Research Article
Genetic and Metabolic Diseases

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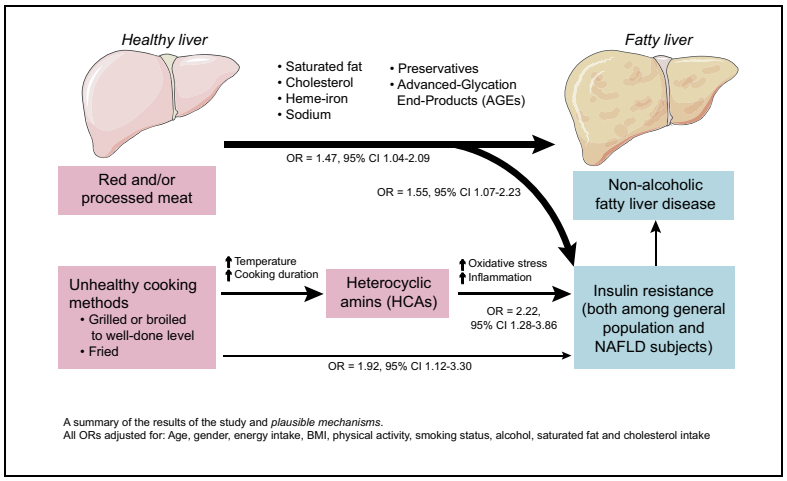
# High red and processed meat consumption is associated with non-alcoholic fatty liver disease and insulin resistance

## Graphical abstract




## Highlights

- High consumption of red and/or processed meat is related to NAFLD and insulin resistance.
- Consumption of meat cooked in unhealthy methods is related to insulin resistance.
- Consumption of HCAs is related with insulin resistance.
- These associations are independent of saturated fat and cholesterol intake.
- If confirmed prospectively, limiting the consumption of unhealthy meats may be advised.

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## Lay summary

High red and processed meat consumption is related to several diseases. In addition, cooking meat at high temperatures for a long duration forms heterocyclic amines, which have harmful health effects. Non-alcoholic fatty liver disease is a significant public health burden and its formation is strongly related to insulin resistance. In this study, both were found to be more frequent in people who consume relatively high quantities of red and processed meat. In addition, a high intake of heterocyclic amines was associated with insulin resistance.

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# High red and processed meat consumption is associated with non-alcoholic fatty liver disease and insulin resistance

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**Background & Aims**: High red and processed meat consumption is related to type 2 diabetes. In addition, cooking meat at high temperatures for a long duration forms heterocyclic amines (HCAs), which are related to oxidative stress. However, the association between meat consumption and non-alcoholic fatty liver disease (NAFLD) is yet to be thoroughly tested. Therefore, we aimed to test the association of meat type and cooking method with NAFLD and insulin resistance (IR).

**Methods**: This was a cross-sectional study in individuals who were 40–70 years old and underwent screening colonoscopy between 2013 and 2015 in a single center in Israel. NAFLD and IR were evaluated by ultrasonography and homeostasis model assessment. Meat type and cooking method were measured by a food frequency questionnaire (FFQ) and a detailed meat questionnaire. Unhealthy cooking methods were considered as frying and grilling to a level of well done and very well done. Dietary HCA intake was calculated.

**Results**: A total of 789 individuals had a valid FFQ and 357 had a valid meat questionnaire. High consumption of total meat (portions/day above the median) (odds ratio [OR] 1.49; 95% CI 1.05–2.13; $p = 0.028$; OR 1.63; 1.12–2.37; $p = 0.011$), red and/or processed meat (OR 1.47; 95% CI 1.04–2.09; $p = 0.031$; OR 1.55; 1.07–2.23; $p = 0.020$) was independently associated with higher odds of NAFLD and IR, respectively, when adjusted for: body mass index, physical activity, smoking, alcohol, energy, saturated fat and cholesterol intake. High intake of meat cooked using unhealthy methods (OR 1.92; 95% CI 1.12–3.30; $p = 0.018$) and HCAs (OR 2.22; 95% CI 1.28–3.86; $p = 0.005$) were independently associated with higher odds of IR.

**Conclusion**: High consumption of red and/or processed meat is associated with both NAFLD and IR. High HCA intake is associated with IR. If confirmed in prospective studies, limiting the consumption of unhealthy meat types and improving preparation methods may be considered as part of NAFLD lifestyle treatment.

**Lay summary**: High red and processed meat consumption is related to several diseases. In addition, cooking meat at high temperatures for a long duration forms heterocyclic amines, which have harmful health effects. Non-alcoholic fatty liver disease is a significant public health burden and its formation is strongly related to insulin resistance. In this study, both were found to be more frequent in people who consume relatively high quantities of red and processed meat. In addition, a high intake of heterocyclic amines was associated with insulin resistance.



## Introduction

Non-alcoholic Fatty liver disease (NAFLD) is becoming a major global health burden in both developed and developing countries.[1] NAFLD is considered as the hepatic component of the metabolic syndrome, with insulin resistance (IR) as the key factor in its pathophysiology.[2] Unhealthy Western lifestyle plays a major role in the development and progression of NAFLD,[3] namely, lack of physical activity and high consumption of fructose and saturated fat.[4,5] There are other common foods in the Western diet, namely red and processed meats, which may also increase the risk for NAFLD.[6] Meat in general contains valuable nutrients for human health including protein, iron, zinc and vitamin B12.[7] However, meat also contains saturated fatty acids (SFA) and cholesterol, both harmful for patients with NAFLD,[8–11] as well as other potentially harmful compounds such as heme-iron,[12] sodium,[13] other preservatives[12] and advanced glycation end products (AGEs).[12,14] Indeed, high meat consumption has been demonstrated to be associated with IR and type 2 diabetes,[15–17] the metabolic syndrome[17] and oxidative stress.[18] More specifically, red meat has been shown to be associated with a higher risk of mortality, owing to chronic liver disease and hepatocellular carcinoma.[19] The association between meat consumption and NAFLD was demonstrated in a few studies,[5,6,20,21] in which meat type and cooking method were not fully addressed. We have previously demonstrated an independent association between high meat consumption and NAFLD,[20] with no distinction between meat types or cooking methods, because of a small sample size and lack of information on the cooking methods in the standard food frequency questionnaire (FFQ).

Meat cooking methods have clinical significance, as unfavorable heterocyclic amines (HCAs) may be formed during

Keywords: Fatty liver; Red meat; Processed meat; Diet; Insulin resistance; Heterocyclic amines.
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