REVIEW ARTICLE

Mini Review on Processed Meat Consumption and the Heart: Risks, Realities and Recommendations

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Abstract: One of the main global health concerns, the burden of cardiovascular illnesses is rising because of aging populations. Strong epidemiological evidence suggests that eating processed meat significantly raises the risk of cardiovascular disease. In contrast, unprocessed red meat has weaker associations with cardiovascular outcomes. This review examines the relationship between consuming processed meat and the risk of cardiovascular disease by examining recent meta-analyses, observational studies, and randomized controlled trials. The increased risk is caused by nitrates, nitrites, polycyclic aromatic hydrocarbons, and high sodium content (four times higher than that of unprocessed meat). These compounds cause systemic inflammation, endothelial dysfunction, hypertension, and the formation of atherosclerotic plaque by interacting with trimethylamine-N-oxide (TMAO) mechanisms. Vulnerable populations, including those with genetic predispositions, diabetes, and the elderly, have higher risk profiles. Substituting processed meat with plant-based proteins, nuts or low-fat dairy products can lower cardiovascular risk by as much as 17%. Current evidence supports recommendations to limit processed meat consumption to 30 –70 g per week while emphasizing the substitution of healthier protein sources for processed meats to reduce the burden of cardiovascular disease.

Keywords: Processed Meat Consumption, Coronary Heart Disease, Cardiovascular Disease, Dietary Guidelines

INTRODUCTION

Dietary meat is a fundamental component of the eating patterns of many populations [1]. In the 1960s, plant-based proteins, particularly those derived from wheat, were the predominant source of dietary protein in many parts of the world. Today, animal-based food accounts for at least 58% of food consumption in many populations.

Meat is the skeletal muscle and associated tissues derived from mammalian, avian, reptilian, amphibian and aquatic species harvested for human consumption [1]. Meat can be categorized into several groups like red, white, process, unprocessed etc. Meat and meat products are rich sources of essential nutrients, including high-quality protein, iron, and vitamins. As part of a balanced diet, meat provides essential micronutrients and amino acids that contribute to the maintenance of overall health.

The global increase in meat production across different regions and meat types are shown in Figures 1 and 2. Specifically, the production of chicken, pork, and beef has risen significantly over the past 40 to 50 years. In many developed countries, meat has become the dominant source of dietary protein. For instance, individuals in the European Union consume approximately 28 g of meat-derived protein per capita per day, accounting for around 30% of the total energy intake from animal-derived foods [2]. However, approximately 5% of the world's population identifies as vegetarian.

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In contrast, a much larger proportion of the population (14–60%) reduces meat consumption without eliminating it entirely from their diets; these individuals are commonly referred to as flexitarians [3].

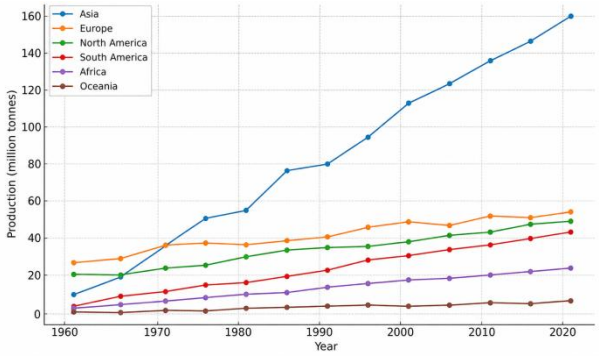

Figure 1: Global meat production during the period of 1961-2023

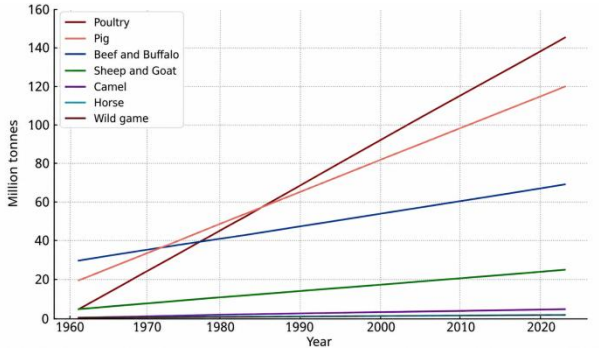

Figure 2: Meat production by livestock type during the period of 1961- 2023

A healthy diet has the potential of reducing the risk of chronic diseases and eating well is of essence especially in critical periods of life such as when one is pregnant, in menopause and in old age [4]. However, the growing consumption of processed meat, including sausages, bacon and canned meat products, has emerged as a significant public health concern due to its established association with cardiovascular disease (CVD) risk. These products, characterized by high levels of sodium, saturated fats and preservatives like nitrates, have been mechanistically linked to endothelial dysfunction, systemic inflammation and oxidative stress.

The main objective of this mini review is to examine the cardiovascular risks associated with processed meat consumption, examine the driving biological mechanisms, and offer certain dietary recommendations to promote heart health.

MECHANISMS AND EVIDENCE LINKING PROCESSED MEAT CONSUMPTION TO HEART DISEASES

There are different categories of meat, such as red meat and white meat. Red meat refers to the muscle tissue derived from mammals, including species such as beef, veal, pork, lamb, and goat, as well as meat obtained from nonbird game animals such as venison, bison, and elk [4] [1]. It can be available in fresh, ground or frozen forms. White meat refers to meat which appears to have a paler color before and after cooking. It also has a lesser amount of myoglobin compared to red meat. Poultry (especially breast muscle) and some aquatic species are known to produce most white meat (e.g. Chicken, turkey and fish and included poultry cold cuts, chicken mixtures, canned tuna, as well as low fat sausages and low-fat hot dogs made from poultry) [5].

Unprocessed meat is the cuts of meat are muscle only, those that have undergone merely cutting, grinding or otherwise standard processes and do not contain any preservatives or other curing agents (e.g. beef fresh cuts, pork chops, lamb chops, chicken breast, fresh fish fillets) [6]. The association between risk of cardiovascular disease and unprocessed red meat is not so robust. Some studies have pointed out the negative effect of unprocessed red meat on cardiovascular health compared with high-quality plant protein sources. A meta-analysis of randomized controlled trials concluded that consuming ≥ 0.5 servings of unprocessed red meat per day does not significantly affect blood lipids, lipoproteins or blood pressure [7]. Moreover, Mendelian randomization studies have not established a causal link between unprocessed red meat consumption and cardiovascular disease risk. Furthermore, some studies have suggested that unprocessed red meat may have a positive impact on cardiovascular health. Because of this disparity of outcomes, several studies have questioned the advisability of limiting unprocessed red meat consumption for cardiometabolic health.

However, scientific evidence supports that the consumption of processed meat is linked to an increased risk of mortality from cardiovascular diseases. Processed meat production undergoes some technical processes such as freezing, salting, smoking, heating, marination or using chemicals to preserve the meat (e.g. Ham, bacon, hamburgers, salami, etc.). Processing involves the addition of extra meat and fat and a lot of ingredients and additives that are not meat-related hence, the result

is unobvious [5]. The potential risk associated with processed meat products may be attributed to the high levels of salt, polycyclic aromatic hydrocarbons, nitrates and nitrites found in processed meat [8]. Industrially processed meat contains preservatives including salts, possibly exerting negative effects on health. During maturation some processed meat products develop a specific microbiota, forming probiotic metabolites with physiological and biological effects yet unidentified, while the concentration of nutrients also increases. Recent meta-analysis of both observational and randomized controlled trials does not support any effect of saturated fat on cardiovascular disease or diabetes. The high contribution of saturated fatty acid (SFA) has been in the spotlight in recent years, as several large observational studies found positive associations between a high intake of red and processed meat and the risk of cardiovascular diseases, cancer and all-cause mortality, as well as type-2 diabetes [9]. Comparatively, studies have shown a weak association between unprocessed red meat consumption and colorectal cancer, breast cancer, type-2 diabetes, and ischemic heart disease. Moreover, there is limited to no evidence of an association between unprocessed red meat and either ischemic or hemorrhagic stroke [10]. While some evidence suggests that eating unprocessed red meat is associated with an increased risk of disease incidence and mortality, it remains weak and insufficient to formulate stronger or more conclusive recommendations [11]. Epidemiological evidence confirms that regular consumption significantly elevates risks for coronary artery disease, stroke and hypertension, even at moderate intake levels [12].

Meta-analysis indicated an increased exposure to coronary heart disease (CHD) due to an increase of 42% with the consumption of processed meat. An example of this includes eating 50 g of processed meat daily and the enhanced risk of CHD of 42 %. Raw red meat in turn did not elevate the risk of CHD. The processed and unprocessed red meat possess approximately equal contents of cholesterol and saturated fats. However, the amount of sodium in processed meats is 4 times higher with approximately 50% more natural nitrate preservatives. The study indicates that the nutrients, as opposed to fat content, could be an explanation why the risk is increased. Sodium in the diet may increase blood pressure, and nitrates may increase atherosclerosis and vascular issues. The risk of CHD across processed meat was 1.42 (95% CI=1.07-1.89) per 50 g portion of processed meat per day. The result remained the same when the only studies included in the review were cohort studies and indicated a 44 % increased risk of CHD per serving consumed. A similar result was yielded by limiting the study to the findings in the U.S with RR of 1.40 (95 % CI 1.03-1.91) [10].

The journal of Nature Medicine has posed the question as to whether consumption of unprocessed red meat is associated with some health conditions. The objective sought to focus on two primary cardiac health indicators; heart disease and stroke (IHD and both ischemic and hemorrhagic). These are the findings on every outcome. The heart disease in the study, there was limited evidence that unprocessed red meat intake increases the risks of IHD. At the dosage of 50 g (50 g d -1), the Relative Risk (RR) was 1.09 and the RR increased to the level of 1.12 at 100 g (100 g d -1). Ischemic stroke in the study, evidence supporting the fact that consumption of unprocessed red meat increases ischemic stroke risks emerging. It received a grade or rating of one star and Risk of Selection or ROS of -0.02. The mean RR was 1.15 at 100 g d-1. Hemorrhagic stroke was also no evidence that intake of unprocessed red meat increases the risk of hemorrhagic stroke. It was ranked as a one star and a ROS as -0.13. The average RR was 0.87, and the Burden of Proof Risk Function (BPRF) value was 1.14 at averaged exposure when the daily intake was 100 g d -1 [13].

Global studies reveal processed meats account for nearly 20% of total meat consumption, with particularly high intake observed in Western nations and rapidly urbanizing regions [13]. Research demonstrated a consistent 12-18% increase in CVD mortality risk per 50 g daily serving [14]. Owing to that, the nutritional transition in South Asia shows traditional plant-based diets being progressively displaced by processed meat products, especially among urban populations and younger demographics [15]. Recent studies indicate processed meat consumption has doubled in urban centers over the past decade, paralleling rising CVD prevalence [16].

Traditional meat processing methods including drying, curing, fermentation, and smoking historically served essential roles in food preservation and flavor enhancement; however, they present significant cardiovascular health implications that require careful examination in contemporary dietary contexts. The high sodium content inherent in curing processes, particularly salt and brine curing methods that utilize sodium nitrate and sodium nitrite, may contribute to hypertension and increased cardiovascular disease risk. Similarly,

smoking techniques, especially hot smoking can generate polycyclic aromatic hydrocarbons (PAHs) and other potentially harmful compounds that may have adverse effects on heart health [17], [18]. However, emerging trends toward natural alternatives such as celery extract instead of synthetic nitrites reduced sodium formulations and controlled fermentation processes using beneficial probiotics suggest opportunities for developing heart-healthier processed meat products [18]. The integration of novel preservation technologies such as high-pressure processing, ultrasound, and cold plasma combined with traditional methods like fat-based preservation, may offer pathways to maintain the cultural and culinary benefits of processed meats while minimizing cardiovascular health risks. Future research should focus on optimizing these processing methods to reduce sodium content, eliminate harmful compounds and potentially incorporate functional ingredients that may provide cardiovascular protective effects thereby bridging the gap between traditional food preservation practices and contemporary health-conscious consumption patterns [17], [19].

Processed meat continues to be consumed for several interconnected reasons. It remains a valuable source of high-quality protein, supplying all essential amino acids with high digestibility and is also rich in critical micronutrients such as iron, zinc, selenium and vitamin B12. Organ meats like liver provide additional benefits, including vitamin A and folic acid. Although fat content varies among products, like fatty bacon, contain up to 90 g/100 g of total fat. Beyond nutrition, factors such as cost, accessibility, convenience and sensory appeal including taste and satisfaction also influence consumption. While some individuals reduce processed meat intake for health (38.2%) or non-health reasons (38.5%) like environmental concerns (22.0%) and animal welfare (20.4%), a smaller portion (4.6%) cite cost. Cultural and social influences, including family practices, personal beliefs about health and sustainability, and enjoyment of eating, further shape dietary habits. Interviews have highlighted that decisions around meat consumption are not solely based on health but also influenced by complex personal and societal factors, as well as uncertainty surrounding the evidence [20], [21].

Several large population-based studies have shown a strong link between processed meat consumption and an increased risk of coronary heart disease (CHD) and heart failure (HF). For CHD, the risk rose by 15% with each additional daily serving of processed red meat. Even total red meat and unprocessed red meat were associated with a 12% and 11% increase in CHD risk per serving, respectively these associations remained statistically significant even after adjusting for various risk factors. The risk was slightly higher in cases of fatal CHD. Notably, substituting processed meat with healthier protein sources such as legumes, nuts, soy, whole grains, dairy products or even eggs was linked to a significant reduction in CHD risk, with a 17% decrease observed when plant-based proteins replaced one daily serving of processed red meat. In the case of heart failure, the high intake of processed meat, especially 75 g or more per day was significantly associated with increased risk [22]. Men consuming more than 75 g/day had a 1.28 times higher incidence and a 2.43 times higher mortality rate from HF compared to those consuming less than 25 g/day. Each 50 g increase in daily processed meat intake was linked to an 8% higher incidence and a 38% higher mortality risk from HF. Potential mechanisms behind these effects include elevated sodium intake and various food additives commonly found in processed meats. These can increase blood pressure and may disrupt cardiovascular function. Nitrites used in meat preservation, though considered cardioprotective in small amounts, have also been associated with endothelial dysfunction at high concentrations. Phosphate-containing additives may lead to phosphate imbalance and contribute to heart failure, while polycyclic aromatic hydrocarbons (PAHs) found in smoked or grilled meats may further raise cardiovascular disease risk. These findings, consistent with previous research, support recommendations to reduce processed red meat consumption due to its contribution to both cardiovascular diseases and cancer [23].

Low-density lipoprotein (LDL) and high-density lipoprotein (HDL) cholesterol levels are critical determinants of cardiovascular health, with elevated LDL and reduced HDL contributing to inflammation, insulin resistance and increased risk of atherosclerotic cardiovascular disease (CVD). Recent studies highlight that the relationship between HDL-C and heart health may not be linear, as both low and very high HDL-C levels (≥80–90 mg/dL) are associated with increased all-cause mortality and CVD risk, suggesting a U-shaped association. Processed meat consumption has been shown to influence these lipid parameters depending on type and frequency. For instance, frequent consumption of frankfurters was significantly associated with elevated LDL-C (2.86 mmol/L) and reduced HDL-C (1.05 mmol/L), while other products like ham and pate

showed no significant changes [24]. These findings indicate that certain processed meats may adversely impact lipid profiles, thereby increasing cardiovascular risk through modulation of LDL and HDL levels.

DOSE-RESPONSE RELATIONSHIP OF PROCESSED MEAT AND CARDIOVASCULAR DISEASES (CVD)

Cardiovascular disease (CVD) is a major global health challenge, contributing significantly to mortality and morbidity. One factor that has received considerable attention is diet, specifically the consumption of red and processed meats. The high content of saturated fats, cholesterol, and heme iron in red meats, such as beef, pork, and mutton, has been hypothesized to contribute to cardiovascular risk. Similarly, processed meats containing preservatives, sodium, and nitrates have been associated with increased CVD risk [24].

Lifestyle modification, especially dietary modification, is a widely accepted cornerstone method for the prevention of CVD and is the first-line strategy for the prevention of Type 2 Diabetes Mellitus (T2DM) and CVD. Excessive intake of saturated fatty acids can significantly increase the concentration of plasma LDL cholesterol, thereby increasing the risk of CVD and coronary heart disease. Reducing the intake of saturated fatty acids can reduce CVD event [25].

Our substitution modeling analyses indicated that replacing red meat with other food sources of protein, such as nuts and skimmed milk, was associated with a lower risk of CVD. Potential mechanisms of detrimental effects of high red meat consumption on cardiovascular health included the high content of saturated fat and heme iron in red meat as well as added sodium in processed red meat, all those factors act on multiple pathways, including hypertension, dyslipidemia and systematic inflammation to an increased CVD risk. In addition, depending on the preparation method of red meat, individuals with a high red meat intake usually had a high intake of nitrite, polycyclic aromatic hydrocarbons and heterocyclic amines that were produced during the cooking process of red meat. These chemicals may increase the risk of diabetes and CVD through pathways of oxidative stress and systemic inflammation. In the liver, TMA is then converted into trimethylamine-N-oxide, which can promote thrombus generation, leading to vulnerable atherosclerotic plaques and eventually, a higher risk of CVD. Red meat consumption is associated with an increased risk of CVD. Our findings support lowering red meat intake and replacing red meat with plant-based protein sources or low-fat dairy foods as a key dietary recommendation for the prevention of CVD [26].

VULNERABLE GROUPS AND RISK FACTORS

A. Diabetes / Metabolic Vulnerability

The susceptibility to diseases such as type-2 diabetes is called metabolic vulnerability. In a mega meta-analysis on all the available studies on about 2 million adults, increased meat, specifically processed and unprocessed red meat intake was associated with the increased prevalence of type-2 diabetes in most of the populations. The research contributes to advising reducing such meat consumption to reduce the likelihood of the condition. Even though some reviews have come up with alternative conclusions concerning the extent to which the evidence is definite, the current analysis presented a positive correlation between the intake of meat and propensity of developing type-2 diabetes [27].

The research there is an evident connection between the consumption of processed red meat with issues that increase the probability of heart diseases. In individuals having diabetes, the analysis finds that consuming processed red meat increases the risk of having uncontrolled blood sugar levels, which are represented using glycated hemoglobin A1c (HbA1c). Individuals with T2DM who consumed processed red meat had an HbA1c value that was 1.76 times more than those who never did. This risk was furthermore intense between two categories of people, namely individuals who did not consume alcohol and individuals who did not use diabetes medicine. The risks were 2.09 and 3.20 times increased in those two groups respectively. A small amount of processed red meat increases the risks of blood sugar, blood pressure and cholesterol levels in individuals with type 2 diabetes. Reducing intakes of processed red meat could reduce heart diseases in individuals that have the same problem [25].

B. Age / Existing Cardiovascular Vulnerability

Consumption of processed meat increases the risk of premature deaths as well as cardiovascular disease deaths among frail elderly people. Consuming greater amounts of processed meat increases the risk of developing cardiovascular mortality. The risks per 25 g/day increment are 1.20 (95% CI 1.02-1.42) with the hazard ratio. Consumption of unprocessed poultry daily

and moderate consumption of unprocessed red hovered down the risk of mortality due to all causes, cancer and cardiovascular deaths [28].

C. Genetic Susceptibility

There was an association between the consumption of meat and death only in older Chinese adults who did not have the APOE-epsilon4 gene. The non-carriers of APOE-e4 and who consumed a lot of meat were at a higher mortality risk. In APOE-e4 carriers, a high consumption of meat did not have a distinct association with death. Only men showed this pattern. Egg consumption was not associated with any mortality in the APOE-e4 carriers or non-carriers [29].

D. Causality, Mechanisms and Broader Context

The authors used a Mendelian randomization perspective in which researchers studied how red and processed meats could increase the risk of four cardiovascular issues: coronary artery disease, atrial fibrillation, heart failure or stroke. Observational studies tend to be inconclusive and demonstrate that the consumption of red or processed meat increases risk. These findings might be conflated with other variables and catalogues might not find a one-to-one correlation between before and after the research. Indeed, genetic variations were used as instrumental variables by the researchers. This method reduces the impacts of other confounding effects that tend to restrict observational studies. They accessed data from the UK Biobank and Finn Gen to conduct their research [24].

PUBLIC HEALTH AND DIETARY GUIDELINES

Processed red meat may play a part in risk factors such blood pressure, obesity and lipid profile, which could explain the positive correlations between red meat and CVD and its subtypes. Furthermore, a high intake of red meat may also be linked to hypertension. Carnitine has also recently been linked to an increased risk of CVD. Carnitine and trimethylamine-N-oxide (TMAO) are elevated in red meat, which may be the cause of the link between red meat consumption and CVD [30]. Due to the addition of flavorings and preservation agents like salt and nitrite, processed red meat may have different health effects than unprocessed red meat. In order to provide evidence regarding alternative protein sources that constitute a healthy dietary pattern in accordance with current dietary guidelines, the reduced risk of incident CVD is by substituting other major protein sources, such as fish, poultry, eggs, dairy products, nuts, legumes and combined plant protein sources (nuts, soy foods and other legumes) for red meat in the diet [26]. Processed meats, including preserved options like bacon, sausage, hot dogs, pepperoni, salami and low-fat deli meats (like chicken, turkey, ham and beef) should only be eaten once a week (about 50 g or 1.75 ounces) due to their high sodium and nitrate content according to Mozaffarian et al [31]. Further, Table 1 depicts Food-Based Dietary Guidelines recommendations for meat for Belgium, Bulgaria, Germany, Estonia and United Kingdom.

The American Heart Association (AHA) states that it's critical to adhere to a heart-healthy eating pattern that can be sustained despite a range of personal and cultural preferences. Two evidence-based diets, the Mediterranean diet and the DASH (Dietary Approaches to Stop Hypertension) diet, reduce processed and red meats, add sugars, sodium and saturated fats while emphasizing fruits, vegetables, whole grains, legumes, nuts and healthy fats like olive oil. These dietary practices have been shown time and time again to improve long-term health overall, lower the risk of cardiovascular disease and maintain normal blood pressure and cholesterol levels [33].

CONCLUSION

This mini review highlights that a high intake of processed meat is strongly linked with an increased risk of heart disease. The findings show that excessive amounts of sodium, saturated fat and chemical preservatives found in processed meat contribute to conditions such as high blood pressure, cholesterol imbalance and other cardiovascular problems. Evidence from global studies confirms that populations with higher processed meat consumption face a greater risk of heart disease compared to those with lower intake. At the same time, the review also points out that adopting balanced diets rich in fruits, vegetables and plant-based protein can help lower this risk and improve overall heart health. From a public health perspective, the growing consumption of processed meat across many countries increases the burden of heart disease and calls for urgent action. Creating awareness, improving consumer education and encouraging healthier food choices are key steps to address this issue. In addition, reducing processed meat intake, promoting safer processing methods and supporting healthier alternatives can make a positive difference.

Future research is essential to develop safer food processing practices and to further study the long-term effects of processed meat on heart health. Overall, this review shows that small but consistent changes in daily diet, along with promoting healthy eating habits can play a powerful role in preventing heart disease in the future.

RECOMMENDATIONS

Studies have revealed that consuming processed meat is linked to increase risk of having heart diseases. These foods may increase blood pressure, worsen cholesterol and injure blood vessels because of the salt, saturated fat and chemical additives these foods contain, (e.g. nitrates). All these are associated with heart attacks and strokes. The evidence here indicates that consumption of processed meat commonly has adverse effects in the heart; therefore, must limit the amount that we consume. This concept has international guidelines to support it. Both WHO and American Heart Association advise reducing the consumption of processed meat as a diet that promotes the health of cardiovascular system.

Similar advice can be equally applied in other places, such as Sri Lanka where traditional diets are predominantly plant based and current trends in changing food preferences and the urban lifestyle are resulting into an increase in the consumption of processed and fast foods. Such a trend might introduce severe long-term impacts on the rate of heart diseases.

Table 1: Food-Based Dietary Guidelines recommendations for meat for Belgium, Bulgaria, Germany, Estonia and United Kingdom [32]

Country	Quantitative recommendations	Qualitative recommendations	Portion size
Belgium	Limit the consumption of processed meat to 30 g per week.	Limit the consumption of red meat, especially processed meat. Red meat can be replaced by e.g. legumes, fish, eggs or poultry.	
Bulgaria		Choose lean meat. Limit the consumption of sausages	1 portion corresponds to 100g
Germany	Eat meat (beef, pork and poultry) once or twice a week and sausage up to 2 portions per week. No more than 300 g of meat and sausage per week	Limit meat and sausage intake (less is more).	Meat:120 g Sausage:30 g
Estonia	Red meat max. 500 g/week (raw weight 700 g).	Processed meat products: as little as possible, prefer with higher meat content, less fat and/or salt.	Red meat products:30 g escalope, rotisserie, Frikandel, etc., 50 g ham, grilled sausage, canned meat, 20 g smoked sausage, salami, 25 g smoked bacon, 10 g fried bacon.
United Kingdom	If you eat more than 90 g of red or processed meat per day, try to cut down to no more than 70 g per day	Eat less red and processed meat.	

The health consequences for the population are very severe. Processed meat intake is already one of the most common causes of illnesses and health in most countries and reducing the per capita consumption of processed meat might mitigate the issue. Nevertheless, it is not simple to change. Processed meat is affordable, readily accessible and frequently involves the cultural food practices. It is for this reason that the changes should engage individuals and governments in the form of food labeling, campaigns and policies to enable people to access healthier food choices. Present studies are limited as well. The largest body of evidence is that of long-term population studies and cannot entirely discount other causes including the overall diet or way of life.

Very little clinical research to determine the direct long-term effects processed meat on heart disease exist. Moreover, the health outcomes of newer products are known to fewer people including low salt or nitrate free meat and plant substitute. Considering what we understand about it; one can suggest several steps. Human beings are urged to reduce their consumption of processed meat and substitute it with alternative dietary sources of protein which include fish, vegetables and legumes or clean breast meat. It would be reasonable that policymakers recommend clear dietary recommendations, organize education efforts and sponsor the food sector to mitigate the hazards of processed meat. Subsequently, it is to be investigated whether the beneficial health outcomes of a low intake of processed meats can be generalized and whether newer options should be investigated.

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