Patient's Guide: Diet and Lifestyle in Peptic Ulcer Disease

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Abbreviations

AA	Ascorbic acid
bLF	Bovine lactoferrin
CagA	Cytotoxin-associated gene A
IDA	Iron deficiency anemia
NO	Nitric oxide
Nrf2	Nuclear factor (erythroid-derived 2)-like 2
Th1	T helper lymphocyte
WHO	World Health Organization

Stomach and the intestines are parts of the body that are exposed at maximum to changes in our daily diet and personal hygiene. Consequently, setting nutritional benchmarks is recognized as a way to promote health and prevent from developing many diseases. Accordingly, dietotherapy has shown the importance in the management of *H. pylori* infection, with the key purpose of protecting and recovering the GI lining and alleviating main symptoms of the infected patients to ensure the individual's health.

To colonize the body, *H. pylori* must sustain the acidic pH in the lumen of the stomach, spread within the mucus lining of the gastric tissue, attach to gastric epithelial cells via a repertoire of adhesins, and mobilize cytotoxins in order to create a hospitable niche for the bacterial proliferation. The release of microbial toxins induces necrosis, autophagy and promotes inflammatory response within the host.

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In *H. pylori*-infected patients, the release of nutrients from degradation of the gastric epithelium and mucosa, as a result of the activation of the immune system, can additionally supply the bacterium with necessary elements and exacerbate its growth, ameliorate its survival, and consequently increase its virulence. Chronic *H. pylori* infection can prompt lifelong acute and chronic gastric inflammation, which further can cause DNA damage, genetic instability and lead to gastric carcinoma development. The simplified model of gastric carcinogenesis assumes that if the *H. pylori* infection is acquired at an early age, especially when stems from malnutrition, it may diminish gastric acid secretion, so that gastric cancer may be the likely outcome. However, if the infection is acquired later in life and in person whose nutritional status and gastric acid secretion are adequate, it can promote hyperchlorhydria or duodenal ulcer disease.

Undoubtedly, diet and lifestyle have an immense impact on the occurrence of *H. pylori* infection. Inappropriate diet and daily habits are able to induce genotypic and phenotypic transformation of gastric epithelial cells, which in the future may negatively affect the course of disease. It is undisputable that high intake of salted foods facilitates the spread of infection and if consumed chronic may induce further gastric complications. Many studies demonstrated a strict correlation between insufficient supply of vitamins, which are abundant with various antioxidants, and gastric mucosa damage. High consumption of spicy food, eating high-temperature food, tobacco chewing/smoking and alcohol habits are independent risk factors that deteriorate the *H. pylori* status and augment the probability of *H. pylori*-infection associated disease. For example, nitrosamines found in diets rich in smoked foods can directly or indirectly (via carcinogens) induce carcinogenesis, which confer risk by either altering the cellular dynamics of the gastric mucosa or by the conversion of pro-carcinogens into carcinogens. Many case–control studies found the protective effects of vegetables and fruits that act against *H. pylori* infection and different types of cancers, including gastric cancer; however, this aspect remains questionable inasmuch as selected cohort studies have not confirmed such association [1]. Interestingly, food such as broccoli sprouts, Manuka honey, and omega-3 oil, independently or in combination, attenuate inflammation and manifest bacteriostatic properties [2]. The type of food, which should be either avoided (or at least minimize) or included into daily eating habits in *H. pylori*-infected patients is shown in (Box 7.1).

Among all approaches mentioned herein, many provide favorable activity in reducing bacterial colonization, diminishing stomach inflammation, and mucosal atrophy. Some methods may enhance the efficacy of traditional antibiotic therapy and reduce the side effects attributed to its use. Even if some nutritional modifications/adjustments seem unlikely to be fully effective to completely eradicate the bacteria in treated individuals, their effects may be applicable to those who plan to incorporate them as food additives to the current therapy. Compared with the use of synthetic pharmaceuticals, such dietary adjustment is inexpensive (affordable to people living in areas underserved by healthcare systems), and due to a variety of options can be modified according to one's dietary preferences.

Box 7.1 Diet recommendations

What to avoid:

☒ Salt
☒ Preserved food, i.e. salted, cured, smoked, and pickled
☒ Ready-to-eat manufactured meals
☒ Spicy food
☒ High-temperature food
☒ Tobacco chewing/smoking
☒ Alcohol
☒ Caffeine
☒ Soft drinks

Recommendations:

☑ Fresh vegetables and fruits (if not ☑ available keep refrigerated)
☑ Fresh squeezed juices
☑ Honey/propolis
☑ Polyunsaturated fatty acids
☑ Lactoferrin and folic acid
☑ Probiotics

Prepare the meal on the day of a planned consumption!

7.1 Micronutrients

H. pylori infection can significantly decrease the level of several vitamins, e.g. vitamin C, vitamin A, vitamin B12, folic acid, and essential minerals, by hampering their absorption in the GI tract. Although the absorption does not take place in the stomach, this organ is responsible for the secretion of hydrochloric acid, which along with other enzymes enables to release the micronutrients from the food matrix. Several retrospective studies demonstrated a significantly lower consumption of fruit, vegetables, and vitamin C among people infected with *H. pylori* vs. non-infected and therefore pointed out the importance of their adequate supply.

7.1.1 Vitamin C

Patients infected with *H. pylori* have low ascorbic acid (AA) level in the gastric juice. AA is a water-soluble antioxidant, a reduced form of vitamin C, which neutralizes nitrite-derived mutagens. It stimulates and activates granulocytes, macrophages, and lymphocytes, and increases the production of immunoglobulin. Although currently available data do not provide a concise and definitive conclusion about the effectiveness of antioxidant vitamins such as vitamin C and E, on *H. pylori* eradication (a positive [3], negative [4, 5] as well as no apparent association were found [6]) still, most of them support the inhibitory impact of vitamins on the growth of *H. pylori*.

An adequate supply in vitamin C can improve host's inflammatory response by maintaining a robust T helper (Th1)-predominant activity to chronic infection [7, 8]. A fair number of studies, including extensive meta-analysis comprising of 52 publications, support inverse association between the intake of vitamin C and *H. pylori* infection. Few reports have shown that long-term treatment with a high dose of vitamin C increases bacteria eradication [5, 9] and causes a significant rise in gastric juice total vitamin C concentration, which persists up to 4 weeks after treatment. In line, gastric acid plays an important role in homeostasis of AA—the compound is unstable in high pH environment and is converted to the less active form of dehydroascorbic acid, and hypochlorhydria that weaken the stability and biological availability of this vitamin. Moreover, AA is a promoter to iron absorption and thus its decreased bioavailability may also affect iron absorption.

A randomized controlled trial on 281 patients with *H. pylori* infection revealed a significant increase in *H. pylori* eradication after addition of vitamin C to standard treatment regimen (amoxicillin, metronidazole, and bismuths) [10, 11]. Adding vitamin C to a one-week triple therapy can also reduce the dosage of clarithromycin and increased the eradication of bacteria from 68 to 85% [9]. However, in patients without previous therapy, administration of vitamin C did not alter the bacteria load [6]. Similarly, individuals with previous antibiotic treatment also failed to achieve eradication of *H. pylori*. Supplementation with vitamin C (1 g twice daily for 4–12 months) decreased the formation of nitrotyrosine, a nitrating product, in individuals with *H. pylori* non-atrophic gastritis; however, short-term supplementation with both vitamin C and E (200 and 50 mg, respectively; twice daily for 4 weeks) failed to reduce reactive oxygen species and lipid peroxidation in the gastric mucosa of these patients [12, 13].

In contrast, the Netherlands Cohort Study as well as study encompassing more than 300 patients with *H. pylori* did not find any association between vitamin C intake and *H. pylori* infection, regardless of simultaneous quadruple therapy [3].

The discrepancies in the outcomes may stem from small sample size and low-to-moderate methodological quality.

7.1.2 Vitamin E and Selenium

Besides AA, the association between vitamin E or selenium and *H. pylori* was investigated but low number of reports do not permit to draw any conclusion.

7.1.3 Folic Acid

H. pylori infection and development of precancerous lesions are associated with a loss of DNA methylation. Since folic acid participates in the methylation of homocysteine to methionine, the intake of folate-rich food is considered as a chemopreventive factor in patients infected with *H. pylori*, in which the concentration of folate is lower than in healthy controls.

Serum folate concentrations were reported as an influencing factor on the level of plasma homocysteine, an intermediate product in the metabolism of methionine, whose action in turn depends on the presence of vitamin B12 and vitamin B6. Due to the decrement of these factors (vitamin B12, B6, and folate) *H. pylori*-infected subjects may develop hyperhomocysteinemia that prompts endothelial dysfunction and results in morphologic changes in the vascular system. However, whether folate or homocysteine serum concentrations are dependent on the presence of *H. pylori* infection is still controversial. Some studies consistently support this association and show lower serum level of folate and higher homocysteine in infected patients [14, 15], whereas other studies did not find any clear association [16, 17]. Data presented in various studies require further analysis.

A decrease in folic acid absorption may occur also as a consequence of reduced concentration of vitamin C in the stomach and/or elevated level of intragastric pH.

7.1.4 Fatty Acids

Although data on a potentially beneficial role of vegetable oil consumption, comprising a high concentration of unsaturated fat or a specific type of unsaturated fatty acids, and peptic ulcer is limited and based predominantly on in vivo experiments, some studies proved their protective effect. In general, an inverse association between consumption of unsaturated fat and *H. pylori* with a significant dose dependency was reported.

Since *H. pylori* is susceptible to polyunsaturated fatty acids, mainly to linoleic acid, recent studies used a liposomal formulation to improve the stability and delivery of fatty acids, which in normal conditions are poorly soluble and unstable. Although oral administration of liposomal linoleic acid to mice failed to exhibit antibacterial activity, when coadministered with a standard triple therapy (omeprazole, clarithromycin, and amoxicillin), its administration reduced the level of *H. pylori*-induced proinflammatory cytokines (IL-6, IL-8, and TNF-α) [18, 19]. It suggests that an upgraded formulation of fatty acid delivery holds potential in reducing the inflammatory response caused by the infection. Similar outcomes were obtained in clinical trials, in which patients were administered daily with 2 g of eicosapentaenoic and docosahexaenoic acids capsules. Although the omega-3 fatty acids treatment had no significant impact on the eradication of *H. pylori*, it caused a desirable effect on the level of interlekukin-8 and high sensitivity C-reactive protein (a marker of inflammation) [20, 21]. Further studies, especially clinical trials are warranted.

7.1.5 Nickel

Despite significant amounts of various forms of nickel that are deposited in the human body, e.g. via different diets over a lifetime or occupational exposure, the essentiality of this element remains questionable. In higher organisms traces of nickel may concentrate in the bone, pancreas, saliva, sweat, and serum. Studies in

animals revealed that nickel-deficient diets may affect the growth of the microbiome (the presence of metal ions in the host environment is frequently critical for the maintenance of many organisms). Nickel serves as a key cofactor for at least nine enzymes, hydrogenase and urease, that play an important role in colonization of the host gastric mucosa [22]. *H. pylori* requires the nickel-containing metalloenzymes urease and NiFe-hydrogenase to survive at the acidic pH environment in the stomach. Therefore nickel is regarded as a virulence determinant for this bacterium [23]. The effect of nickel supplementation was evaluated in a recent clinical trial, in which patients were treated with either standard LCA (lansoprazole, clarithromycin, and amoxicillin) with a common diet, or standard LCA plus a nickel free diet [24]. The addition of a nickel free diet to a standard triple therapy significantly enhanced the *H. pylori* eradication rate, possibly by depletion of both enzymes, hydrogenase and urease [24].

7.1.6 Iron

H. pylori infection very often leads to an imbalance of body iron homeostasis due to the growing demand of bacterium for this element. Long-term *H. pylori* infection may cause hypochlorhydria (a state which occurs in *H. pylori*-induced atrophic gastritis), diminish the level of ascorbic acid in the body, and subsequently reduce the absorption of iron. Iron deficiency, in turn, both from blood loss and low-iron diet can pose a considerable threat to patient's health. Moreover, iron deficiency correlates with an increased risk for gastric cancer and neoplasms, which can arise elsewhere in the GI tract.

H. pylori infection is one of the major risk factors for iron deficiency anemia (IDA), particularly among children, adolescent, and pregnant women [25]. It affects gastric absorption and bioavailability of dietary or supplement iron (gastric acidity and AA promote iron absorption). In pregnant *H. pylori*-infected woman, the association between the effects of antibacterial drugs and inadequate iron storage in the body has been linked with low initial hemoglobin level, unfavorable change in hemoglobin during the course of pregnancy, and a high chance of *H. pylori* occurrence in children of these mothers. The possible mechanism for the development of IDA in *H. pylori*-infected patients is low intragastric pH, inadequate level of vitamin C in the stomach, and sequestration of iron and ferritin in serum by gastric *H. pylori* strains [26]. Studies showed that after eradication of infection with triple drug therapy, the response to iron folic acid supplementation in pregnant woman suffering from IDA was significantly enhanced [27]. Moreover, *H. pylori* eradication therapy with simultaneous iron administration is effective in the treatment of IDA [28]. In *H. pylori*-infected patients with IDA the iron therapy response is enhanced by the concomitant elimination of the infection [29, 30]. It is recommended to intake 45 mg of iron daily [31].

Of note, heme iron, an organic form that represents two-thirds of total body iron, is readily nitrosated and can also nitrosate other substrates in the presence of nitric oxide (NO). Considering the fact that *H. pylori* infection increases the production of

NO in response to bacterial overgrowth, it is possible that high heme iron intake can contribute to gastric cancer development. The results obtained from a prospective study involving 23 centers from ten European countries showed a dose response relationship between iron consumption from meat and endogenous formation of N-nitroso compounds [32, 33]. A higher intake of red meat was also linked to the lower intake of fiber or vitamin C, which are considered as protective factors against gastric cancer [34]. The carcinogenic effect of iron was confirmed in animal models. The catalytic potential of iron was associated with the formation of hydroxyl radicals, an increase in lipid peroxidation, the suppression of the activity of host defense cells, and increase in cancer cell proliferation.

An elevated level of nitrite in the gastric juice is also observed during hypochlorhydria, a state which occurs in *H. pylori*-induced atrophic gastritis.

Small quantities of nitrosamines and preformed N-nitroso compounds can be present in cured meats, instant soups, coffee, and dried milk. Besides dietary components, cooking practices such as broiling of meats, grilling, baking, deep frying, salting, curing, and pickling are also involved in the formation of N-nitroso compounds [35].

Lactoferrin is a multifactorial iron-binding glycoprotein found in milk, both human and bovine, saliva, neutrophils, and lacrimal fluid. Recently, in vitro and in vivo studies provided data on the inhibitory activity of bovine lactoferrin (bLF) against *H. pylori* infection [36]. The outcomes were confirmed also in clinical trials on *H. pylori*-infected patients, in which oral administration of bLF in combination with antibiotics suppressed colonization of bacteria in the stomach and increased the eradication rate to 90–100% [37, 38]. A randomized, double-blind, placebo-controlled clinical trial showed that administration of bLF alone is effective in exterminating bacterium strains in the stomach. The anti-*H. pylori* activity of fermented milk-based probiotic preparations improves eradication rates by 5–15% [39].

7.2 Dietary Ingredients

7.2.1 Salt

Dietary salt consumption significantly exceeds physiological needs almost everywhere in the world. The results from in vivo and clinical studies support causal association between a high salt diet and exacerbation of *H. pylori* infection.

The intake of sodium tends to be higher in men than women, but this aspect is related to men's higher food and energy intakes. In children and adolescents, similar gender-dependent trend is observed. In elderly, the intake of sodium is independent of gender, and seems to be similar in both sexes; however, it has to be mentioned that in this group of people there are many methodological difficulties in obtaining valid dietary data, thus this general assumption needs to be treated with caution. There are two main ways by which sodium intake can be estimated: indirect via questionnaire or food consumption data, or directly by urinary excretion over a 24-h period (85–90% of ingested sodium is excreted through the kidneys).

Generally, it is difficult to assess salt intake as it is a natural component of most foods. It is very often added during cooking or at the table in amounts that people are unable to report accurately or simply ignore. The content of salt in different types of salted foods may vary depending on the food habits and type of food preparation, specific for each region in the world. Therefore, the food-frequency questionnaires are less accurate and tend to underestimate true sodium intake, as compared with intake estimates in a 24-hour urine collection. The assessment of the public perception of deleterious influence of salt may also result in a Hawthorne effect (a psychological phenomenon, in which human subjects improve their behavior to variables used in the experiment, in response to the awareness of being observed). On the other hand, levels of salt intake reported as "high" in one study might be considered "low" in other studies due to variation of setting scales of salt exposure, e.g. the salt retained by the food after cooking, variation in the sodium content of manufactured foods or the concentration of sodium in local water supplies, which additionally produces discrepancies in clinical studies. A list of selected foods and their salt contents is depicted in Box 7.2.

Box 7.2 Sodium content for representative items from different types of foods

Food type	Average sodium content (mg/100 g dry weight)
Grains	
Wheat	4.6
Oats	8.6
Rice	3.1–6.9
Rye	3.1
Barley	11.8
Muscle food	
Raw salmon	62
Canned salmon	570
Fish sticks	444
Raw tuna	47
Tuna canned in oil	290
Cod in batter, fried	100
Ground beef	77
Salami	1350
Roasted chicken breast	1140
Chicken nuggets	661
Vegetables	
Frozen broccoli	15
Raw tomato	3
Raw cucumber	2
Raw potatoes	9
Fresh green beans	0.4
Raw sweet corn	47
Sweet corn canned, re-heated	270

Box 7.2 (continued)

Food type	Average sodium content (mg/100 g dry weight)
Dairy products	
Whole milk	39
Skim milk	42
Hard cheese, average	620
Butter	576
Chocolate pudding	09
Savory snack	
Potato chips	490
French fries	113
Plain popcorn	0.3
Confection	
Chocolate bar with nuts	210
Milk chocolate	71
Lollipop	50
Beverage	
Bottled water	0.5
Orange juice	3
Coffee	2
Diet cola	4

In developed countries, a large proportion of consumers got used to eating away from home, which is usually associated with the consumption of ready-to-eat manufactured meals full of salt. One of the effective solutions to avoid or at least diminish the consumption of preserved food, i.e. salted, cured, smoked, and pickled, is to refrigerate the fresh foods such as seasonal or all year round vegetables and fruits, or prepare the meal on the day of a planned consumption.

It needs to be emphasized that high salt intake also increases the risk for precancerous gastric lesions. An elevated intragastric salt concentration causes atrophy of parietal cells and alters the viscosity of the mucosal barrier, which in consequence induces the inflammatory process and facilitates the invasion and growth of the pathogen. The induced proliferous change may additionally expose the gastric linen to food-derived carcinogens. Some in vivo studies reported that high dietary salt consumption significantly ameliorates gastric cancer incidence in a animal models of chemically induced carcinogenesis model, and similarly to *H. pylori* infection can induce intestinal metaplasia (by shifting in mucin production from glandular to surface mucous cells) in a dose-dependent manner [40–42]. High salted food—e.g., pickled vegetables, salted fish roe, miso soup, dried fish, or processed meat—which usually have a high content of nitrosated (e.g., *N*-methyl-*N*-nitro-*N*-nitrosoguanidine), can also exert pro-carcinogenic effects [43–46].

New guidelines issued by the World Health Organization (WHO) recommend less than 2 mg of sodium or 5 g of salt per day, as a maximum intake for adults [47].

7.2.2 Vegetables and Fruits

Fruit and vegetables are rich sources of carotenoids, folate, vitamin C, and phytochemicals. It is possible that modulation of xenobiotic-metabolizing enzymes, such as phase II enzymes, and mechanisms of antioxidant activity are putative preventive mechanisms against gastric damages. Studies provide an overall inverse association, particularly for citrus fruits and raw allium vegetables.

Cruciferous vegetables, glucosinolate/isothiocyanate and sulforaphane-rich foods have been of special interest as dietary strategies for *H. pylori*-infected patients and those at higher risk for peptic ulcer. In line, edible crucifers, particularly broccoli are abundant with cognate glucosinolate-derive sulforaphane, and exert potent anti-bactericidal activities that ameliorate gastritis in *H. pylori*-infected individuals (sulforaphane is known as an activator of cytoprotective enzymes that exert anti-oxidant effects) [48]; the effect of sulforaphane is obtained via up-regulation of the host's systemic protection against inflammation or oxidative stress which consequently diminishes bacteria colonization [49]. Studies showed that daily intervention with broccoli sprouts for 2 months reduced the course of bacterial infection and improved the sequelae of infection in infected mice and humans [48]. Although broccoli sprout-derived sulforaphane had no effect on the eradication or inhibition of *H. pylori* infection, it significantly inhibits lipid peroxidation in the gastric mucosa and therefore prevents from damages caused by oxidative stress [2]. Moreover, a significant reduction in markers of inflammation following daily consumption of broccoli sprouts (supplementation with 6 g/d of high sulforaphane broccoli sprouts powder for 4 weeks or 70 g/d of glucoraphanin-rich broccoli sprouts for 8 weeks) was also reported [50]. Despite a considerable effect of broccoli sprouts on *H. pylori* eradication, the effectiveness of this regimen cannot compete with the standard triple therapy.

Various types of fruits, their juices, and extracts inhibit *H. pylori* colonization in vitro. The substances included in fruits and vegetables may have both a direct antibacterial effect on *H. pylori* or having an indirect (systemic) effect by increasing the mammalian cytoprotective response.

Berries, such as elderberry, cranberry, bilberry, strawberry, and raspberry, have been the focus of particular attention for their ability to attenuate the growth of bacterium when used alone or in combination with antibiotic regimens [51]. The effects of berry's juices were evaluated in colonized human beings. It has been reported that natural berry compounds enhance the susceptibility of the bacterium to one of the most frequently used antibiotics—clarithromycin, and to exert anti-adhesion activity against *H. pylori* [51–54]. The observed effect is possibly related to the high content of proanthocyanidins, which inhibit the adhesion of bacteria to the human gastric mucosa, and diminish the growth of the microbe [55]. In spite of the potential held in berry's extract and juices as an effective, diet-based approach for the prevention or management of *H. pylori* that could be used in combination with currently available antibiotics in the future, only few clinical trials addressed this issue, therefore the above-mentioned findings need further confirmation.

The extracts of the skin and seed of grapes, pomegranate apple fruits, and ellagic acid-rich juice can prevent the spread of *H. pylori* in vitro [56]. Nonetheless, it remains unclear which components of fruits have antimicrobial activity and if similar results can be obtained in humans.

A negative significant relation between onion consumption and *H. pylori* colonization was also observed [57].

7.2.3 Meat

When looking at the pattern of red meat consumption, individuals who eat mainly fresh meat tend to select more healthy food, when compared with those eating processed meats. Although both types of meat, fresh and processed, comprise high amount of heme iron, processed meat is more abundant with saturated fats, salt, and food preservatives that may increase the pathogenicity of *H. pylori* [33]. The amount of heme iron varies greatly depending on types of meat; beef has the highest content of heme iron per gram but pork and white meat (poultry and fish) content is also significant. Red meat should not be considered as totally undesirable, since it has both negative and positive attributes.

7.2.4 Honey/Propolis

Honey is extensively used in food, beverages and in folk medicine for treating a broad spectrum of ailments. Recently, its influence on the occurrence of *H. pylori* was examined in clinical trials in dyspeptic patients—those consuming honey ≥1 day weekly had reduced prevalence of *H. pylori* infection. The effect was attributed to honey's anti-inflammatory and anti-bacterial properties with regard to its high osmolarity, acidity, and content of hydrogen peroxide and non-peroxide components [21]. Manuka honey and Mountain honey possess the strongest antimicrobial activity, however as a result of climatic variation and distribution of flowers and plant species, the exact concentration of honey that would inhibit the spread of *H. pylori* has not been established so far. Moreover, due to a variety of honey on the market, the actual composition and at the same time the same activity of each type of honey vary depending on, e.g., pollen source, environmental conditions, and the processing [58].

Propolis, a flavonoid-rich by-product collected by bees from exudates and buds of selected plants and mixed with bee enzymes and wax, exhibits anti-inflammatory and immune stimulatory activity—both mechanisms being involved in the pathophysiology of *H. pylori* infection. The anti-*H. pylori* properties of propolis have been correlated mainly with phenolic compounds that show activity against the enzyme responsible for the growth of the bacterium, nevertheless these effects have been confirmed only in vitro and so far cannot be translated into humans [59].

7.3 Probiotics

Probiotics are proposed as a useful adjunct to increase eradication rate and do diminish the frequency of side effects associated with anti-*H. pylori* therapy. According to WHO, probiotics are live organisms which when administered in adequate amounts confer a health benefit on the host. Most frequently taken probiotics contain microorganisms belonging to *Bifidobacterium, Lactobacillus, Bacillus,* and *Saccharomyces* [60]. The effect of probiotics is strain- and dose-dependent. Certain bacteria strains are able to synthesize antimicrobial compounds—bacteriocins that possess antimicrobial activity, and secrete various antibacterial substances, such as short chain fatty acids, lactic acid, or hydrogen peroxide. Moreover, microorganisms included in probiotics can prevent *H. pylori* adhesion to gastric epithelial layer by competing with adhesion receptors and stimulate mucin production, which consequently protects gastric surface from damage. Finally, modulation of immune response to microbial pathogens should be also highlighted as a potential mechanism of probiotic efficacy. It has to be pointed out that distinct probiotic strains generate different immune response, which in turn depends on the host's immune system.

In vivo studies demonstrated that probiotic treatment, although unable to fully eradicate bacteria, is effective in reducing bacterial colonization and diminishing gastric inflammation [61, 62]. Translational studies performed on *H. pylori*-infected patients support the beneficial impact of probiotics in lowering the colonization of this pathogen in the stomach, and thus suggest its regular intake concurrently with triple anti-*H. pylori* therapy [63–66]. For example, a systematic review of five randomized controlled trials, involving 1307 patients, showed that daily administration of *S. boulardii* for 2–4 weeks giving along with triple therapy significantly increased the eradication rate and diminished overall therapy-related side effects [67]. Similar observations were obtained elsewhere [68, 69]. Increased *H. pylori* eradication rate was also proved in patients treated with *Lactobacillus* [70–72] and *Bifidobacterium* [73–75]. However, not all studies confirm the effectiveness of probiotics in children [76].

Although probiotics alone cause a temporary inhibition of *H. pylori* that disappears once the administration of the inhibiting factors is interrupted, taken as an adjuvant treatment, probiotics may ameliorate the response to the conventional anti-*H. pylori* therapy, decrease the bacterial load, and improve dyspeptic symptoms.

7.4 Alcohol and Smoking

Little research investigated direct association between alcohol consumption and *H. pylori* status. However, the majority of outcomes come from in vitro or in vivo studies and thus cannot be directly referred to human subjects.

Alcohol consumption in low doses showed a negative dose-related response to active infection in humans [77, 78]. It has been suggested that the apparent decrease in *H. pylori* colony among drinkers might stem from other direct or indirect effects of ethanol on gastric mucosa or gastric acid secretion, which affect the living

conditions of bacteria [79]. However, when it comes to red wine, the anti-*H. pylori* properties may result from the radical trapping activity and high content of phenolics from grapes (approximately 60%). Surprisingly, alcohol is not considered as a risk factor, unless it is not heavily consumed.

Significantly more data describe the effects of smoking on the occurrence of peptic ulcers or gastric cancer [80–82]. A positive independent correlation between smoking and peptic ulcer, rather than *H. pylori* infection was identified [82]. The effect of smoking is dose-dependent and is mediated by other additives consumed or taken concurrently.

Smoking diminishes secretion of mucus and bicarbonate, raising the duodenal and gastric flow, which consequently increases the risk of ulcer formation. Passive smoking does not seem to significantly alter gastric mucosa; however, its influence should not be neglected. With no doubts, the coexistence of *H. pylori* infection increases the risk for gastric carcinoma in smokers contributing to the formation of oxygen radicals and release of carcinogenic nitrosamines (a major chemical compound found in tobacco), which further prompt gastric atrophy [82]. Smokers usually consume more salt than non-smokers, which possibly potentiates all above detrimental effects.

7.5 Coffee and Soft Drinks

Coffee, even decaffeinated, raises gastric acid secretion leading to mucosal irritations. The epidemiological studies showed a positive dose–response relation between coffee consumption and *H. pylori* infection among those patients who drink more than two cups of caffeinated drink a day. However, until now no strict recommendations for the amount of coffee consumed daily exist.

Similar effect of mucosal irritations is observed among those drinking soft drinks. It is probably caused by carbon dioxide and enhanced acid production, which additionally prompts gastric distention. Considering variances in individual's tolerance, consumption of either coffee or soft drinks is not prohibited but should be avoided especially among people with peptic ulcer.

7.6 Mediterranean Dietary Pattern

In spite of some regional variations, the Mediterranean pattern includes the high consumption of fruit, vegetables, legumes, fish and seafood, cereals, seeds and nuts, olive oil (as a main source of fat), moderate alcohol consumption, and relatively low intake of red and processed meat. Numerous cohort studies showed that adherence to the Mediterranean pattern led to a substantial and significant reduction in incidence of gastric cancer [83]. Although many studies were conceptually similar, very often the food components and differences in the consumption within the population group varied, and consequently affected study endpoints. It is advisable to interpret these results with caution.

It is unknown whether this diet is suitable for those carrying the *H. pylori* infection.

Conclusion

The eradication of *H. pylori* infection is a major primary preventive strategy against peptic ulcer. Substantial evidence from case–control and cohort studies indicates a strong relationship between dietary and lifestyle habits, and the occurrence of the pathogen.

High intake of traditional salt-preserved foods, processed meat, and inadequate supply of macronutrients directly damages the gastric mucosa and therefore favors *H. pylori* colonization. Smoking also acts as underlying cause together with an excessive alcohol consumption—both promote the activity and virulence of the bacterium.

Adequate nutritional status, including high consumption of certain fruits, vegetables, vitamins and probiotics appears to diminish pathological consequences of *H. pylori* infection and increase its eradication rate.

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