

BMJ Open Public knowledge, attitudes and practices related to antibiotic use and resistance in Singapore: a cross-sectional population survey

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ABSTRACT

Objectives The WHO's Global Action Plan on Antimicrobial Resistance (AMR) includes increasing overall public awareness of appropriate antibiotic use and resistance as a key priority area. We aimed to measure public knowledge, attitudes and practices of antibiotics and antibiotic resistance in Singapore, as well as their healthcare-seeking behaviours relating to respiratory illnesses, providing baseline data against which to measure the progress of future interventions.

Design A cross-sectional study.

Setting The general population in Singapore.

Participants Between May and June 2019, we conducted a survey via an online panel in Singapore with 706 respondents.

Results Our findings indicated common misconceptions surrounding antibiotic effectiveness and mechanisms of antibiotic resistance—most participants thought that resistance occurs when our bodies become resistant to antibiotics (62.5%) or when antibiotics become less powerful (48.5%). In multivariable analyses, better knowledge scores were associated with more favourable antibiotic attitudes ($\beta=0.29$; 95% CI 0.20 to 0.37). In addition, more favourable attitude scores were associated with lower odds of both expecting (OR: 0.84, 95% CI 0.72 to 0.99) and being prescribed antibiotics by a primary care doctor (OR: 0.76, 95% CI 0.63 to 0.90).

Conclusions This study presents important information about population perceptions towards antibiotics and antibiotic resistance in Singapore. Results from this study emphasise the importance of effective public communication strategies to promote responsible antibiotic use locally and should be used to inform future implementation of programmes and activities as laid out in Singapore's National Strategic Action Plan on AMR.

INTRODUCTION

One of five key priority areas highlighted in the WHO's Global Action Plan on Antimicrobial Resistance (AMR) is the improvement of overall public awareness of antibiotics and AMR to promote effective behavioural change population-level antibiotic use.¹ Research on the drivers of antibiotic use

Strengths and limitations of this study

- This is the first population-level study on public knowledge, attitudes and practices of antibiotics and antibiotic resistance in Singapore. Findings from this study provide baseline information against which to measure the progress of future antibiotic interventions.
- A key strength of our online survey is increased access to groups and individuals in the community who may not have been reached through other channels.
- A potential limitation of our study is that respondents in online surveys may not be fully representative of the general population. In our study, we had an over-representation of respondents with at least a university education and those living in private accommodation. This may affect the generalisability of our results.
- In an online survey where the research team is unable to clarify or answer questions in person, respondents may have misinterpreted questions especially relating to the mechanisms of antibiotic resistance.

in several countries highlights widespread misconceptions among the public regarding appropriate use of antibiotics and the development of antibiotic resistance, showing that less antibiotic knowledge is often associated with unfavourable antibiotic use behaviours, such as self-medication with antibiotics or sharing left-over antibiotics with others.² These findings are supported by qualitative studies indicating that the general public is unfamiliar with technical terms such as 'antimicrobial resistance', that they feel they 'know' when they need antibiotics and that antibiotic prescription is often viewed as a form of validation for their illness.^{3–5}

Singapore is a high-income city state in Asia with a comprehensive system of hybrid public and private primary, secondary and tertiary



healthcare. Currently, all antimicrobials for human use in the country are prescription-only medicines and regulated by the Health Sciences Authority, the national authority that enforces health product regulation and registration.⁶ However, antibiotic resistance is an increasing concern in acute care hospitals^{7,8} and in the community,⁹ an indicator of inappropriate antibiotic consumption. Although antibiotics can be obtained only via prescription by licensed healthcare professionals⁶ in Singapore, patients seeking primary healthcare for upper respiratory tract infections are commonly misinformed about the role of antibiotics in the treatment of viral infections and often seek primary care expecting antibiotics from a medical professional.¹⁰

The development of the WHO's Global Action Plan on AMR and subsequent national action plans¹¹ serves to complement existing strategies and to prioritise future AMR interventions in both healthcare institutions and the community in preserving antimicrobial effectiveness. To measure the progress of future interventions, as well as to yield evidence-based insights¹² into effective public communication strategies to promote responsible antibiotic use, we conducted an online population survey in Singapore to measure public perceptions of antibiotics and antibiotic resistance.

METHODS

Study design + data collection

Survey respondents were participants in an online survey panel recruited and maintained by the Singapore Population Health Improvement Centre (SPHERiC) within the National University Health System. Members of the public are eligible to be part of the online survey panel if they are community-dwelling Singapore citizens or permanent residents, aged 21 and above, English literate, frequent users of web-based services and if they have a personal email account. Panel participants were recruited using two main strategies. The first strategy was a door-to-door approach conducted to recruit eligible community-dwelling Singaporeans and/or permanent residents. The second strategy involved mailing invitations to deidentified household addresses available from the Singapore Department of Statistics.

From 23 May to 1 June 2019, a total of 1001 SPHERiC panel members were invited to participate in the survey via an online link in an email or text message notification. The survey was available to panel members for 10 days and could be completed on any type of personal digital device (eg, laptops, mobile phones). A reminder notification was sent to panel members who did not respond to the first notification within 5 days. The self-completed survey was administered in English using REDCap software¹³ and took approximately 10–15 min to complete. Participants received a reimbursement of SGD5 (~US\$3.70) for completing the survey. Survey data were provided by SPHERiC to the research team in an anonymised form for analysis.

Survey questionnaire

The questionnaire consisted of six sections, eliciting information from respondents about their sociodemographic characteristics (8 questions), knowledge about the effectiveness of antibiotics (5 questions), knowledge about the mechanisms of antibiotic resistance and the spread of antibiotic-resistant infections (12 questions), attitudes towards appropriate antibiotic use (9 questions), antibiotic practices in relation to the last time they had an acute respiratory illness (11 questions), as well as their healthcare-seeking behaviours (17 questions) (online supplemental appendix A).

The questionnaire was developed by reviewing available questionnaires from previously published surveys.^{14,15} Additionally, to enhance cross-country comparability, questions about antibiotic resistance were taken from the WHO country survey.¹⁶ To ensure that questions in the survey were well understood and adapted to the local context, the questionnaire was field tested with 29 individuals over a period of 6 days.

Data analysis

We assessed representativeness of the survey sample by comparing respondents' sociodemographic characteristics with the Singapore Census of Population.¹⁷ We then assessed respondents' general awareness towards antibiotics by tabulating variables related to antibiotic effectiveness, resistance and appropriate use. We also tabulated respondents' practices in relation to antibiotic use for common respiratory illnesses.

We assigned each respondent a knowledge and attitude score based on the number of correct or favourable responses in the respective sections (online supplemental appendix B). All knowledge and attitude questions had three response options: 'Agree', 'Disagree' or 'Not sure'. Correct knowledge and favourable attitude responses were assigned 1 point while incorrect or unfavourable responses scored 0 point.

Respondents' antibiotic practice responses during their last consultation with a primary care provider for acute respiratory illness were dichotomised into: (1) whether respondents expected antibiotics from their doctor (yes=1; no=0), (2) whether they asked their doctor for antibiotics (yes=1; no=0), and (3) whether they were prescribed antibiotics by their doctor (yes=1; no=0).

We first investigated the respective relationships between respondents' sociodemographic characteristics and their antibiotic knowledge and attitude scores using a multivariable linear (Gaussian) regression. Sociodemographic explanatory variables included age group, gender, housing type, household income, education, ethnicity and marital status.

In subsequent regression analyses, we investigated the association between antibiotic practices and antibiotic knowledge and attitude scores using a multivariable linear (Gaussian) regression, controlling for sociodemographic variables. We then conducted separate multivariable logistic regressions to investigate whether respondents'

attitude scores were associated with each of the three antibiotic practices as outcome variables: (1) whether respondents expected antibiotics, (2) whether they asked for antibiotics, and (3) whether they were prescribed antibiotics. We summarised associations using adjusted ORs and corresponding 95% CIs. Regression residual distributions can be found in online supplemental appendix C.

All data were analysed using R V.3.6.1.¹⁸ No patients were involved.

Patient and public involvement

No patients were involved in the study. To inform the survey content, we pilot tested the survey with members of the public external to our research. Key findings will be disseminated to study respondents in an online newsletter.

RESULTS

Of 1001 eligible panel members, 706 (70.5%) completed the survey. Respondents had a median age of 44 years (range: 22–86 years). Four hundred (56.7%) respondents were female and 306 (43.3%) were male. Most respondents were married (60.8%) and had higher than secondary education (78.0%). The survey sample had a similar gender and ethnic group composition compared with the Singapore Census of Population¹⁷ but had slightly lower proportions of individuals who lived in private housing (ie, condominium, landed property) and a higher proportion of individuals with a university education (table 1).

Descriptive analysis

Tabulations and frequencies of the descriptive analysis are shown in table 2.

Awareness of antibiotic effectiveness

Almost all the respondents (97.5%) had heard of the term ‘antibiotics’ before. When asked if antibiotics were effective against bacterial and viral infections, only about a third of the respondents (35.6%) answered both questions correctly. A large proportion of respondents believed that antibiotics could help speed up recovery from the common respiratory illness (35.4%), or alleviate serious symptoms associated with these illnesses (45.2%).

Awareness of antibiotic resistance

Among respondents, 60.5% reported having heard of the term ‘antibiotic resistance’, but only 11% had heard of the abbreviation ‘AMR’. About half of the respondents were aware that resistance occurs when bacteria become resistant to the antibiotics. However, many respondents also thought that resistance occurs when our bodies become resistant to antibiotics (62.5%) or when antibiotics become less powerful (48.5%).

There was also lower awareness among respondents about how antibiotic-resistant infections could spread or affect common conditions. More than half (56.1%) either disagreed or were not sure that antibiotic resistance can

Table 1 Demographic and socioeconomic characteristics of survey participants compared with Singapore Census of Population (2010)

	Survey respondents n (%)	Census (2010) (%)
Gender		
Male	306 (43.3)	49.3
Female	400 (56.7)	50.7
Age		
Median age	44	37.4
Ethnicity		
Chinese	549 (77.8)	74.1
Malay	82 (11.6)	13.4
Indian	51 (7.2)	9.2
Other	24 (3.4)	3.3
Education		
Below secondary	13 (1.8)	32.4
Secondary	138 (19.5)	18.9
Postsecondary	243 (34.5)	11.1
Diploma and professional qualification		14.8
University	308 (43.6)	11.7
Prefer not to say	4 (0.6)	–
Housing		
1 to 2-room HDB	19 (2.7)	2.1
3 to 4-room HDB	393 (55.7)	38.1
5-room HDB and executive flat	247 (35.0)	21.5
Private housing	36 (5.1)	36.5
Others	11 (1.5)	1.4
Household income		
<\$2000	81 (11.5)	21
\$2000–\$3999	148 (21.0)	16.5
\$4000–\$5999	141 (20.0)	15.3
\$6000–\$9999	178 (25.2)	21.7
\$10 000+	79 (11.2)	25.5
Do not know	35 (5.0)	–
Prefer not to say	44 (6.1)	–

HDB, Housing and Development Board.

affect the treatment of common infections such as sore throat and urinary tract infection. More than a third of respondents (39.7%) believed that their own use of antibiotics does not have any impact on other people’s chances of acquiring antibiotic-resistant infections, and that they do not have to worry about getting antibiotic-resistant infections as long as they use antibiotics appropriately themselves (44.5%). Overall, respondents agreed that interventions to reduce AMR include implementing better infection control measures in hospitals (76.2%)

**Table 2** Participants' responses on antibiotic knowledge, attitudes and antibiotic resistance

Antibiotic knowledge	Response	n=706 n (%)
Have you ever heard of a type of medication called 'antibiotics'?	Yes	688 (97.5)
	No	18 (2.5)
n=688 n (%)		
Antibiotics can help me recover from bacterial infections.	Agree	574 (83.4)
	Disagree	43 (6.2)
	Not sure	71 (10.3)
Antibiotics can help me recover from viral infections.	Agree	314 (45.6)
	Disagree	266 (38.7)
	Not sure	108 (15.7)
Antibiotics can help me recover from the common cold and influenza.	Agree	228 (33.1)
	Disagree	364 (52.9)
	Not sure	96 (14.0)
Antibiotics can help me recover from serious symptoms of cold and influenza.	Agree	319 (46.4)
	Disagree	256 (37.2)
	Not sure	113 (16.4)
Antibiotics can speed up my recovery from the common cold and influenza.	Agree	250 (36.3)
	Disagree	315 (45.8)
	Not sure	123 (17.9)
Antibiotic attitudes		
It is okay to share my antibiotics with family and friends when they are sick with the same symptoms.	Agree	50 (7.3)
	Disagree	595 (86.5)
	Not sure	43 (6.2)
It is okay to share my antibiotics with family and friends when they are sick with different symptoms.	Agree	9 (1.3)
	Disagree	652 (94.8)
	Not sure	27 (9.3)
It is okay to share my antibiotics with my pets when they are sick.	Agree	7 (1.0)
	Disagree	661 (96.1)
	Not sure	20 (2.9)
It is okay to keep left-over antibiotics and use them again when I fall sick in the future.	Agree	39 (5.7)
	Disagree	604 (87.8)
	Not sure	45 (6.5)
It is okay for me to use my left-over antibiotics when I have the same symptoms as before.	Agree	59 (8.6)
	Disagree	590 (85.8)
	Not sure	39 (5.7)
It is important to always finish the course of antibiotics prescribed to me.	Agree	642 (93.3)
	Disagree	28 (4.1)
	Not sure	18 (2.6)
It is okay not to finish the course of antibiotics prescribed to me when I feel better.	Agree	56 (8.4)
	Disagree	592 (86.0)
	Not sure	67 (9.7)
It is okay not to finish the course of antibiotics prescribed to me when I have an alternative remedy.	Agree	58 (8.4)
	Disagree	563 (81.8)
	Not sure	67 (9.7)
It is okay to miss a dose during the course of antibiotics prescribed to me.	Agree	139 (20.2)
	Disagree	433 (62.9)
	Not sure	116 (16.9)

Continued

Table 2 Continued

Antibiotic resistance knowledge	Response	n=706 n (%)
Have you ever heard of the abbreviation 'AMR'?	Yes	78 (11.0)
	No	628 (89.0)
Have you ever heard of the term 'antibiotic resistance'?	Yes	427 (60.5)
	No	279 (39.5)
Antibiotic resistance occurs when antibiotics become less powerful so they don't work as well.	n=427 n (%)	
	Agree	207 (48.5)
	Disagree	177 (41.4)
Antibiotic resistance occurs when your body becomes resistant to the antibiotics and they no longer work as well.	Not sure	43 (10.1)
	Agree	266 (62.3)
	Disagree	127 (29.7)
Antibiotic resistance occurs when bacteria become resistant to the antibiotics so they are more difficult to kill.	Not sure	34 (8.0)
	Agree	382 (89.5)
	Disagree	18 (4.2)
Antibiotic resistance only affects people with serious infections in hospitals.	Not sure	27 (6.3)
	Agree	31 (7.3)
	Disagree	334 (78.2)
Antibiotic resistance affects common infections such as sore throats and urinary tract infections.	Not sure	62 (14.5)
	Agree	188 (44.0)
	Disagree	100 (23.4)
If I use antibiotics appropriately, I don't have to worry about getting antibiotic-resistant infections.	Not sure	139 (32.6)
	Agree	190 (44.5)
	Disagree	141 (33.0)
How other people use antibiotics doesn't affect my chance of getting antibiotic-resistant infections.	Not sure	96 (22.5)
	Agree	157 (36.8)
	Disagree	183 (42.9)
How I use antibiotics doesn't affect other peoples' chances of getting antibiotic-resistant infections.	Not sure	87 (20.4)
	Agree	169 (39.6)
	Disagree	176 (41.2)
	Not sure	82 (19.2)

AMR, antimicrobial resistance.

and using fewer antibiotics (71.9%), although a lower percentage recognised hand hygiene (61.7%) and vaccination (59.5%) as important interventions.

Awareness on how to use antibiotics responsibly

There was generally high awareness about appropriate practices in sharing antibiotics—respondents generally agreed that it is inappropriate to share antibiotics with family and friends when they are sick with either same (84.3%) or different (92.4%) symptoms. Respondents were also reluctant to share antibiotics with their household pets—only 1% thought it was appropriate to do so.

Less than 10% of the respondents said that they felt comfortable keeping left-over antibiotics for future use. While over 90% of the respondents agreed that it is important to always finish the course of antibiotics prescribed, a small proportion of respondents believed that they do not have to finish a prescribed course of

antibiotics when they feel better (7.9%) or when they have an alternative remedy (8.2%).

Cold/influenza practices

We asked all 706 respondents what they did the last time they had symptoms of the common cold or influenza (figure 1). More than half (50.6%) chose to see a doctor. The rest chose to take extra rest (59.0%), over-the-counter medication (39.9%), traditional Chinese medicine (12.4%) or did nothing about the symptoms (12.6%). Only 2.8% of respondents used left-over antibiotics (1.4%).

Of the 350 respondents who chose to see a doctor for their cold and influenza symptoms, 12.6% expected an antibiotic prescription and 11.4% explicitly asked their doctor for antibiotics. Despite this, nearly half (49.7%) of the respondents who visited the doctor for cold or influenza symptoms reported that their doctor prescribed

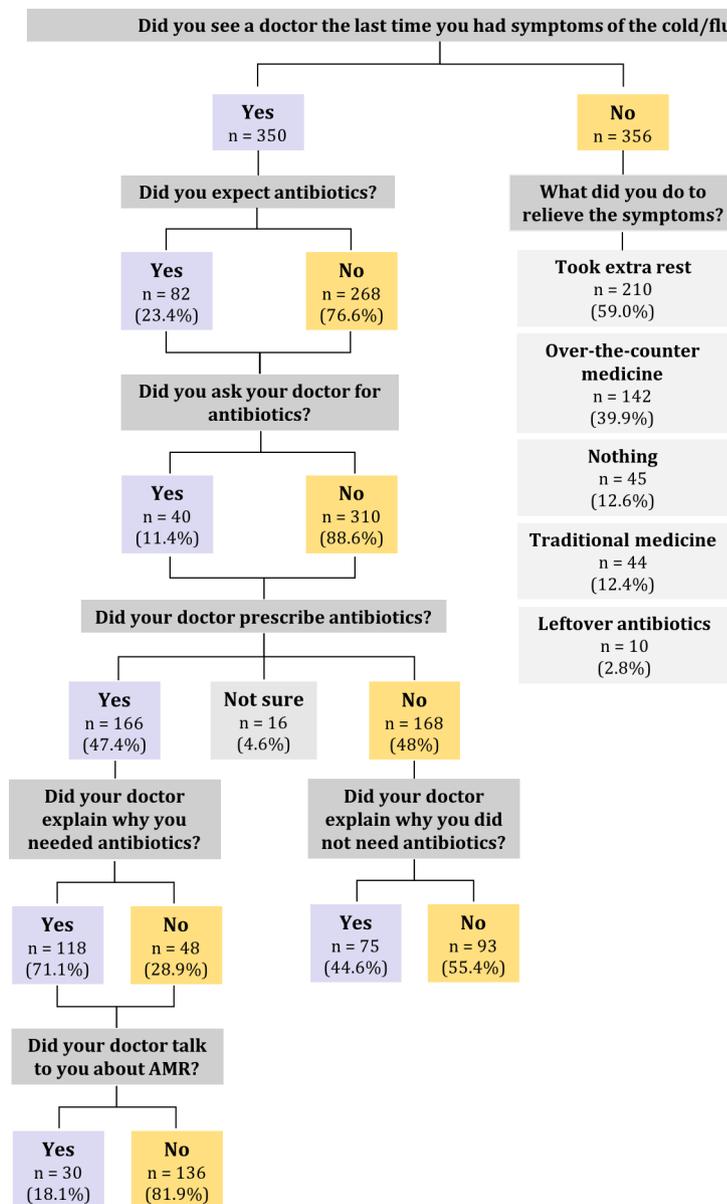


Figure 1 Participants' cold/flu practices. AMR, antimicrobial resistance.

them antibiotics, regardless of whether they asked for them explicitly or not.

For respondents who were prescribed antibiotics, 71.1% said that the doctor explained to them why they needed antibiotics, but only a minority stated that their doctor talked to them about possible side effects of antibiotics (28.3%) or about antibiotic resistance (18.1%). For respondents who were not prescribed antibiotics, 44.6% of them said that the doctor explained why they did not need them.

Multivariable analysis

Respondents' knowledge and attitude scores

Respondents' median knowledge score was 8 (range: 0–14) and median attitude score was 7 (range: 0–11).

Compared with female respondents, males scored better in terms of antibiotic knowledge (β : 0.68; 95% CI -0.15 to 1.22) but scored worse for attitudes (β : -0.40;

95% CI -0.77 to -0.03). Malays had lower knowledge (β : -0.69; 95% CI -1.81 to -0.43) and attitude scores (β : -1.04; 95% CI -1.76 to -0.33) relative to their Chinese counterparts. Respondents with secondary education also scored lower for both knowledge (β : -1.64; 95% CI -2.53 to -0.75) and attitudes (β : -1.16; 95% CI -1.71 to -0.60) compared with respondents with a university education. Respondents in three-room Housing and Development Board (HDB) (public housing) flat scored lower for both knowledge (β : -1.01; 95% CI -1.90 to -0.13) and attitudes (β : -0.83; 95% CI -1.42 to -0.24) compared with respondents in five-room HDB and executive flats (table 3).

Attitude scores increased by 0.29 (95% CI 0.20 to 0.37) for every unit increase in antibiotic knowledge score (table 4).

Table 3 Univariate analysis: participant characteristics associated with knowledge and attitude scores

	Knowledge score		Attitude score	
	Coefficient	95% CI	Coefficient	95% CI
Estimate	10.99	7.80 to 11.35	8.19	6.99 to 9.38
Sex				
Female†				
Male	0.68*	0.15 to 1.22	-0.40*	-0.77 to -0.03
Ethnicity				
Chinese†				
Malay	-0.69	-1.81 to -0.43	-1.04**	-1.76 to -0.33
Indian	0.23	-0.62 to 1.08	-0.32	-0.89 to 0.25
Other	-0.13	-1.61 to 1.35	0.25	-0.73 to 1.22
Age	-0.03*	-0.06 to -0.01	0.01	-0.00 to 0.03
Education				
University†				
Primary (Primary School Leaving Examination)	-0.47	-4.48 to 3.53	-1.10	-3.06 to 0.86
Secondary ('O'/'N' level)	-1.64***	-2.53 to -0.75	-1.16***	-1.71 to -0.60
'A' level/polytechnic/diploma	0.33	-0.26 to 0.94	-0.50*	-0.94 to -0.06
Institute of Technical Education (ITE)/National Technical Certificate (NTC)	0.06	-1.92 to 2.04	-0.13	-1.17 to 0.91
Housing				
5-room HDB/executive flat†				
1 to 2-room HDB‡	0.23	-2.13 to 2.59	-0.59	-1.79 to 0.62
3-room HDB	-1.01*	-1.90 to -0.13	-0.83**	-1.42 to -0.24
4-room HDB	-0.24	-0.81 to 0.34	-0.37	-0.78 to 0.05
Condominium	0.22	-1.13 to 1.56	-0.56	-1.56 to 0.44
Landed house	-1.02	-2.79 to 0.74	0.78	-0.73 to 2.28
Income				
<\$2000†				
\$2000-\$3999	-0.80	-1.91 to 0.31	-0.26	-0.95 to 0.42
\$4000-\$5999	-0.49	-1.63 to 0.65	-0.24	-0.95 to 0.48
\$6000-\$10 000	-0.21	-1.35 to 0.94	-0.12	-0.84 to 0.60
>\$10 000	0.40	-0.83 to 1.62	-0.17	-1.01 to 0.68
Marital status				
Married†				
Divorced	-0.34	-1.97 to 1.29	0.04	-0.88 to 0.96
Never married	0.23	-0.44 to 0.91	-0.32	-0.79 to 0.14
Widowed	-0.71	-3.50 to 2.19	-0.34	-1.95 to 1.29
Separated but not divorced	2.02	-1.80 to 5.83	0.85	-1.85 to 3.56
	Adjusted R ² =0.12		Adjusted R ² =0.05	

*P≤0.05; **p≤0.01; ***p≤0.001.

†Reference groups.

‡Public housing in Singapore managed by the Housing and Development Board (HDB).

Respondents' knowledge and attitude scores with practice variables

We found that more favourable antibiotic attitude scores were associated with lower odds of expecting antibiotics

(OR: 0.84, 95% CI 0.72 to 0.99) per unit increase in score. Antibiotic knowledge and attitude scores were not associated with whether participants asked their doctors for antibiotics. However, higher scores on knowledge of

**Table 4** Multivariable regression analysis

	Multivariable linear regression		Multivariable logistic regression					
	Attitudes		Expected antibiotics		Asked for antibiotics		Prescribed antibiotics	
	Coefficient	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Estimate	7.49	5.80 to 9.18	–	–	–	–	–	–
Knowledge score	0.29***	0.20 to 0.37	0.90	0.77 to 1.04	0.96	0.79 to 1.16	0.90	0.79 to 1.05
Attitude score	–	–	0.84*	0.72 to 0.99	0.78	0.71 to 1.07	0.76	0.63 to 0.90

All regression results are adjusted for sociodemographic variables (ie, gender, income, housing, education, ethnicity, marital status and age)
*p<0.05; ***p<0.001.

antibiotic resistance (OR: 0.90, 95% CI 0.79 to 1.05) and attitude (OR: 0.76, 95% CI 0.63 to 0.90) were associated with lower odds of being prescribed antibiotics by the doctor (table 4).

DISCUSSION

Our cross-sectional study of 706 participants in Singapore showed that there is a high level of awareness towards appropriate antibiotic use among the Singapore general population, but greater knowledge and awareness can be beneficial for curbing expectation and receipt of antibiotics during primary care consultations.

While most of the respondents said that they had heard of the term antibiotics before, only about a third of the respondents could correctly identify that antibiotics are effective towards bacterial and not viral infections. Comparable to previously published surveys in other countries,^{15 19 20} almost half of the respondents believed that antibiotics could be used for speeding up recovery or alleviating symptoms from conditions like the common cold and the influenza, indicating knowledge gaps in the appropriate use of antibiotics.

In terms of awareness of antibiotic resistance, only about a tenth of the respondents were able to correctly identify the mechanisms of resistance, suggesting a need for increased public education in this area. These misconceptions are also mirrored in other population-level antibiotic surveys^{21–23} as well as the WHO multicountry antibiotic resistance public awareness survey in 12 countries.¹⁶ Similar to our findings, a majority of respondents in all countries surveyed thought that antibiotic resistance occurs when our bodies become resistant to antibiotics, while approximately half of the respondents thought that antibiotic resistance is only a problem for people who take antibiotics regularly.

Approximately half of the respondents went to a medical doctor when they experienced symptoms of the cold or influenza, and a tenth of these respondents expressed that they explicitly asked for antibiotics. These results are congruent with a previously published study on Singaporean adult patients seeking medical care for upper respiratory tract infection symptoms, where a

third of patients said that they would ask the doctor for antibiotics or see another doctor if antibiotics were not prescribed.¹⁰ While the studies looked at different target populations, this could indicate favourable population-level changes in antibiotic-seeking behaviours over time.

While only a small proportion of respondents who sought care for their symptoms of the cold or influenza said that they expected antibiotics, close to half of them left the clinic with antibiotics whether they asked for them or not. While respondents with higher attitude scores were less likely to expect antibiotics and to leave the clinic with an antibiotic prescription, this discrepancy between patient expectation and prescription is an indication of suboptimal antibiotic prescribing. As respondents' antibiotic prescribing information was self-reported, we were unable to verify whether they actually received antibiotics, or if those who knew more about antibiotics were less likely to take any form of prescription. We also do not know from our study if there are significant differences in patient antibiotic-seeking behaviours or clinician-prescribing practices between public and private healthcare sectors. However, previous research in other countries indicates the effectiveness of potential strategies such as delayed prescription^{24 25} and shared decision-making^{26 27} to reduce inappropriate antibiotic use especially for acute respiratory infections. Additional strategies from other settings have also found that decreasing the frequency of medical consultations pertaining to respiratory illnesses was effective in reducing ambulatory antibiotic prescriptions.^{28 29}

These findings highlight the importance of disseminating clear information about antibiotics and antibiotic resistance to reduce public expectations surrounding antibiotic prescriptions. It also emphasises the need to provide resources such as clinical practice guidelines on antibiotic use in acute upper respiratory infections,³⁰ accessible diagnostic tools in upskilling primary care healthcare professionals as well as more comprehensive policies to manage profit making in antibiotic dispensation.^{31 32} Further, while public campaign messages have focused on antibiotic effectiveness towards specific medical conditions,^{12 28 33 34} our findings suggest that more

should be done with regard to how people can use antibiotics more effectively and how health professionals can communicate that information. Future research should further explore where people usually get information about antibiotics and how this influences their antibiotic-seeking behaviours. Additionally, follow-up population surveys using consistent methods and question structures can provide valuable insights into progress of future AMR interventions.

A potential limitation of our study is that respondents in online surveys may not be fully representative of the general population. Although our survey sample was compared with the Singapore census population in terms of gender and ethnic group, there was a pronounced over-representation of respondents with at least a university education and those living in private accommodation. This may affect the generalisability of our results as these sociodemographic characteristics might be associated with greater awareness about health-related issues as well as knowledge relating to AMR,^{35–37} as indicated in prior survey findings in similar contexts. Further, although preserving question structure enabled us to maintain comparability with WHO's multicountry antibiotic resistance public awareness survey, respondents may have misinterpreted questions relating to the mechanisms of antibiotic resistance, especially in an online survey where the research team is unable to clarify or answer questions in person.

CONCLUSION

This is the first study on public knowledge, attitudes and practices of antibiotics and antibiotic resistance in Singapore, providing baseline information against which to measure the progress of future interventions. Results from this study serve to emphasise the importance of raising awareness surrounding effective antibiotic use, as well as the mechanisms of antibiotic resistance. They also highlight the benefit of clinical practice guidelines on antibiotic prescribing, educational resources and clinical diagnostic tools for providers. These recommendations should be used to inform future implementation of programmes and activities as laid out in Singapore's National Strategic Action Plan on AMR.

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Competing interests None declared.

Patient consent for publication Not required.

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Survey title: A survey of knowledge, attitudes and practices surrounding antibiotics and vaccines in Singapore

Section 1 - Knowledge and attitudes regarding antibiotics

<i>First, I'd like to ask you some questions about antibiotic medications</i>		
1.1	<p>Have you ever heard of a type of medication called 'antibiotics'?</p> <p><i>If necessary, prompt: "Antibiotics are a type of medication used to treat certain types of infections. Some examples of antibiotics are Augmentin, Zithromax, amoxicillin, clarithromycin, streptomycin"</i></p>	<input type="checkbox"/> Yes (go to 1.2) <input type="checkbox"/> No (go to Section 2)
<i>Now I will tell you a few statements regarding antibiotics. For each statement, please let me know if you agree, disagree or not sure</i>		
1.2	Antibiotics can help you recover from bacterial infections	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.3	Antibiotics can help you recover from viral infections	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.4	Antibiotics can help you recover from the common cold and flu	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.5	Antibiotics can help you recover from serious symptoms of cold and flu	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.6	Antibiotics can speed up your recovery from the common cold and flu	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.7	It is okay to share my antibiotics with family and friends when they are sick with the same symptoms	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.8	It is okay to share my antibiotics with family and friends when they are sick with different symptoms	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.9	It is okay to share my antibiotics with my pets when they are sick	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.10	It is okay to keep leftover antibiotics and use them again when I fall sick in the future	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure

1.11	It is okay for me to use my leftover antibiotics when I have the same symptoms as before	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.12	It is important to always finish the course of antibiotics prescribed to me	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.13	It is okay not to finish the course of antibiotics prescribed to me when I feel better	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.14	It is okay not to finish the course of antibiotics prescribed to me when I have an alternative remedy	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
1.15	It is okay to miss a dose during the course of antibiotics prescribed to me	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure

Section 2 - Knowledge and attitude regarding antibiotic resistance

<i>Thanks a lot. We will now move on to questions about antibiotic resistance.</i>		
2.1	Have you ever heard of the term 'antibiotic resistance'?	<input type="checkbox"/> Yes (go to 2.2) <input type="checkbox"/> No (go to Section 3)
<i>I will now state a few statements regarding antibiotic resistance. Please tell me if you agree, disagree or not sure</i>		
2.2	Antibiotic resistance occurs when antibiotics become less powerful so they don't work as well	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
2.3	Antibiotic resistance occurs when your body becomes resistant to the antibiotics and they no longer work as well	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
2.4	Antibiotic resistance occurs when bacteria become resistant to the antibiotics so they are more difficult to kill	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
2.5	If I use antibiotics appropriately, I don't have to worry about getting antibiotic resistant infections	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
2.6	How other people use antibiotics doesn't affect my chance of getting antibiotic resistant infections.	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure
2.7	How I use antibiotic doesn't affect other people's chance of getting antibiotic resistant infections	<input type="checkbox"/> Agree <input type="checkbox"/> Disagree <input type="checkbox"/> Not sure

<i>Which of the following do you think can reduce the spread of antibiotic resistance? For each option, please answer yes, no or not sure</i>		
2.8	Using fewer antibiotics	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure
2.9	Vaccination	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure
2.10	Handwashing	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure
2.11	Better hygiene and infection control measures in hospitals	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure

Section 3 – Experiences in using health care services

<i>I will now ask you some questions about the last time you had symptoms of cold and flu, like sore throat, coughing, runny nose and fever.</i>		
3.1	When was the last time you had symptoms of cold and flu?	_____ months ago
3.2	How long did your symptoms last?	<input type="checkbox"/> 1-3 days <input type="checkbox"/> 4-6 days <input type="checkbox"/> ≥ 1 week <input type="checkbox"/> Not sure
3.3	On a scale of 1 to 10, where 1 is not at all severe and 10 is extremely severe, how severe were your symptoms at that time?	___ (fill a number from 1 to 10)
3.4	Did you see a doctor for these symptoms?	<input type="checkbox"/> Yes (go to 3.6) <input type="checkbox"/> No (go to 3.5)
3.5	If no, what did you do to relieve the symptoms?	<input type="checkbox"/> Took extra rest <input type="checkbox"/> Took left-over antibiotics <input type="checkbox"/> Other: ___ <input type="checkbox"/> Took traditional medicine <input type="checkbox"/> Took over-the-counter medicine
3.6	If yes, did you feel your doctor took the time to explain your illness to you?	<input type="checkbox"/> Yes <input type="checkbox"/> No
3.7	On a scale of 1 to 10, where 1 is not at all satisfied and 10 is extremely satisfied, how satisfied were you with how your doctor answered your questions about your illness?	___ (fill a number from 1 to 10)

3.8	When you went to see the doctor, what did you expect?	<input type="checkbox"/> Advice for self-care <input type="checkbox"/> Information about the illnesses such as duration <input type="checkbox"/> Rule out more serious illnesses <input type="checkbox"/> For referral to hospital or specialists <input type="checkbox"/> Medical leave for work <input type="checkbox"/> Antibiotics <input type="checkbox"/> Other (please specify: _____)
3.9	Did you ask your doctor for antibiotics?	<input type="checkbox"/> Yes <input type="checkbox"/> No
3.10	Did your doctor prescribe you antibiotics?	<input type="checkbox"/> Yes (go to 3.11) <input type="checkbox"/> No (go to 3.14) <input type="checkbox"/> Not sure (go to Section 4)
3.11	Did your doctor explain to you why you needed antibiotics?	<input type="checkbox"/> Yes <input type="checkbox"/> No
3.12	Did your doctor talk to you about antibiotic resistance?	<input type="checkbox"/> Yes <input type="checkbox"/> No
3.13	Did your doctor talk to you about possible side-effects of antibiotics?	<input type="checkbox"/> Yes <input type="checkbox"/> No
3.14	Did your doctor explain to you why you did not need antibiotics?	<input type="checkbox"/> Yes <input type="checkbox"/> No

Section 4 – Vaccination behaviors for different age groups

<i>For all participants (all ages): I will now ask you some questions about your use of different vaccines to protect against infections</i>		
4.1	Have you ever received an influenza vaccine? <i>(prompt: Also known as flu shot, flu vaccine, flu jab)</i>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure
4.2	Have you received an influenza vaccine in the past year?	<input type="checkbox"/> Yes (go to 4.3) <input type="checkbox"/> No (go to next section) <input type="checkbox"/> Not sure
4.3	When was the last time you received it?	<input type="checkbox"/> In the past month <input type="checkbox"/> 1-3 months ago <input type="checkbox"/> 4-6 months ago <input type="checkbox"/> 6-12 months ago
4.4	What was the reason that you received the influenza vaccine?	<input type="checkbox"/> Recommended by my doctor because I am/was traveling <input type="checkbox"/> Recommended by my doctor because I am/was pregnant <input type="checkbox"/> My job requires it <input type="checkbox"/> It was offered at no cost by my employer

		<input type="checkbox"/> I usually get annual flu vaccinations <input type="checkbox"/> Other (please specify: _____)
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<i>For participants aged 65 and above</i>		
5.1	Have you ever received the pneumococcal vaccine? <i>(Prompt: This is a vaccination against pneumonia)</i>	<input type="checkbox"/> Yes (go to 5.2) <input type="checkbox"/> No (go to 5.4) <input type="checkbox"/> Not sure
5.2	How many doses of the vaccine did you receive? <i>(Prompt: Pneumococcal vaccines in the NAIs include 13-valent pneumococcal conjugate vaccine (PCV13) and 23-valent pneumococcal polysaccharide vaccine (PPSV23)—one dose each is recommended for persons aged 65 and above)</i>	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> Not sure
5.3	When did you receive the last dose ?	_____ <input type="checkbox"/> Not sure
5.4	Have you ever received the varicella vaccine? <i>(Prompt: The varicella vaccine protects against chickenpox and shingles)</i>	<input type="checkbox"/> Yes (go to 5.5) <input type="checkbox"/> No (go to next section) <input type="checkbox"/> Not sure
5.5	How many doses of the vaccine did you receive?	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> Not sure
5.6	When did you receive the last dose?	_____ <input type="checkbox"/> Not sure

<i>For female participants (18-26 years old) and parents with daughters from the ages of 9-18 years old</i>		
6.1	Have you/has your daughter ever received the HPV vaccine? <i>(Prompt: HPV stands for Human Papillomavirus; two vaccines, Gardasil and Cervavix, are currently approved for use in Singapore; the HPV vaccine protects against cervical cancer and is claimable under Medisave)</i>	<input type="checkbox"/> Yes (go to 6.2) <input type="checkbox"/> No (go to next section) <input type="checkbox"/> Not sure
6.2	How old were you/was your daughter when you/she received the HPV vaccine?	Age: _____

		<input type="checkbox"/> Not sure
6.3	How many doses of the vaccine did you/your daughter receive? <i>(Prompt: This is recommended for females 9-26 years, this vaccine can be given in either 2 or 3 doses)</i>	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> Not sure
6.4	When did you/your daughter receive the last dose of the HPV vaccine?	_____ <input type="checkbox"/> Not sure

<i>For parents with <u>young children under the age of 5</u></i>		
7.1	Do you have any children under the age of 5? <i>(Prompt: Your child has not had his/her 5th birthday yet)</i>	<input type="checkbox"/> Yes <input type="checkbox"/> No
7.2	How many children do you have under the age of 5?	_____
<i>If you have more than one child under the age of 5, please first answer questions about the child <u>whose birthday is next</u>:</i>		
7.3	What is your child's birth month and year?	Month: ____ Year: ____
7.4	Has your child received an influenza vaccination in the past year? <i>(Prompt: This is also known as flu vaccine, flu shot, flu jab)</i>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure
7.5	Has your child ever received the pneumococcal vaccine? <i>(Prompt: Also known as PCV13 or Prevnar. This vaccine is given in 3 doses usually at 3, 5 and 12 months of age. PCV13 is claimable under Medisave)</i>	<input type="checkbox"/> Yes (go to 7.6) <input type="checkbox"/> No (go to 7.9) <input type="checkbox"/> Not sure
7.6	How many doses of the pneumococcal vaccine did your child receive?	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> Not sure
7.7	When did your child receive the last dose of pneumococcal vaccine?	_____ <input type="checkbox"/> Not sure
7.8	Has your child ever received the rotavirus vaccine? <i>(prompt: This vaccine protects against childhood diarrhoea and is given as drops in the mouth. Usually 2 or 3 doses are given before 8 months of age).</i>	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not sure

	<i>there are two types licenced in Singapore, Rotarix (RV5, 2 doses) and RotaTeq (RV1, 3 doses) usually given before 8 months of age. This vaccine is not currently claimable under Medisave)</i>	
7.9	How old was your child when he/she received the rotavirus vaccine?	Age: ____ months <input type="checkbox"/> Not sure
7.10	Which type of rotavirus vaccination did your child receive?	<input type="checkbox"/> RotaTeq™ (given in 3 doses) <input type="checkbox"/> Rotarix™ (given in 2 doses) <input type="checkbox"/> Not sure
7.11	How many doses of the vaccine did your child receive?	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> Not sure

APPENDIX B

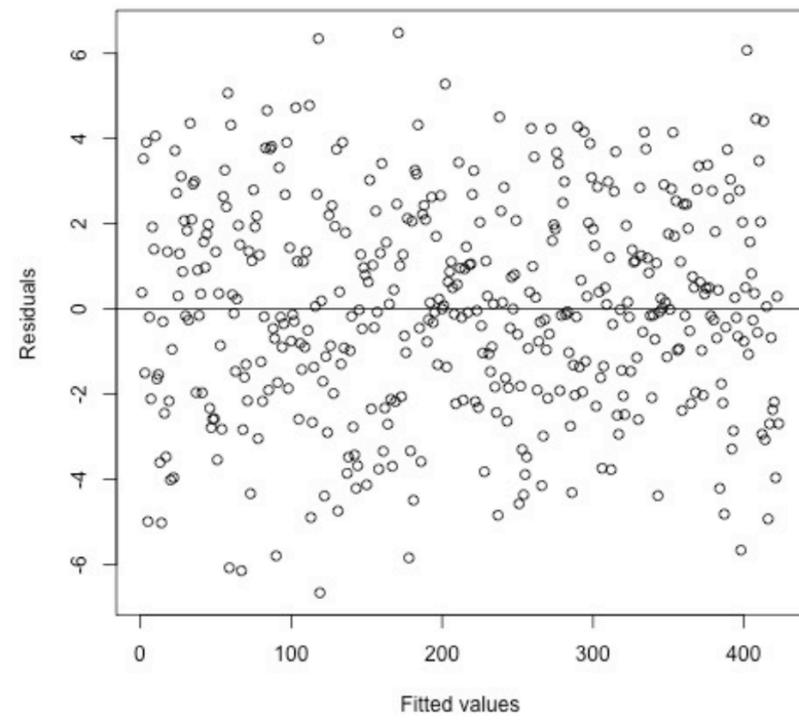
Knowledge score Range: 0 – 14 Median: 8		
Knowledge of antibiotic resistance	Have you ever heard of the abbreviation 'AMR'?	Yes = 1 point
	Have you ever heard of the term 'antibiotic resistance'?	
	Antibiotic resistance occurs when antibiotics become less powerful so they don't work as well	Disagree = 1 point
	Antibiotic resistance occurs when your body becomes resistant to the antibiotics and they no longer work as well	
	Antibiotic resistance only affects people with serious infections in hospitals	
	If I use antibiotics appropriately I don't have to worry about getting antibiotic resistant infections	
	How other people use antibiotics doesn't affect my chance of getting antibiotic resistant infections	
	How I use antibiotics doesn't affect other people's chances of getting antibiotic resistant infections	Agree = 1 point
	Antibiotic resistance occurs when bacteria become resistant to the antibiotics so they are more difficult to kill	
	Antibiotic resistance affects common infections such as sore throats and urinary tract infections	
	Using fewer antibiotics will reduce the spread of antibiotic resistance	
	Vaccinations will reduce the spread of antibiotic resistance	
	Handwashing will reduce the spread of antibiotic resistance	
	Better hygiene and infection control measures in hospitals will reduce the spread of antibiotic resistance	

APPENDIX B

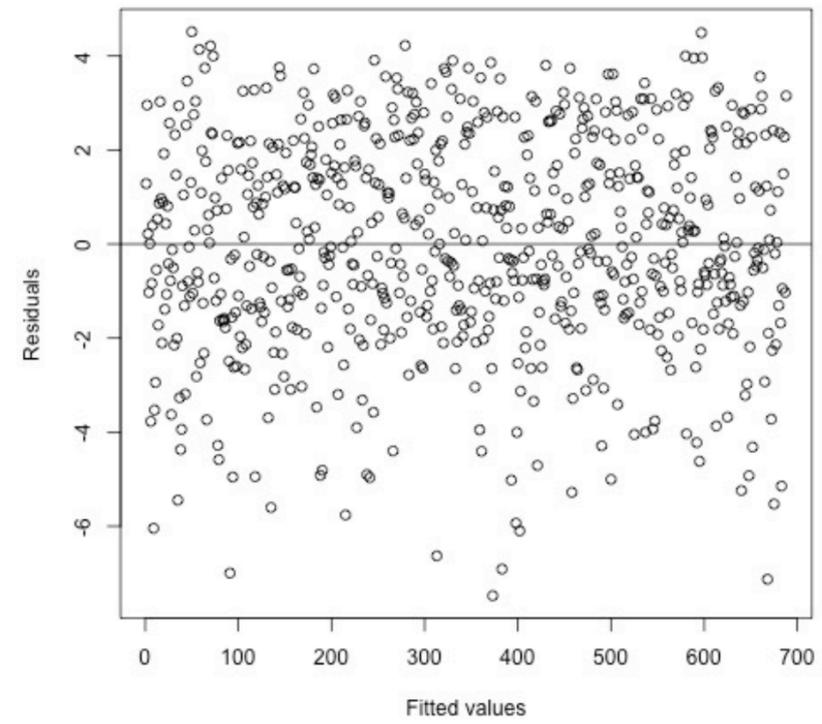
Attitudes score Range: 0 – 11 Median: 7		
Attitudes towards antibiotic use (6 points)	Antibiotics can help me recover from bacterial infections	Agree = 1 point
	It is important to always finish the course of antibiotics prescribed to me	
	Antibiotics can help me recover from viral infections	Disagree = 1 point
	Antibiotics can help me recover from the common cold and flu	
	Antibiotics can help me recover from serious symptoms of cold and flu	
	Antibiotics can speed up my recovery from the common cold and flu	
	It is okay to keep leftover antibiotics and use them again when I fall sick in the future	
	It is okay to use my leftover antibiotics when I have the same symptoms as before	
	It is okay not to finish the course of antibiotics prescribed to me when I feel better	
	It is okay not to finish the course of antibiotics prescribed to me when I have an alternative remedy	
	It is okay to miss a dose during the course of antibiotics prescribed to me	

Appendix C

Knowledge scores (Univariable analysis)



Attitude scores (Univariable analysis)



Attitude scores (Multivariable analysis)

