Original Research Article

The Impact of Antibiotics on the Human Gut Microbiome

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ABSTRACT

This paper analyzes the adverse effects of antibiotics on the human gut microbiome, combining survey data with published literature. A 31-question survey was administered across multiple U.S. states (CA, WA, MA, NC, TX, IL, GA, NJ, RI, AZ), Edmonton and Toronto in Canada, and Hyderabad, Kolkata, Bengaluru, and Surat in India, and Basel in Switzerland, to collect public experiences with antibiotic use. Respondents (n=103) were surveyed and the results were compared with peer-reviewed studies and national databases, including the CDC and NIH. The findings suggest that antibiotic use disrupts gut microbial diversity, leading to digestive issues, immune dysregulation, skin irritation, and mood disorders. This disruption is especially concerning given the essential role of the gut microbiome in digestion, immunity, and the gut–brain axis. Literature demonstrates that microbiome development begins at birth and stabilizes in early childhood, but antibiotics can permanently reduce bacterial diversity. We discuss how antibiotic-induced dysbiosis contributes to chronic conditions, explore the relationship between the gut microbiome and immunity, and examine alternatives to antibiotics such as probiotics, prebiotics, bacteriophage therapy, and fecal microbiota transplantation. Understanding both the risks of antibiotics and pathways for microbiome restoration is crucial for future health management.

Keywords: antibiotics; gut microbiota; bacteria; immune system; probiotics; dysbiosis

INTRODUCTION

Antibiotics are medications designed to fight and prevent bacterial infections by either killing bacteria directly or inhibiting their growth. Their discovery marked a major milestone in medicine, transforming previously fatal infections into treatable conditions. However, despite their lifesaving potential, antibiotics are not selective solely for pathogenic bacteria. They often eliminate beneficial microorganisms in the gut as well, which are critical for digestion, immunity, and overall health (1-7). By reducing the diversity of the gut microbiome, antibiotics can unintentionally disrupt the intricate balance of microbes that the human body relies upon for proper function.

The gut microbiome, composed of trillions of microorganisms including bacteria, viruses, archaea, and fungi, is essential for maintaining health. These microbes metabolize complex dietary components such as fibers and polysaccharides that the human body cannot digest on its own. In the process, they produce short-chain fatty acids and essential vitamins, including certain B vitamins and vitamin K, which are necessary for metabolic processes and neurological health. The gut microbiome also interacts closely with the immune system, helping to regulate immune responses, maintain self-tolerance, and prevent infections. Beyond digestion and immunity, gut

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Accepted March 30, 2026
https://doi.org/10.70251/HYJR2348.42256265

microbes influence the gut-brain axis, affecting mood, cognitive function, and mental health (6-7, 11-16, 17, 27, 28, 30). Humans and their gut microbiota have coevolved over thousands of years, forming a mutually beneficial symbiotic relationship. This symbiosis underpins many aspects of human physiology, from nutrient absorption to immune development, highlighting the critical importance of microbial diversity.

Historical analyses suggest that ancient human microbiomes were far more diverse than those found in modern populations. Early humans had diets rich in unprocessed plant matter, lived in environments with constant exposure to soil and natural microbes, and had lifestyles that promoted microbial exchange through daily contact with the outdoors. In contrast, contemporary diets—often high in animal products, processed foods, and refined sugars—combined with urban living, reduced outdoor exposure, and widespread use of sanitizing products, have significantly diminished gut microbial diversity. Even in remote populations today, such as isolated communities in Africa or South America, scientists have identified gut bacterial species absent from urbanized populations, reflecting how lifestyle and diet shape the microbiome (18-26).

Antibiotics exacerbate this problem by indiscriminately eradicating both pathogenic and beneficial bacteria. Repeated or broad-spectrum antibiotic use can result in a lasting loss of key microbial species, such as Bifidobacterium, which are particularly important during early childhood for establishing a resilient gut ecosystem. Once these bacteria are eliminated, restoring them becomes difficult, potentially leading to persistent alterations in the microbiome. Such disruptions are associated with gastrointestinal issues, including bloating, constipation, diarrhea, and irritable bowel syndrome, as well as systemic effects, including unexpected weight changes, chronic fatigue, skin irritations, food intolerances, and mood disturbances.

In summary, while antibiotics have revolutionized medicine by controlling bacterial infections, their widespread use has contributed to unintended consequences for gut microbial diversity. Understanding the interplay between antibiotics, lifestyle, diet, and early-life microbial exposures is essential for preserving and restoring a healthy gut microbiome, ensuring both immediate and long-term health outcomes. This study aims to compare the unintended consequences of the respondents' gut health with the antibiotics they used, providing original data that highlight the severity of these consequences.

METHODS AND MATERIALS

This study was conducted as a literature review supplemented with survey data. A 31-question survey was created in Google Forms and distributed via WhatsApp groups and flyers (QR Codes) in ten U.S. states (California, Washington, Illinois, Texas, North Carolina, Massachusetts, Georgia, New Jersey, Arizona, and Rhode Island), Edmonton and Toronto in Canada, Hyderabad, Bengaluru, Kolkata, and Surat in India, and Basel in Switzerland. Responses were compiled in Google Sheets and analyzed using GraphPad Prism to identify trends and visualize results. The survey asked about antibiotic use, symptoms experienced, knowledge of antibiotics, and perceptions of gut health.

This survey was anonymous and completely voluntary. This survey was designed to be exempt from IRB review because no participant information was requested other than race. Name and age were not requested in the survey. To be included, a person had to have a phone and be in one of the regions included in the survey. Participants need to understand English or have an interpreter available to translate. Participants also had to complete the form by the deadline. Exclusion criteria included participants who couldn't complete the survey due to poor eyesight, limited access to phones, living in regions without a flyer, not understanding English, lack of access to an interpreter, or failure to complete the form by the deadline. Anyone who was able to complete the survey was included.

In parallel, a literature search was conducted using PubMed, Google Scholar, and official health databases, including the CDC, NIH, and WHO. Search terms included "gut microbiome," "antibiotics," "dysbiosis," "probiotics," and "immune system." Peer-reviewed research articles, reviews, and systematic analyses (n=39) were included. The findings were compared with survey results to contextualize patient experiences with scientific evidence.

RESULTS

Survey respondents reported a wide range of symptoms following antibiotic use. Digestive disturbances were particularly common, including bloating, diarrhea, constipation, and heartburn. Additional effects such as skin irritation, mood changes, and fatigue were also observed, with some participants reporting new food intolerances and unexplained weight changes. Compared to the side effects most frequently listed by the CDC—

such as rash, dizziness, nausea, yeast infections, and diarrhea—the symptoms highlighted in this survey were distinct. In particular, bloating, acid reflux, and changes in appetite were frequently reported, suggesting either demographic differences in the surveyed population or variability in the specific antibiotics most prescribed to respondents.

Beyond symptoms, the survey also revealed significant gaps in knowledge and behavior surrounding antibiotic use. A portion of respondents believed that antibiotics could treat viral infections, such as the flu or the common cold. This misconception, combined with the fact that many participants admitted to not completing their full course of antibiotics, underscores the persistent behavioral challenges associated with proper antibiotic stewardship. Both misunderstandings about the conditions that antibiotics can treat and incomplete adherence to prescribed regimens contribute to antibiotic resistance, a global health concern.

When asked about the reasons for antibiotic prescriptions, respiratory infections emerged as the most common cause. Participants frequently reported being prescribed antibiotics for conditions such as bronchitis, pneumonia, and, in some cases, for illnesses that may have been viral in origin. The majority of prescriptions were for short durations, lasting only a few days. Over half of the respondents reported courses lasting less than a week, while approximately 10 respondents reported courses lasting several weeks. No participants reported taking antibiotics for several months, suggesting that the majority of infections treated were relatively mild and resolved quickly. Importantly, more than half of the respondents indicated that they had only taken antibiotics once or twice in the past five years, while fewer reported more frequent use. The distribution showed approximately 45 respondents in the 1–2 times range, around 25 reporting 3–4 times, about 10 reporting 5–6 times, and a slightly larger number reporting more than 6 times over the same period.

The survey data mirror global trends in rising antibiotic use. According to U.S. data, approximately 234.6 million people were prescribed antibiotics in 2022, and worldwide antibiotic prescriptions have increased by 16.3% between 2016 and 2023, rising from 29.5 billion to 34.3 billion daily doses. The high percentage of respondents who reported taking antibiotics—104 of 105 participants, or roughly 99%—further underscores the prevalence of antibiotic use. Nearly half of the respondents reported antibiotic use within the last 6–12 months alone. These findings emphasize not only the widespread reliance on antibiotics but also their integration into routine healthcare, even for relatively minor infections.

A greater proportion of respondents identified as female than male. In terms of age, the largest group was 36–53 years old, with approximately 20 individuals in the 18–35 age group and fewer than 10 under 18. Around 10 respondents were between 54 and 71 years old, and none were older than 72. Ethnic distribution was less balanced: of the 106 participants, nearly 90 identified as Asian, while approximately 10 identified as White and 5 as Hispanic/Latino (Figure 1). These demographic factors may have influenced the reported side effects and perceptions of antibiotics.

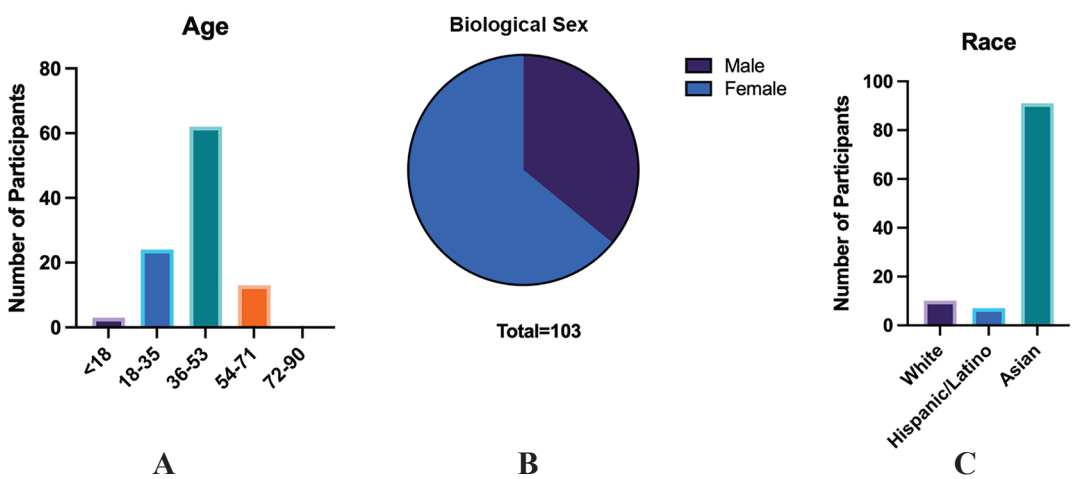

Figure 1. *Shows how demographic data revealed a diverse respondent population, though certain groups were more heavily represented. Age ranges (A), biological sex (B), and race information (C) are displayed with total (n=103) respondents.*

There near-universal use of antibiotics in this sample, with 104 of 105 participants reporting that they had taken antibiotics at some point in their lives (Figure 2A). This represents approximately 99% of respondents, a figure that reflects the widespread reliance on antibiotics worldwide. To place this in perspective, in a hypothetical population of one million people, such a rate would mean that 990,000 individuals had taken antibiotics. The survey results are consistent with broader public health data indicating high prescription rates. For example, in the United States alone, approximately 234.6 million people were prescribed antibiotics in 2022. Moreover, between 2016 and 2023, global antibiotic prescriptions increased by 16.3%, rising from 29.5 billion to 34.3 billion daily doses. Notably, studies estimate that approximately 35% of antibiotic prescriptions are unnecessary, underscoring ongoing issues with over-prescription.

Nearly half of all survey participants reported taking antibiotics within the past 6–12 months, further highlighting the frequency of their use (Figure 2B). When asked about the reasons for their prescriptions, respiratory infections were cited most often. Conditions such as bronchitis and pneumonia were among the leading causes for antibiotic prescriptions in this group. However, many respondents appeared to confuse bacterial and viral infections, with some reporting antibiotic use for illnesses that are primarily viral in origin. This aligns with the earlier finding that misconceptions about antibiotics remain widespread.

Figure 2 also details the frequency of antibiotic use over the last five years. The most common response was 1–2 courses of antibiotics, reported by approximately 45 participants. Around 25 respondents reported taking antibiotics 3–4 times, while roughly 10 reported using them 5–6 times. Interestingly, the number of respondents who reported taking antibiotics more than six times was higher than those in the 5–6 times category, highlighting that a small subset of participants are heavy users. Treatment duration also varied. As shown in the figure, the majority (approximately 85 respondents) were prescribed antibiotics for several days, while around 10 reported taking them for several weeks. None indicated taking antibiotics for several months, suggesting that the infections treated were generally mild to moderate in severity. The short duration of most prescriptions may reduce the risk of long-term microbiome disruption compared to prolonged courses.

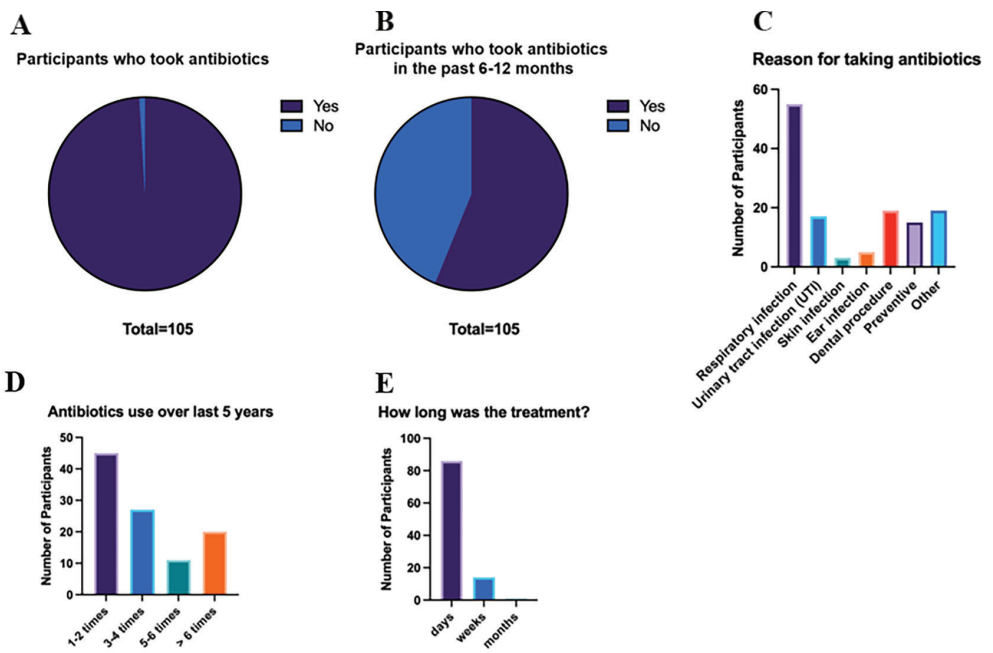

Figure 2. *Shows the data on the number of people who took antibiotics (A), the number who took it in the last 6-12 months (B), the reason for taking antibiotics (C), antibiotics usage over the last 5 years, and how long the treatment was (E). There was a total of n=105 responses for these questions, despite the overall population being n=103. These two extra responses were taken into account while making these graphs.*

Figures 3 and 4 summarize the reported side effects associated with antibiotic use. Digestive symptoms were particularly common. Approximately 15 respondents reported constipation, 10 reported diarrhea, and 5 reported stomach cramps. Acid reflux, appetite changes, and food intolerances were reported by around 20 participants each, while bloating and gas were the most frequent complaints overall. Food intolerances were especially notable, as they suggest that antibiotic use disrupted the microbial capacity to metabolize certain foods, resulting in sensitivities that were not present before treatment. A smaller number of respondents also reported unexplained weight changes. Importantly, these changes were not attributed to shifts in diet or activity, making antibiotic-induced alterations to the gut microbiome a likely factor. Mood-related symptoms were also prevalent, with about one-quarter of respondents reporting mood changes such as irritability or low mood. These findings align with growing evidence linking gut microbial diversity to mental health outcomes. Figure 4 further summarizes the persistent symptoms after completing the prescribed antibiotic regimen. A solid majority [60-80] of respondents did not report any persistent mental health symptoms or diagnosis post-antibiotic usage. A small number [20-40] reported sleep disturbances, mood disorders, cramps, diarrhea, and brain fog. Most such respondents reported struggling with digestive disorders after completion of the antibiotic regimen. This pattern suggests that although antibiotics may influence the gut-brain axis, digestive symptoms remain the more immediate and widespread consequence of disrupted microbial diversity.

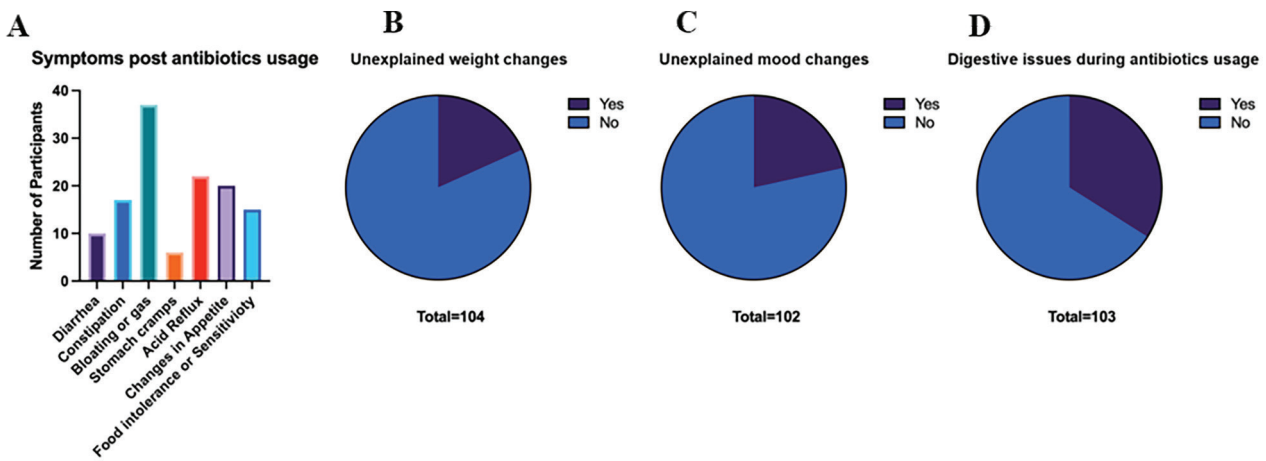

Figure 3. *Shows the side effects of antibiotic usage. The panels show the symptoms after antibiotic usage (A), the number of people with unexplained weight changes (B), mood changes (C), and digestive issues during antibiotic usage (D). This data was made with a population count of n=104, 102, and 103, respectively, and these extra samples were taken into account.*

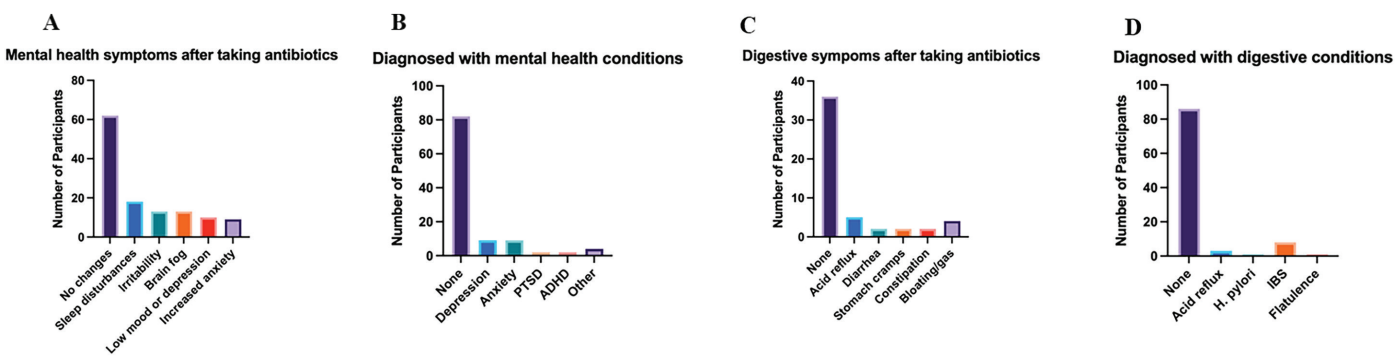

Figure 4. *Shows persistent symptoms after the completion of antibiotic regimen. Specifically, we focus on mental health symptoms and diagnoses (A & B) and digestive complaints (C &D).*

As illustrated in Figure 5, post-antibiotic supplementation and dietary habits varied among respondents. Most respondents did not take any supplements specifically to improve gut microbial health. Among those who did, multivitamins were the most common choice, reported by about 15 participants, while probiotics or prebiotics were used by only around 5. A small number reported consuming fermented foods such as yogurt or fermented vegetables, both of which can help restore microbial diversity. However, a majority of participants also reported frequent consumption of refined sugars and artificial sweeteners, which are known to negatively impact microbial health. Despite these practices, most participants rated their gut health as excellent, good, or fair at the time of the survey.

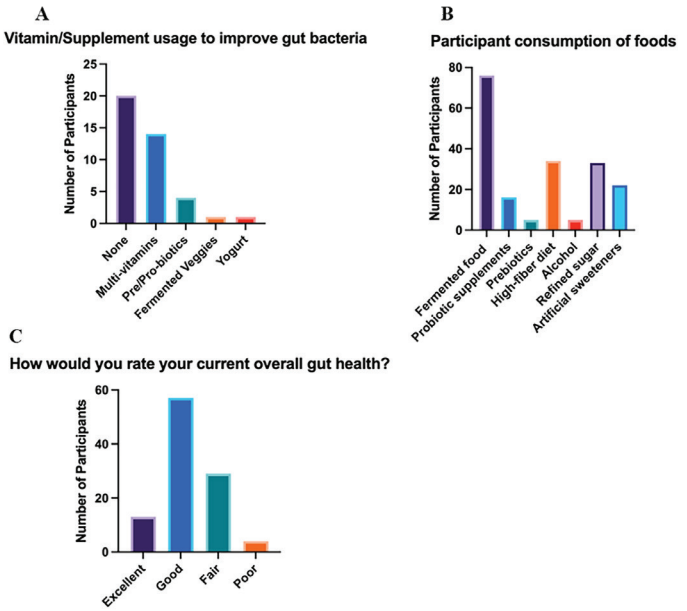

Figure 5. *Presents data on post-antibiotic supplementation and dietary habits (A and B), and their current gut health (C).*

Disruption of the gut microbiome affects the entire body. As summarized in Figure 6, antibiotic-induced microbiome disruption can influence digestion, immune function, and the gut–brain axis. Some disruptions can never be recovered from, especially if bacteria can only colonize the gut between ages 0 and 3. This can lead to many diseases, such as autoimmune disorders and mental health issues.

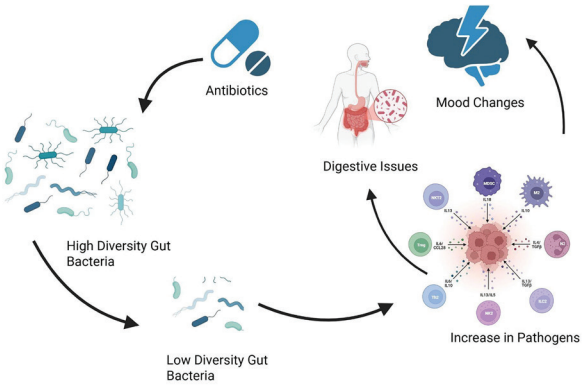

Figure 6. *Shows how antibiotics can impact gut bacteria, and the secondary impacts on digestion, immune system, and mood changes. Reducing bacteria can have many effects on their following processes, including the immune system and the gut-brain barrier.*

DISCUSSION

Interpretation of Survey Findings in the Context of Gut Microbiome Function

Based on my data, 22.4% of all respondents faced food intolerance. Additionally, 14.9% respondents faced diarrhea. Both of these are generally caused by a weaker immune system because the cells are weaker and unable to identify between food cells and the pathogens. Additionally, 9% of respondents faced stomach cramps. 25.4% of the respondents faced constipation, and 32.8% of respondents faced acid reflux. A weaker immune system (both innate and adaptive) can assist the stomach in digesting food, but if it is unable to identify if a cell is food or a pathogen, it will cause the above-mentioned health problems (11).

Many respondents were even diagnosed with digestive issues. 8.1% of respondents were diagnosed with IBS or irritable bowel syndrome. IBS is a common disease that people get with antibiotics, but it has major long-term issues that affect day-to-day life. The gut microbiome prevents such issues but when they are killed, there is no major protectors against them. 1% of the respondents even had *H. pylori* infection, a major issue that requires biopsies and eradication. There exists a symbiotic relationship between the host and the immune system. The gut microbiota allow for the induction of protective responses to pathogens and the maintenance of regulatory pathways (13). Overuse of antibiotics and changes in

diet have led to a less diverse gut microbiome, which in turn leads to a lack of balanced immune responses. The gut microbiome maintains balance within the immune system, but an imbalance between the microbiome and the immune system can cause many side effects, including autoimmune disorders and inflammatory conditions.

Gut dysbiosis refers to an imbalance in gut bacteria, indicating that harmful pathogens are overtaking beneficial microbes. There will be a reduction in the beneficial microbes and an increase in the pathogens. Dysbiosis can lead to altered immune responses, with autoimmune disorders and chronic inflammation playing a big role, as stated earlier. As importantly, the gut barrier will be weakened, contributing to various health issues (14). While most of my respondents did not experience as much gut dysbiosis as expected, 18.3% still experienced unexpected weight change. Even 21.6% of respondents faced mood changes. Antibiotics kill the microbiome, and while that is generally expected, the fact that it has major side effects highlights that gut dysbiosis by antibiotics is impactful.

The Gut-Brain Axis and the Gut Barrier

8.9% of respondents faced increased anxiety, while 9.9% of respondents faced depression. 12.9% of respondents experienced irritability, and 12.9% experienced brain fog. When the gut microbiome was killed by antibiotics, everything that the microbiome affects was also damaged. The respondents had low gut bacteria, and that immediately caused a spike in mental issues. Environmental factors, diet, and antibiotic use profoundly influence gut-brain signaling. Fiber-rich diets that support SCFA-producing bacteria promote gut barrier function and anti-inflammatory immune responses, while high-fat, low-fiber diets or repeated antibiotic usage compromise gut integrity and microbial diversity. These changes can result in neuroinflammatory responses, altered neurotransmitter levels, and increased susceptibility to neuropsychiatric disorders, highlighting the critical role of the gut microbiome in neurological and behavioral health (15).

The functions of the gut help keep a balance in the nervous system as well. The nervous system manages digestion and many other tasks that would not be possible without the gut microbiome.

Alternatives To Antibiotics and Microbiome Restoration

Overuse of antibiotics has resulted in widespread microbial resistance and significant disruption of gut microbial communities, a phenomenon known as antibiotic-associated dysbiosis. This has led to the exploration of alternative therapeutic approaches that target pathogens while preserving the beneficial microbiota. Prominent alternatives include bacteriophage therapy, probiotics, prebiotics, and fecal microbiota transplantation (FMT) (17, 18).

77.6% of respondents actually ate yogurt, while 16% of respondents actually took probiotic supplements. 5.1% of respondents took prebiotic supplements. All of this was done to recover from the antibiotics. Yogurt was especially popular because it is a type of probiotic. Inulin was a relatively rare solution that people took to cure themselves. This reduced their reliance on the antibiotics while using a more gentle method on their microbiome.

As illustrated in Figure 7, probiotics may help restore gut microbial balance following antibiotic-induced disruption. Maintaining a healthy microbiome relies not only on therapeutic interventions but also on lifestyle factors. Diets rich in fiber, polyphenols, and fermented foods, combined with reduced unnecessary antibiotic use, exposure to diverse environmental microbes, and stress management, support microbial resilience. These strategies enhance SCFA production, reinforce gut barrier function, modulate immune responses, and strengthen gut-brain communication, ultimately contributing to holistic health.

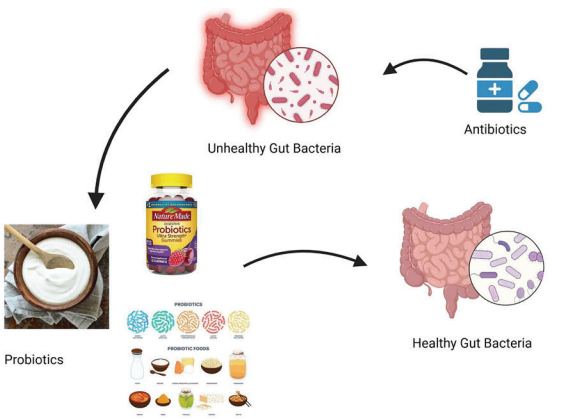

Figure 7. *Shows how antibiotics destroy the microbiome, but probiotics can restore it by implanting gut bacteria into the body. The bacteria probiotics store can be vital to the microbiome if the bacteria are lost. Another benefit of probiotics is that they are readily available. Protein shakes and flavored yogurt all contain some beneficial bacteria.*

CONCLUSION

The findings of this study demonstrate that antibiotics, while lifesaving, have profound effects on the human gut microbiome. Reducing microbial diversity contributes to digestive issues, immune dysregulation, mood disorders, and long-term health risks. Survey results confirmed that individuals commonly experience digestive disturbances after antibiotic use and revealed widespread misconceptions about when antibiotics should be used. The literature supports these findings and further highlights the links among microbiome diversity, immunity, and the gut–brain axis.

Future solutions must balance the medical necessity of antibiotics with the protection of the gut microbiome. Public education, antibiotic stewardship, and the use of alternatives such as probiotics, prebiotics, phage therapy, and fecal microbiota transplantation are essential steps toward protecting human health. Ultimately, safeguarding microbiomes requires both medical innovation and behavioral change.

CONFLICT OF INTEREST

The author declares there are no conflicts of interest related to this work.

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