The Association of Red and Processed Meat with Prostate Cancer Risk: A Review Emphasizing Regional Dietary Patterns

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Abstract: Prostate cancer is one of the most common cancers among men worldwide. Diet is a significant modifiable risk factor. More importantly, red and processed meat intake received much attention. However, conclusions remain inconsistent across studies and regions, and few reviews have systematically compared findings while considering regional dietary patterns. In this work, we reviewed existing epidemiological studies in order to examine the association between red and processed meat consumption and prostate cancer risk, with a focus on regional dietary differences. This paper conducted a structured literature review of cohort and case-control studies published after 2000. Studies from the United States, Europe, East Asia, and the Middle East were included. Data on meat intake, prostate cancer incidence, and disease stage were extracted and compared across regions. Study quality was assessed using the CASP checklist. The results showed that red meat intake was weakly associated with total prostate cancer risk. In contrast, processed meat intake showed a more consistent association, especially with advanced prostate cancer. Several large cohort studies reported dose-related increases in risk with higher processed meat consumption. In Asian populations, higher total meat intake was linked to a greater increase in risk compared with Western populations. Dietary patterns high in plant-based foods were associated with lower prostate cancer risk. This work highlights the importance of considering meat type, overall diet quality, and regional dietary habits when assessing prostate cancer risk.

1. Introduction

The current study aims to explore whether high red meat consumption is associated with prostate cancer. Prostate cancer is one of the most common cancers in men worldwide and is a significant public health problem owing to its high prevalence and high mortality. It is the second most diagnosed cancer in men and the fifth leading cause of cancer-related death worldwide. While genetic factors, age, and ethnicity are all established risk factors for prostate cancer, reversible lifestyle factors such as diet have increasingly been noticed as a potential role in disease development. Among dietary habits, red meat consumption has been contentious over years as a possible risk factor. Red meat, including beef, pork, and lamb, and processed types like bacon or sausages which provide nutrients like protein, zinc, and iron.

However red meat also contains compounds such as saturated fats, heme iron, and heterocyclic amines (HCAs), which are formed during high-temperature cooking and have been proposed as biologically plausible contributors to carcinogenesis. Saturated fat intake has been associated with chronic inflammation and altered androgen and inulin-like growth factor signaling, which may promote prostate tumor development [1]. Heme iron can catalyze the formation of reactive oxygen species, leading to oxidative stress and DNA damage in prostate cells [2]. Additionally, HCAs are mutagenic compounds capable of forming DNA adducts and disrupting normal cell-cycle regulation [3]. Although these biological mechanisms provide a plausible explanation for how red meat components could influence prostate carcinogenesis, mechanistic plausibility alone does not establish a causal association at the population level.

The scientific evidence linking red meat consumption and prostate cancer is not established. Large-scale cohort studies and reports from the National Cancer Institute (NCI) publications have suggested a positive relationship between high intakes of red meat and rising prostate cancer risk, indeed aggressive forms of the disease [4-5]. In contrast, several meta-analyses and reviews have found weak or no evidence for supportive relationships, crediting it to confounding lifestyle influences and variability in dietary reporting [6]. Furthermore, regional differences in diet and environmental exposures in the United States may influence red meat-eating habits and consequently prostate cancer risk. These factors highlight the importance of taking both individual intake and the

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broader environmental context into account. However, many existing reviews have not systematically compared associations across diverse geographical and dietary settings, nor have they adequately adjusted for regional dietary cultures and environmental confounders. This gap limits the generalizability of findings and hampers the development of region-specific dietary recommendations.

In this article, we will conduct a literature search focusing on studies of varying regions in the world comparing the dietary habits of men with diagnosed prostate cancer to men without prostate cancer. Specific attention will also be paid to how regional lifestyles and dietary cultures could influence red meat consumption levels, gaining insight into potential geographic differences in prostate cancer risk.

The purpose of this study is grounded in the urgent need to clarify modifiable prostate cancer risk factors in the most affected populations. If a clear link between red meat consumption and prostate cancer is shown, adjusting for environmental and regional influences, it could set the stage for specific dietary recommendations and guide public health policy for targeted communities. The objective of this research is to investigate whether higher red meat intake in men is associated with an increased risk of prostate cancer, and to investigate the impact of regional differences on red meat intake.

2.Methods

The objective of this study was to assess the relationship between red meat consumption and the incidence of prostate cancer, employing a specified systematic process for the identification, selection, extraction, and evaluation of case-control studies. To begin the research, we first systematically identified relevant studies. We made use of databases that were recognized in the fields of medicine and nutrition, such as PubMed, Jstor, and EBSCO. These databases were considered reliable as they include peer-reviewed literature, various epidemiological studies, and diverse inquiries undertaken in nutrition and health science. We targeted studies utilizing certain keywords, which primarily included the following: “risk of prostate cancer,” “association,” and “red meat.” The keywords “AND” were utilized to search for the merged phrases, for instance, “prostate cancer risk AND association AND red meat.” By using these keywords, we included all studies that examined whether consumption of red meat increased the risk of developing prostate cancer.

In the beginning, we did not impose restrictions regarding the type of study until a possible exclusion criterion was found already applied in the process. Accordingly, at a later stage, the process was narrowed down to the studies meeting the above-mentioned inclusion criteria. Titles, abstracts, and the articles themselves were subsequently examined to determine whether they were relevant to our research. Furthermore, we also included filters from the databases in the process. We decided to include major findings only from the studies published after the year 2000 to expose the most recent scientific data predominantly.

The search was conducted multiple times by six reviewers so as not to miss vital information. We made certain that each reviewer operated under identical keywords and databases. Thereafter, the included findings were compared, and inconsistencies regarding individual studies were discussed with an external specialist.

Only the studies meeting the following criteria were included. Studies ought to compare diets of men diagnosed with prostate cancer and without prostate cancer, respectively. The included studies ought to be from credible publishers. We aimed at using the most recent studies, thus only articles published after 2000 were accepted. By employing this criterion, we ensured that the content concerned recent data sets about prostate cancer diagnosis and dietary habits. The studies ought to be formatted in English and contain quantitative and clearly anticipated data for red meat intake, such as frequency in times a week per serving. By using this criterion, we also excluded articles without mentioned interventions. With the implementation of the above-mentioned criteria, our review included information only from recent and relevant studies. We also ensured that all of the articles were comparable as they had been performed in the same way and used the same type of format for their results. Thirty prospective studies were identified and included, of which there were a number of relevant subjects with diagnosed prostate cancer. The extraction of data was performed after the identification and screening of studies.

The process was done by six reviewers, and there was an independent advisor to provide oversight. In the current study, "red meat" was defined as beef, pork, and lamb, including fresh cuts and processed meat in the form of bacon or sausages. We ascertained the method used to diagnose and stage prostate cancer in each study. Since prostate cancer is of different severity, the stage of prostate cancer at diagnosis was significant. We looked for the data on levels of red meat intake. This was frequency of consumption, portion size, and total intake by week or month. Some studies utilized food-frequency questionnaires, while others utilized dietary recall interviews. All measurements were recorded. Data were independently extracted by each reviewer, and then compared with the group. Disagreements or points of confusion were argued out until an agreement was reached. The independent advisor mediated when disagreements could not easily be resolved. The quality of studies included was assessed using the Critical Appraisal Skills Programme (CASP) checklist.

This tool was chosen as it is widely used to judge the strengths and weaknesses of primary research. It also gives clear questions about the study design, sample, data, and results. The checklist was employed to determine whether the study design used was suitable for the research question. In this case, a case-control design was employed for the comparison between men with and without prostate cancer. This was suitable because the aim was to find out if red meat intake was linked to prostate cancer.

The CASP tool also guided the review of the sample. Data collection methods were also checked. Food-frequency questionnaires were used in the research to

record meat consumption and cooking practices. These methods are standard, but they depend on memory and honesty, which can bring in recall bias. This is a key issue in case-control studies, because men with cancer may think about their diet differently compared to men without cancer. The checklist was also used to determine if the results were reported clearly and straightforwardly. The study provided detailed tables and statistical results, making the findings easy to follow. However, we noted that the role of cooking methods and mutagen exposure added complexity, and this might have created room for measurement error. The CASP tool also highlighted the possibility of selection bias. The controls were drawn from populations that may not be fully matched to the cases in lifestyle and environment. This can affect the strength of the comparisons.

3.Results

The review included both cohort and case-control studies from East Asia, the Middle East, Europe, and the United States. Across these studies, the data showed weak or inconsistent associations with prostate cancer. Increased evidence of a more positive association with prostate cancer was seen with processed meat consumption, especially with more advanced disease. The largest dataset included was a pooled meta-analysis in 25 prospective studies with 1,900,910 men and 35,326 cases of prostate cancer [7].

Follow-up in these cohorts ranged from 6 to 23 years. Most studies used food frequency questionnaires to assess dietary intake. The NIH-AARP study in the United States included over 175,000 men [4]. In Asia, a Taiwanese case-control study included 143 prostate cancer patients and 135 controls [8], while an Iranian case-control study included 97 cases and 184 controls [9]. Together, these studies enabled a comparison of red and processed meat intake across various dietary and cultural environments.

3.1 Overall collated data

Summary of findings from included studies can be seen in table 1.

Table 1. Summary of findings from included studies

Study / Region	Exposure	Outcome	Effect Estimate	95% CI	Significance
Meta-analysis (25 prospective studies, US/Europe/Asia)	Red meat (highest vs lowest)	Total prostate cancer	RR = 1.04	1.00–1.09	Weak (fixed-effects)
	Red meat	Advanced prostate cancer	RR = 1.07	0.98–1.18	Not significant
	Processed meat	Total prostate cancer	RR = 1.06	1.01–1.10	Significant
	Processed meat (+50 g/day)	Total prostate cancer	RR = 1.04	1.00–1.08	Weak but present
	Processed meat	Advanced prostate cancer	RR = 1.17	1.09–1.26	Significant (fixed-effects)
	Total meat (all types)	Advanced prostate cancer	RR = 1.09	1.02–1.16	Significant (fixed-effects)
Sinha et al., 2009 (NIH-AARP, US)	Red meat (Q5 vs Q1)	Total prostate cancer	HR = 1.12	1.04–1.21	Significant
	Red meat	Advanced prostate cancer	HR = 1.31	1.05–1.65	Significant
	Processed meat (Q5 vs Q1)	Total prostate cancer	HR = 1.07	1.00–1.14	Borderline
	Processed meat	Advanced prostate cancer	HR = 1.32	1.08–1.61	Significant
	Red processed meat (+10 g/day)	Advanced prostate cancer	HR = 1.10	1.03–1.17	Linear trend
	Heme iron intake	Advanced prostate cancer	HR = 1.28	1.03–1.58	Significant
Mahmoodi et al., 2024 (Iran)	Non-healthy diet index (red/processed meat, refined grains, sweets)	Total prostate cancer	OR = 3.01	1.20–7.57	Significant risk
	Pro-healthy diet index (fruits, veg, whole grains, fish, dairy)	Total prostate cancer	OR = 0.31	0.11–0.85	Protective
	Pro-vegetarian diet index	Total prostate cancer	OR = 0.34	0.15–0.75	Protective
Chang et al., 2023 (Taiwan)	High total meat intake (≥1 serving/meal)	Total prostate cancer	OR = 2.74	1.26–5.94	Significant risk
	Red meat (>50% of total meat consumed)	Total prostate cancer	Elevated risk	Not reported	Significant trend ($p < 0.001$)
	White meat/seafood dominant	Total prostate cancer	Protective	Not reported	Higher in controls

3.2 Red meat consumption

Red meat intake showed weak or inconsistent associations across studies. The meta-analysis found a weak association with total prostate cancer cases, as seen in Table 1 (RR = 1.04; 95% CI: 1.00–1.09, p = 0.048), and no significant link with advanced disease (RR = 1.07; 95% CI: 0.98–1.18, p = 0.12). The NIH-AARP study in the United States showed stronger effects, with a 12% higher risk for total prostate cancer (HR = 1.12; 95% CI: 1.04–1.21, p = 0.003) and a 31% higher risk for advanced prostate cancer (HR = 1.31; 95% CI: 1.05–1.65, p = 0.016) [4]. In Taiwan, the risk also increased when more than half of the meat consumed was red meat (significant trend, p < 0.001), suggesting that the effects may be stronger in Asian populations. [8] Overall, red meat was linked to prostate cancer more clearly in US and Asian data than in pooled global data.

3.3 Processed meat consumption

Processed meat intake was more consistently associated with prostate cancer than red meat. The pooled analysis reported a 6% increase in total prostate cancer, as illustrated in table 1, (RR = 1.06; 95% CI: 1.01–1.10, p = 0.015) and a 17% increase in advanced cases (RR = 1.17; 95% CI: 1.09–1.26, p < 0.001) [7]. In the NIH-AARP cohort, processed meat was also linked to advanced prostate cancer (HR = 1.32; 95% CI: 1.08–1.61, p = 0.007) [4]. A dose-response relationship was observed: a 10 g/day increase in processed meat intake was associated with a 10% higher risk of advanced cancer (HR = 1.10; 95% CI: 1.03–1.17, p = 0.004) [4]. These findings show that processed meat has a more consistent effect than unprocessed red meat, overall, processed meat showed a consistent association with an increased incidence of overall prostate cancer cases and advanced prostate cancer cases.

3.4 Total meat intake in Asian population

Total meat intake was associated with increased risk, especially in Asian populations. In Taiwan, men who ate at least one serving of meat per meal had 2.7 times higher odds of prostate cancer than controls (OR = 2.74; 95% CI: 1.26–5.94, p = 0.011), with reference to table 1 [8]. In contrast, the pooled meta-analysis revealed a more modest but statistically significant increase in advanced cases (RR = 1.09; 95% CI: 1.02–1.16, p = 0.014) [7]. This difference suggests that populations with lower baseline meat intake may face higher risks when adopting meat-heavy diets. Overall, studies found that higher total meat intake was linked with a greater risk of prostate cancer.

3.5 Dietary patterns

Dietary patterns influenced the risk of prostate cancer in addition to meat intake. The Iranian case-control study showed that men following a non-healthy diet high in red and processed meat, refined grains, and sweets had three times the risk of prostate cancer (OR = 3.01; 95% CI: 1.20–7.57, p = 0.019) as indicated in table 1 [9]. Men with pro-healthy or pro-vegetarian diets had much lower risks (OR = 0.31; 95% CI: 0.11–0.85, p = 0.023; and OR = 0.34; 95% CI:0.15–0.75, p = 0.008) [1]. These results underscore the significance of overall diet quality, rather than individual food groups, in influencing prostate cancer risk. Overall, dietary patterns either increased or reduced the risk, depending on the food choices.

3.6 Possible bias

Most studies relied on food frequency questionnaires, which depend on memory and self-report. This can lead to recall bias. Patients with prostate cancer may recall diet differently than controls, which can misclassify intake. Not all studies controlled for confounders such as alcohol intake or family history, which may influence results. Overall, differences in study methods may have affected the accuracy of reported associations.

4. Discussion

4.1 Overview

This review asked if eating red meat is linked to prostate cancer and if results differ by region and diet. In our analysis, processed meat was consistently linked to a higher risk of prostate cancer. However, red meat showed weak or mixed links. Additionally, total meat consumption appeared to have a more substantial effect in some Asian groups. The overall diet quality also had a significant impact.

4.2 Red meat consumption

Across 25 long-term studies, it was observed that red meat showed only a small link with total prostate cancer (RR = 1.04; 95% CI: 1.00–1.09) and no clear link with advanced disease (RR = 1.07; 95% CI: 0.98–1.18) [7]. However, the U.S. NIH-AARP study found higher risks at the highest intake level: 12% higher for total cases (HR = 1.12; 95% CI: 1.04–1.21) and 31% higher for advanced cases (HR = 1.31; 95% CI: 1.05–1.65), as displayed in Table 1 [4]. To add on, a Taiwanese case-control study also found a higher risk when more than half of the meat eaten was red [8].

These mixed results likely stem from the way studies measured diet and how people actually eat. Long-term studies often use food-frequency questionnaires that can also obscure minor effects due to reporting errors. Case-control studies can be subject to recall bias because men with cancer may recall their diets differently, leading to a recall error. The cooking style and the degree of doneness of the meat can also affect exposure to harmful compounds. Hence, if red meat affects risk, the effect appears to be small and may be easily overlooked without very accurate diet data.

4.3 Processed meat consumption

Processed meat showed a clearer and steadier link with risk. The combined estimate showed a 6% higher risk for total prostate cancer (RR = 1.06; 95% CI: 1.01–1.10) and a 17% higher risk for advanced disease (RR = 1.17; 95% CI: 1.09–1.26) [7]. The NIH-AARP study also found a 32% higher risk of advanced disease at high intake (HR = 1.32; 95% CI: 1.08–1.61) [4]. The more people ate, the higher the risk. Each additional 10 g per day was associated with a 10% increase in advanced disease (HR = 1.10; 95% CI: 1.03–1.17), as shown in Table 1 [4]. This makes sense because processed meats often contain added nitrates or nitrites, as well as more salt, and are frequently smoked or cured. These steps can lead to exposure to carcinogens [10-11]. People who eat more processed meat may also have other habits that raise risk. That is why processed meat appears to be a more reliable risk factor than unprocessed red meat. Nitrites and nitrates in processed meat can form N-nitroso compounds, and curing, smoking, or high heat can add HCAs and PAHs [3,12]. Heme iron may increase oxidative stress and increase the likelihood of these reactions [2]. Even after adjusting for other diet and lifestyle factors, studies still show a consistent, often dose-related link.

4.4 Total meat intake

Total meat intake appeared to be more significant in some Asian settings than in Western ones. In Taiwan, men who ate at least one meat serving at every meal had much higher odds of prostate cancer (OR = 2.74; 95% CI: 1.26–5.94) [8]. However, combined results, which were mostly from Western groups, showed only a slight rise for advanced disease (RR = 1.09; 95% CI: 1.02–1.16) [7].

One reason for this is the starting level. Where usual meat intake is low, moving to higher intake can raise exposure more sharply. Where intake is already high, consuming a bit more may not significantly alter the risk, and other lifestyle factors can mask small effects.

4.5 Dietary patterns

Dietary patterns changed risk as well. An Iranian case-control study found that a “non-healthy” pattern high in red and processed meat, refined grains, and sweets tripled the odds of prostate cancer (OR = 3.01; 95% CI: 1.20–7.57) [9]. A “pro-healthy” or “pro-vegetarian” pattern lowered risk (OR = 0.31 and 0.34) [9]. This shows that meat intake does not act alone. Fruits, vegetables, legumes, and seafood appear to offer protection, likely due to their fiber and antioxidant content [13-16]. Fruits, vegetables, and legumes, because fiber promotes gut bacteria and lowers inflammation, limiting DNA damage. Legumes and soy add plant compounds that steady hormone signals [14,16], and seafood adds omega-3s, vitamin D, and selenium [17]. When these foods replace processed meat and refined foods, total exposure to harmful compounds falls, and overall diet quality improves.

4.6 Strengths and limitations

One of the advantages of this review is that it included studies from several different regions, allowing us to compare outcomes across diets and cooking methods. A second advantage is the uniform signal for processed meat [4,7,9]. There are still constraints. Most studies used food-frequency questionnaires, meaning dietary reports were false affecting outcomes. In case-control studies, cancer men can recall diet differently compared to controls. Not all the studies controlled for other potential risk factors (alcohol, activity, BMI, smoking, or family history), so some residual bias may exist. Methods of cooking and doneness were not quantified by an exact number of studies, so it is hard to assign risk to some compounds from cooking or curing. [3,12]

4.7 Implications

In general, processed meat is a more specific and more uniform risk factor for prostate cancer, including stage at diagnosis [4,7]. Red meat has less and less consistent associations, so any effect is perhaps smaller and depends on where and how people eat. Risk was higher in some Asian and Middle Eastern groups, which is consistent with reduced previous intake and a fast diet transition [8-9]. So, therefore, public health guidance should be on consuming less processed meat and on improved whole-diet habits involving a greater proportion of plant foods and seafood [13-17], instead of simply reducing red meat alone.

4.8 Future research

Future investigations would benefit from the use of more accurate diet measurement, such as use of multiple food records. Incorporation of urine and serum biomarkers, such as lipid panels, hemoglobin A1c, and markers of inflammation, could also be helpful. More uniform reporting of the cooking method, portion size, and whether there was curing would be helpful in the assessment. Outcomes should be reported separately and in unambiguous terms, for example, total, advanced, and fatal cases, and stage and grade. Models should test substitutions, for example, replacing processed meat with fish, poultry, legumes, or whole grains, so recommendations are plausible [18-19]. Cohorts should evaluate diet many times in a lifetime, and they should include more settings in Southeast Asia, South Asia, the Middle East, and Africa. Work should also try out what are the most critical aspects of processing to work on, like gut microbiome testing, and use standard methods and pooled data so small effects can be detected more easily [20-21].

6. Conclusion

This research examined whether high red meat consumption is associated with prostate cancer risk, comparing studies across the world to identify regional and dietary influences. The findings indicate that while

red meat itself shows weak or inconsistent associations with prostate cancer, processed meat demonstrates a stronger and more consistent link, particularly in advanced stages of the disease [4,7]. Populations in Asia, where baseline meat consumption is lower, exhibited a higher relative risk when diets became more meat-heavy, suggesting that dietary shifts may play a critical role in cancer risk [8-9]. In contrast, Western populations showed smaller increases, likely due to an already high meat intake and general lifestyle differences. Overall, the results suggest that total and processed meat intake contribute modestly but meaningfully to prostate cancer risk, while diet quality exerts a larger influence. Diets rich in fruits, vegetables, whole grains, and seafood appeared protective [13-17], emphasizing the importance of balanced nutrition rather than focusing on a single food group. Therefore, the conclusion to our objective is that high red and processed meat consumption is associated with an elevated risk of prostate cancer, influenced by regional dietary patterns, and public health recommendations should focus on reducing processed meat intake and promoting healthier, plant-based eating habits.

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