

# **The Causes and Implications of the Overuse of Antibiotics in Healthcare**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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## Introduction

Strains of drug resistant bacteria, specifically called carbapenem-resistant Enterobacteriaceae (CRE), have emerged as a growing and urgent issue in healthcare facilities, resulting in around 3 million infections in the United States each year (CDC, 2021). Carbapenem antibiotics, currently considered to be the most potent and highly effective class of antimicrobial agents, are often considered a last-resort, reserved specifically for the treatment of severe multidrug-resistant bacterial infections (Iovleva & Doi, 2017; Papp-Wallace et al., 2011). By far the most common cause of these infections is the bacterial pathogen *Klebsiella pneumoniae*, with over 50% of *K. pneumoniae* infections now being resistant to carbapenem antibiotics in parts of the Eastern Mediterranean and Europe (Iovleva & Doi, 2017; Zhu et al., 2020).

This rise in drug-resistant bacteria is being accelerated by the vast over-prescription of antibiotics in the healthcare field. As of 2016, it was found that at least 30 percent of antibiotics prescribed in the United States are unnecessary, equating to over 47 million excess prescriptions every year in the United States alone (CDC, 2016). As antibiotics are more and more commonly prescribed, the bacteria that these drugs are meant to kill begin to have increasingly more exposure to these drugs, and thus, more chances to evolve resistance to them (CDC, 2020). Exemplifying the effect of this, data has been collected showing that countries with a higher consumption of antibiotics also show higher rates of bacterial resistance (Llor & Bjerrum, 2014). As these microbes become resistant to antibiotics, they are able to multiply and spread into new settings and even between countries. In addition, some resistant bacteria have even developed mechanisms to spread their antibiotic-resistant adaptations directly to other germs, further accelerating this problem (CDC, 2020).

As antimicrobial resistance is now recognized as one of the greatest threats to human health worldwide, a striking lack of development of new drugs to combat these superbugs has been noticed, threatening a future of a post-antibiotic world where simple infections may once again become unmanageable (Llor & Bjerrum, 2014; Papp-Wallace et al., 2011). *K. pneumoniae* has been rapidly acquiring antibiotic resistance and rendering almost all available treatments ineffective. Thus, the discovery of new treatment strategies for this bacterial pathogen are critical. To address this, I will first identify and validate novel therapeutic targets in *K. pneumoniae* through leveraging computational-modeling and genetic engineering approaches, and then research the social aspects influencing the overprescribing of antibiotics in the healthcare field.

### **Case Context**

Germs, such as bacteria, can evolve the ability to become resistant to the drugs which are designed to kill them. When this occurs, these germs are deemed antibiotic resistant. These antibiotic resistant bacteria then have the ability to result in infections that are much more difficult, if not impossible, to treat. Drug-resistant pathogens now kill over 35,000 people in the United States each year, with the occurrence of yearly antibiotic-resistant infections growing at an alarming rate (CDC, 2020).

Though evolution towards antibiotic resistance is a naturally occurring process, current practices in antibiotic usage are vastly accelerating this rise in resistance. Antibiotic resistance is known to be accelerated when more bacteria are exposed to antibiotics, since each time bacteria come into contact with antibiotics, they are under pressure to adapt resistance. Naturally, the more opportunities these pathogens have to develop resistance, the better resistance they will be

able to evolve. Even more alarming, some antibiotic-resistant germs have developed mechanisms for sharing their resistance mechanisms with other bacteria, further accelerating this growing medical issue (CDC, 2020).

It is currently estimated that one in three antibiotics that are prescribed are unnecessary. This equates to almost half a billion antibiotics being overprescribed each year in the United States alone, and this number estimated to continue to grow in the coming years (CDC, 2016). Aside from this potentially putting patients at unneeded risk for potential drug complications, it also perpetuates the cycle of antibiotic resistance in bacteria. As previously stated, each time bacteria are exposed to antibiotics, they have an additional chance to evolve better mechanisms to evade these drugs (CDC, 2020). Therefore, this vast overuse of antibiotics is essentially resulting in 50 million unnecessary chances every year for pathogens to develop new resistance mechanisms to the drugs we rely on to treat these bacteria. This continual evolution towards complete antibiotic resistance is being rapidly accelerated by current prescribing habits, and these trends need to be altered before all ability to treat bacterial infections is lost.

### **The Sociotechnical Aspects of Antibiotic Overuse**

To work towards combatting the rapid increase of antibiotic resistant bacteria, it is necessary to understand the social aspects affecting antibiotic overprescribing in the healthcare field. The unnecessary prescribing of antibiotics is commonplace, even though antibiotic overuse is costly and leads to antibiotic resistant pathogens (Ackerman & Gonzales, 2012). Most often, these antibiotic prescriptions are being written unnecessarily in primary care settings where viruses, which do not respond to antibiotics, cause the vast majority of infections seen (CDC, 2016; Llor & Bjerrum, 2014). The technical and social aspects of this project go hand in hand.

These two aspects of this problem are trapped in a viscous cycle; clinicians over-prescribe antibiotics, bacteria grow more resistant, clinicians prescribe continually more courses of antibiotics to be able to treat these resistant bacteria, new therapeutics become in dire need, and the cycle begins all over again (CDC, 2020; Llor & Bjerrum, 2014; Thakolkaran et al., 2017). Furthermore, the common expectations of patients to receive medication, and of healthcare professionals to administer medications, results in a demand for new treatment options that vastly outweighs the ability of the pharmaceutical industry to research, develop, and get approved for new therapeutics. This viscous cycle of bacterial resistance and doctor-patient interactions is putting the health of the world at risk, and therefore urgently needs to be addressed.

Central to the issue of antibiotic overuse are the clinicians prescribing these drugs and the patients who are receiving them. Studies have shown that oftentimes the doctor will feel pressured by the patient's expectations to prescribe antibiotics, and will then succumb to those pressures, even if the doctors themselves do not feel as if they should be prescribing these drugs (Ramachandran et al., 2019). This has now seemingly become the standard of care. If a patient has an appointment with a healthcare professional regarding an illness, both parties involved expect the result to be the writing of a prescription. Further, while it may be expected that the interest in, and the level of knowledge about a given subject would align well, this is oftentimes not the case regarding the general public and science. Surveys have been collected about self-reported public interest in antibiotics and the correlating public knowledge about antibiotics. These studies have shown that while the public can be considered highly interested in antibiotics, they are very ill-informed on the topic overall (Durant et al., 1989). Further, another study demonstrated that, while approximately 90 percent of Americans claimed to support scientific

and medical advances, less than half of Americans (~45 percent at the start of the 2000s) understood that antibiotics do not kill viruses (Miller, 2004). This exemplifies that there are huge discrepancies between what people support and what they actually understand, highlighting why the public may unnecessarily desire, and pressure clinicians towards, antibiotic prescriptions.

To analyze the many factors that influence the unnecessary prescribing of antibiotics (Thakolkaran et al., 2017), I will use Star's article on infrastructure. This article, "The Ethnography of Infrastructure," describes infrastructure as hidden, yet incredibly important, mechanisms which underly the abundance of processes necessary for systems to function properly. Specifically, infrastructure is framed as a fundamentally relational concept, investigated in the context of those actors using the system put in place. Star additionally presents a series of characteristics that all good infrastructures should have. Of these, four of the characteristics most applicable to the problem of antibiotic overuse are embeddedness (being sunk into and inside of other existing structures), learned as part of membership (defined as communities of practice taking their infrastructures for granted), becomes visible upon breakdown (the invisibility of an infrastructure fades away when it breaks), and finally is fixed in modular increments, meaning infrastructures are not installed or fixed in one single pass (Star, 1999). Using this framework to analyze infrastructure allows for the easier identification of deficiencies within a given system, so that these shortfalls may be addressed.

The infrastructure around antibiotic prescriptions in healthcare is learned as a member (be it doctor or patient), resulting in the constant pressures felt from both parties to continually rely on antibiotics (Ramachandran et al., 2019). Yet, the parties within this system are incredibly ill informed, and thus continue to make decisions blindly based on previous trends (Durant et al., 1989; Miller, 2004). The result is seen in our everyday lives; the infrastructure that has been so

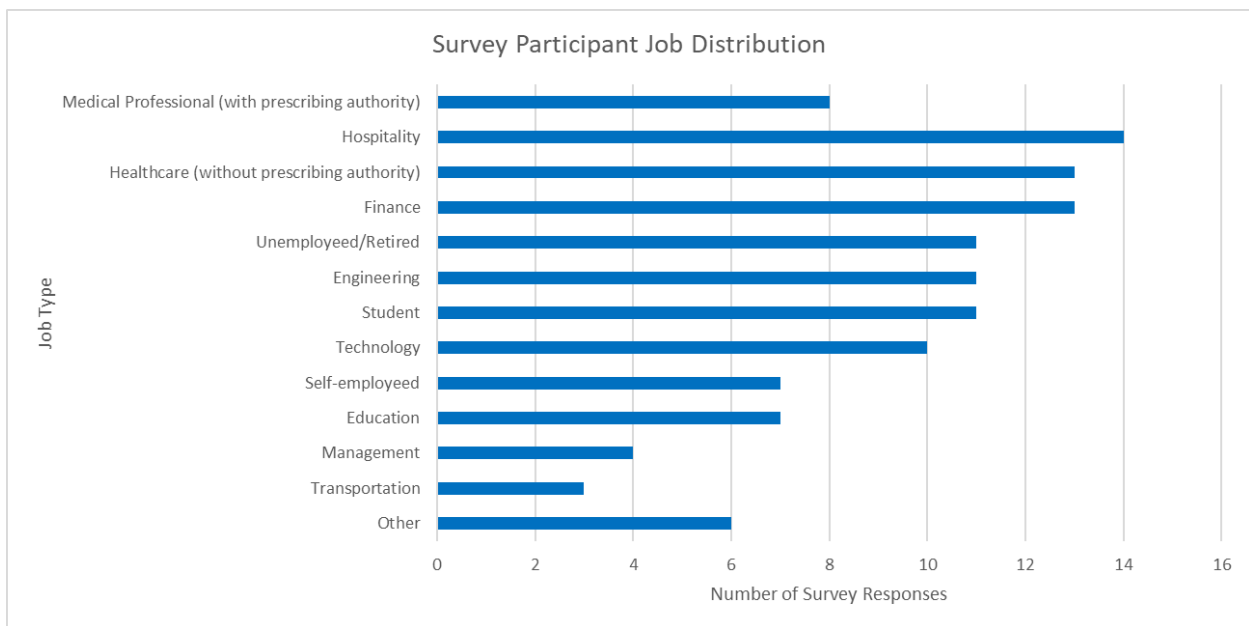
carefully built around keeping the world protected from infectious diseases is now very visibly broken and desperately needs to be repaired.

### **Research Question and Methods**

I aim to research: From the perspectives of clinicians and patients, what factors influence the unnecessary prescribing of antibiotics, and how does each factor influence this? This research is necessary because the vast overprescribing of antibiotics has led to a recent rise in antibiotic resistant pathogens, rendering even the most potent antibiotics useless (CDC, 2020; Llor & Bjerrum, 2014). Star's article on infrastructure will further be used frame the issue of antibiotic resistance prior to detailing the findings from my research question of interest (Star, 1999). If the details around why antibiotics are being overused can be better understood, proper actions will be able to be taken to ameliorate the situation.

To collect data on this particular research question, surveys were conducted with both healthcare professionals and the general public about their knowledge on, and tendencies towards, antibiotic usage. In order to receive the most amount of survey responses from both groups, the snowball sampling method was used, where each group of people who take the survey are asked to recommend new people to participate in this study (Kirchherr & Charles, 2018). The two methods used to distribute these surveys were sending them out via email and posting them on a variety of social media platforms. When conducting these surveys, clinicians were asked a series of questions about general knowledge on antibiotics, pressures felt from a variety of sources towards or against antibiotic prescriptions, and frequency of training updates on antibiotics. Eight total survey responses were received from medical professionals with antibiotic prescribing authority.

People from outside the medical field were additionally asked to answer a similar set of questions about general knowledge on antibiotics, overall desire/tendencies to receive antibiotics when seeing a medical professional, and general knowledge on antibiotic resistance. A total of 110 survey results were collected from the general public. While the survey responses were largely anonymized by not collecting personal information, qualifying data was collected regarding job status of survey participants in order to provide context for the general population of participants (Figure 1).



**Figure 1.** Total combined survey participant job distribution for both of the two surveys together (118 total responses) categorized based on survey responses.

Using the results from this survey, I have identified trends in the results (parsing out majority answers, minority answers, and unique trends across survey responses) indicating the common knowledge around, and actions towards, antibiotics from both the clinicians’ and the patients’ points of view. Specific quotes were additionally collected that were submitted by both healthcare professionals and the general public further indicating their specific opinions on and



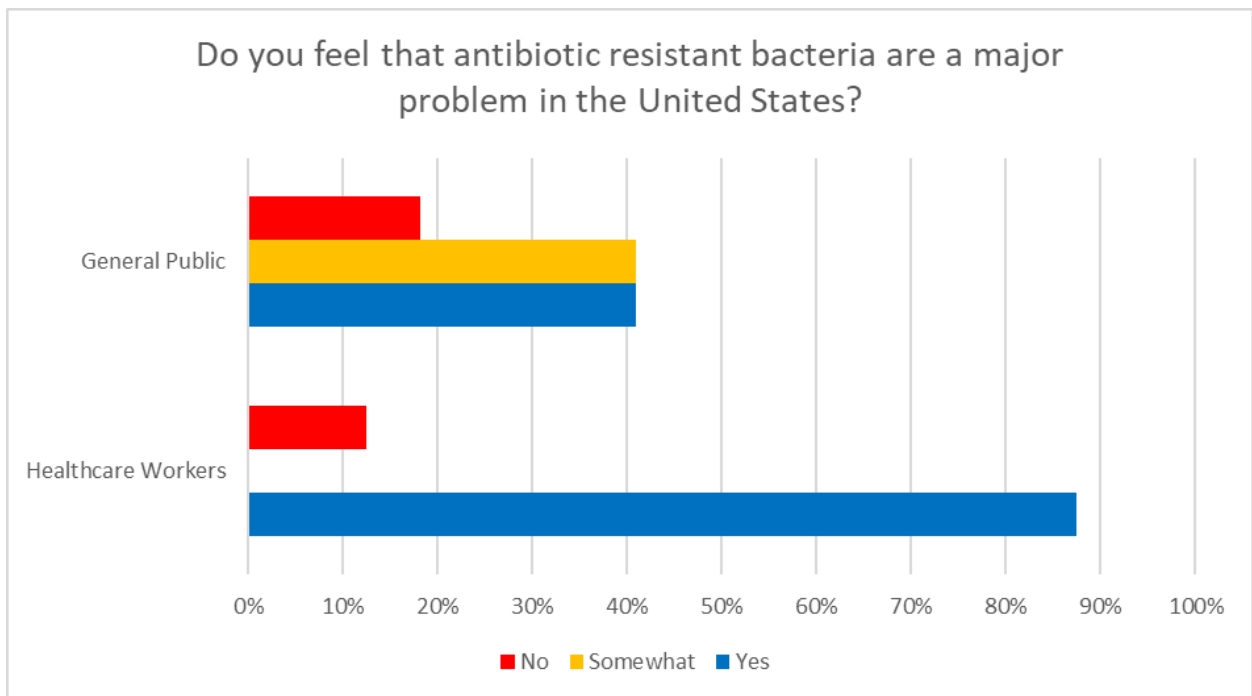
attitudes around antibiotics. These quotes were used to further contribute individual experiences around antibiotics to the more granular survey responses. Cumulatively, this research will allow for the better understanding of the sociotechnical aspects causing antibiotic over-prescription, which may lead to plausible ways to work towards resolving this issue.

## **Results**

Three primary factors influence the unnecessary prescribing of antibiotics: the lack of knowledge that the general public has regarding antibiotics, the overall expectations of the general public to receive a prescription for medications when seeing a medical professional, and the different interpretations of interactions that occur between patients and medical professionals. Each of these factors contribute to the misunderstanding of antibiotics by the general public and to the pressures felt by medical professionals to prescribe antibiotics. Although this research cannot identify absolute causation, it has uncovered striking trends around antibiotic usage. The overarching trends found throughout this study is that of public misinformation around antibiotics and of vastly differing perspectives regarding antibiotics between medical professionals and the general public. This study further explores the opinions of each of these social groups by analyzing direct quotes collected from the survey responses. While there are a plethora of different factors influencing antibiotic overuse, this research was able to uncover many of these underlying factors so that work may be done in the future to resolve this vast healthcare issue.

This study uncovered the strikingly large amount of public misunderstanding around antibiotics in the United States, illustrated through numerous different survey responses. First, the survey-takers were asked if they feel that antibiotics are an effective way to treat the common

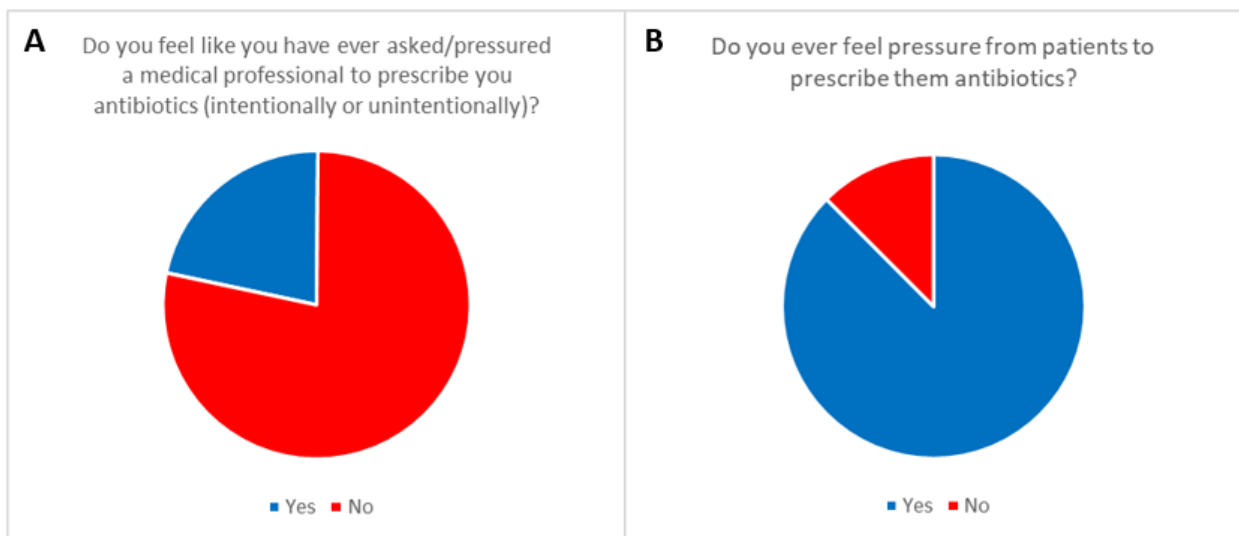
cold, to which only about half (52.7%) responded with the correct answer of “No”. They were then asked if they think antibiotics affect viruses, bacteria, or both. About two-thirds of survey responders provided the correct answer of “Bacteria” (65.5%), with the remaining 21.8% and 12.7% responding with “Both” and “Viruses” respectively. Further, almost 15% of the survey responders who indicated that antibiotics are used to treat bacterial infections also responded that antibiotics are an effective way to treat the common cold. This insinuates that 15% of survey responders have the misconception that bacteria cause the common cold. The responses to these two survey questions illustrated both the lack of understanding around how antibiotics work and the lack of knowledge that viruses, not bacteria, cause the common cold.



**Figure 2.** Representation of collected survey responses gauging general knowledge around antibiotic resistant bacteria in the United States.

Further demonstrating the public’s lack of knowledge around antibiotics, Figure 2 illustrates the differing survey responses between healthcare professionals and the general public

when asked if they feel that antibiotic resistant bacteria are a major problem in the United States. While almost all healthcare professionals responded “Yes” to this survey question (87.5%), less than half of the general public survey takers responded with “Yes” (40.9%). The general public were additionally asked to rate how comprehensive they felt their understanding of antibiotics was. Only about one-third of survey respondents indicated that they had a comprehensive understanding of antibiotics, yet interestingly these same respondents were the most likely to answer incorrectly to the questions assessing general knowledge around antibiotics. Cumulatively, this research has uncovered how a concerning large portion of the general population is very poorly educated on antibiotics, likely contributing to the ongoing issue of antibiotic misuse.



**Figure 3.** Survey responses regarding pressures around antibiotic prescriptions within patient-clinician interactions. **A.** Patient opinions on pressures put on clinicians. **B.** Healthcare professional opinions on pressures felt due to their patients.

In addition to this overall lack of understanding, a striking difference in the perception of clinician-patient interactions was found. Figure 3 highlights this point, demonstrating how, while the majority of patients do not feel that they have ever pressured a medical professional into

prescribing them antibiotics, the majority of healthcare professionals do feel these pressures from their patients. Further, every person who responded that they have asked/pressured a medical professional to prescribe them antibiotics, also responded that they did receive antibiotics after pressuring the medical professionals. Offering further insight into these interactions, healthcare professionals reported that, “Patients often expect an antibiotic... regardless of infection status. It seems as though past experiences with antibiotics for some reason make patients think antibiotics will fix it (healthcare issues) without addressing the underlying cause.” These findings agree with prior work which further emphasizes that patients are indeed pressuring medical professionals towards giving more prescriptions. It has additionally been shown that when medical professionals feel these external pressures, they are more likely to write prescriptions for these patients (Allen et al., 2022; Sirota et al., 2017; Stivers, 2021). Further, since patients oftentimes do not realize that they are pressuring these professionals, they continue to act in the same manner, hence perpetuating this cycle of poor clinician-patient interactions.

Illustrating the immediate impacts of these interactions, the general public reported how they now frequently expect and frequently receive antibiotics. The general public was asked if they tend to want/expect to receive a prescription for medication when seeing a medical professional, to which only 4.5% stated that they did not expect to receive a prescription prior to leaving. Additionally, almost two-thirds of people responded that they received at least 1-2 antibiotic prescriptions per year (63.6%), with some people reporting that they receive more than 5 antibiotic prescriptions per year. Each of these results emphasize how patients and healthcare professionals perceive the same interactions in vastly different ways, which results in the overarching theme of antibiotic overuse in the healthcare system.

## **Discussion**

The theory of infrastructure as outlined by Star structures the analysis of antibiotic overuse in the healthcare system. The healthcare system as a whole can be analyzed as an infrastructure, defined by Star as a fundamentally relational concept (Star, 1999). Specifically analyzing antibiotic usage in the healthcare system, this system does not meet Star's outlined requirements for a properly functioning infrastructure. For example, Star emphasizes that an infrastructure should be invisible when it is working as intended, yet becomes visible upon breakdown. Currently, this system has reached a point where it has broken down and become visible as it is now causing countless problems throughout the healthcare field, particularly contributing to the massive issue of antibiotic resistant bacteria (Ackerman & Gonzales, 2012; Blaser et al., 2021; CDC, 2021). Additionally, Star defines infrastructure as supposing to be transparent to the users of the system. Here, this infrastructure is also failing as the users of the system have an incredibly poor understanding of the system as a whole, hence causing them to use the infrastructure improperly.

Similar findings have been obtained from numerous different studies in recent years, further demonstrating the vast amount of misunderstanding occurring around the world relating to antibiotic usage. For example, one study showed that many American's do not currently feel that antibiotic resistance is an important issue in the United States (Carter et al., 2016). A different study identified the most common reasons antibiotics were being inappropriately overused in the pediatric field in Australia to work to combat this issue in the future (Arnolda et al., 2020). Finally, another study in Northern Ireland found that knowledge around antibiotics directly correlated to the proper usage of antibiotics (Shebehe et al., 2021). Cumulatively, it has been demonstrated countless times that there is a vast knowledge gap in public understanding of

antibiotics across the world, and that this misinformation is directly contributing to the misuse of antibiotics.

As with any study, there are limitations around the work done here, the primary shortcoming being the limited number of survey responses that were collected. Particularly, the number of responses from healthcare professionals was substantially lower than the number of general public responses, therefore being a large limiting factor within this study. Additionally, the vast majority of the healthcare professionals surveyed work in the private sector, therefore potentially misrepresenting those that work primarily in a public healthcare setting. Finally, both of the surveys were primarily taken by people living in and around the state of Virginia, which may not properly represent the remainder of the country.

To combat these limitations, I would alter my survey distribution methods to encompass a more diverse set of survey takers in the future. For example, I would ensure the survey reached more healthcare professionals from both the public and private sectors, as well representing a more diverse geographic distribution. Additionally, systematically ensuring a more diverse set of survey takers to represent the general public would be important for the accurate representation of the United States population.

This research is a central part of my development as a professional engineer. Moving forward, I will use this to advance my engineering practice by incorporating the current state of public understanding of a given topic into my design of any novel medical device or therapeutic. Since I will be pursuing a graduate education in the coming years, I will work to help educate the general public on important biomedical issues since this clearly has a huge impact on the effectiveness of our healthcare system. While science is not always extremely accessible to those with non-scientific backgrounds, it is important that we in the scientific community work

towards making it more accessible, particularly to improve public understanding of basic healthcare.

## **Conclusion**

Through the identification of the most frequent causes of antibiotic misuse presented here, proper actions can and should subsequently be taken to combat the underlying issues found. This will help to minimize future antibiotic overuse and lead to less antibiotic resistant bacteria overall. Recommendations for future researchers therefore include combating public misinformation about antibiotics by providing more information to patients prior to writing prescriptions, and working with both patients and clinicians in an informative setting (such as schools) to minimize negative pressures and expectations felt on both sides of these interactions. Cumulatively, this work and the work of future studies may contribute to the overall negation of the antibiotic misuse that is accelerating the vast problem of antibiotic resistant bacteria across the world.

Antibiotic resistant bacteria result in almost 3 million infections and over 32,000 deaths each year in the United States alone (CDC, 2021), demonstrating the severity of this global health crisis and the need for continued work in this field. To better the future of public health, it is necessary to work towards basic knowledge on healthcare for all, more straightforward clinician-patient interactions, and less antibiotic misuse within the world as a whole.

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