.45 [0.21 - 0.97]	0.043
Lower levels	49	49.0% (24)	0.61 [0.32 - 1.16]	0.133	0.47 [0.22 - 0.99]	0.048	75.5% (37)	0.40 [0.18 - 0.90]	0.027	0.18 [0.06 - 0.53]	0.002
Expertise ^B											
Scientific	163	67.5% (110)	ref		ref		91.4% (149)	ref		ref	
Other	188	50.5% (95)	0.49 [0.32 - 0.76]	0.001	0.37 [0.23 - 0.62]	<0.001	77.1% (145)	0.32 [0.17 - 0.60]	<0.001	0.23 [0.10 - 0.50]	<0.001
Living condition ^B											
(Sub)urban	220	59.1% (130)	ref		ref		82.7% (182)	ref		ref	
Rural	130	57.7% (75)	0.94 [0.61 - 1.47]	0.798	0.72 [0.43 - 1.21]	0.211	85.4% (111)	1.22 [0.67 - 2.22]	0.516	0.74 [0.33 - 1.63]	0.451
Occupation ^B											
Government	303	61.4% (186)	ref		ref		86.8% (263)	ref		ref	
Non- government	45	18.0% (40)	0.42 [0.22 - 0.80]	0.008	0.73 [0.30 - 1.75]	0.483	62.2% (28)	0.25 [0.13 - 0.50]	<0.001	0.43 [0.14 - 1.27]	0.127
Detailed occup. ^D											
Municipal / regional	183	61.8% (113)	ref		ref		88.5% (162)	ref		ref	
Province	64	60.9% (39)	0.97 [0.54 - 1.73]	0.909	0.79 [0.43 - 1.48]	0.453	89.1% (57)	1.06 [0.43 - 2.61]	0.907	0.54 [0.19 - 1.50]	0.237

National	25	60.0% (15)	0.93 [0.40 - 2.18]	0.866	1.21 [0.44 - 3.30]	0.715	88.0% (22)	0.95 [0.26 - 3.45]	0.939	0.70 [0.15 - 3.22]	0.644
Non government	79	48.1% (38)	0.57 [0.34 - 0.98]	0.041	0.88 [0.38 - 2.03]	0.765	67.1% (53)	0.26 [0.14 - 0.51]	<0.001	0.18 [0.05 - 0.61]	0.006

^A Missing and unknown was not shown in the table, and total count does therefore not always equal 351.

^B Multivariate analysis based on gender, age group, time at current role (duration), country class (HIC or LMIC), living condition, education, field of expertise and occupation (government or non-government)

^C Only participants from the Netherlands, Spain and Myanmar were included. Multivariate analysis similar as for B, excluding country class (HIC or LMIC)

^D Similar as for B, excluding occupation (government or non-government)

Figures

Figure 1

Spatial plot of all countries represented in current multinational study: the Netherlands (48.7%, n=171), Spain (27.6%, n=97), Myanmar (9.7%, n=34), India (3.1%, n=11), Nigeria (2.6%, n=9), Mexico (1.7%, n=6), Morocco (1.4%, n=5), Australia (1.1%, n=4), Brasil (1.1%, n=4), Belgium (0.9%, n=3), Canada (0.9%, n=3), Curaçao (0.3%, n=1), Guatemala (0.3%, n=1), Panama (0.3%, n=1) and Singapore (0.3%, n=1)

Figure 2

Barplot on knowledge among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. The correct answer option (yes/no) is shown behind each statement. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.

Figure 3

Barplot on good personal attitude and perception among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.

Figure 4

Barplot on first part of statements assessing the political knowledge, attitude and perception (KAP) among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.

Figure 5

Barplot on second part of statements assessing the political knowledge, attitude and perception (KAP) among all participants, and stratified for high-income country (HIC) and low- and middle-income country (LMIC) participants. Significance as *** for $p < 0.001$, ** for $p < 0.01$ and * for $p < 0.05$.

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