Meat consumption and risk of 25 common conditions: outcome-wide analyses in 475,000 men and women in the UK Biobank study

Keren Papier*, Georgina K Fensom, Anika Knuppel, Paul N Appleby, Tammy YN Tong, Julie A Schmidt, Ruth C Travis, Timothy J Key, Aurora Perez-Cornago

Affiliation of all authors: Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, Oxford, OX3 7LF, UK.

Correspondence to: Dr Keren Papier (Keren.Papier@ndph.ox.ac.uk)
Abstract

Background There is limited prospective evidence on the association between meat consumption and many common, non-cancerous health outcomes. We examined associations of meat intake with risk of 25 common conditions (other than cancer).

Methods We used data from 474,998 middle-aged men and women recruited into the UK Biobank study between 2006 and 2010 and followed-up until 2017 (mean follow-up of 8.0 years) with available information on meat intake at baseline (collected via touchscreen questionnaire), and linked hospital admissions and mortality data. For a large sub-sample, dietary intakes were re-measured using an online, 24-hour questionnaire.

Results In multi-variable adjusted (including body mass index (BMI)) Cox regression models corrected for multiple testing, a higher consumption of red and processed meat combined was associated with higher risks of ischaemic heart disease (HR per 70 g/day higher intake 1.14, 95% CI 1.06-1.22), pneumonia (1.28, 1.15-1.41), diverticular disease (1.18, 1.10-1.26), colon polyps (1.09, 1.04-1.13), and diabetes (1.29, 1.19-1.40), and a lower risk of iron deficiency anaemia (IDA), driven by a higher consumption of red meat (HR per 50g/day higher intake 0.77, 0.69-0.86). Higher poultry meat intake was associated with higher risks of gastro-oesophageal reflux disease (HR per 30g/day higher intake 1.14, 1.06-1.23), gastritis and duodenitis (1.10, 1.04-1.16), diverticular disease (1.09, 1.04-1.16), and diabetes (1.13, 1.06-1.20), and a lower risk of IDA (0.80, 0.73-0.87).

Conclusions Higher red, processed, and poultry meat consumption was associated with higher risks of several common conditions; higher BMI accounted for a substantial proportion of these increased risks. Higher red and poultry meat consumption was associated with lower IDA risk.
Introduction

The World Health Organization\textsuperscript{1} and many national dietary advice bodies (e.g. the UK dietary guidelines\textsuperscript{2}) have in recent years recommended the reduction of red and processed meat consumption, based on consistent evidence linking high processed meat, and probably red meat consumption with colorectal cancer risk\textsuperscript{1}. While the association between meat intake and cancer risk has been comprehensively studied\textsuperscript{3,4} there is little information on the association between meat consumption, especially poultry meat, and incidence of major non-cancerous health outcomes\textsuperscript{5}. This lack of evidence might relate to outcome selection bias (i.e. only reporting the outcomes that are found to be associated with meat\textsuperscript{6}), differences in the definition of outcomes, sample size, control of confounders and/or length of follow-up used among different studies. Examining the association between meat consumption and multiple non-cancerous health outcomes in the same cohort may help to clarify these associations\textsuperscript{7}.

This study uses an outcome-wide approach to prospectively examine associations of meat consumption with risk of 25 common conditions identified as the 25 leading causes of hospital admission (other than cancer) in a large UK cohort.

Methods

Study population

We used data from the UK Biobank study, a cohort of 503 317 men and women from across the UK\textsuperscript{8}. Potential participants were recruited through the National Health Service (NHS) Patient Registers and invited to attend one of the 22 assessment centres between 2006 and 2010. Participants joining the study completed a baseline touchscreen questionnaire, provided anthropometric and biological data, and gave informed consent for their health to be followed-up through linkage to electronic medical records. The UK Biobank study was
approved by the North West Multi-Centre Research Ethics Committee (reference number 06/MRE08/65).

Assessment of dietary intake

Dietary intake was assessed using a touchscreen dietary questionnaire administered to all participants at baseline that included 29 questions on diet, assessing the consumption frequency of each listed food. Responses to the five questions on meat (unprocessed beef, unprocessed lamb/mutton, unprocessed pork, unprocessed poultry, and processed meat) were assigned values for frequency per week (never=0, less than once per week = 0.5, once per week=1, 2-4 times per week=3, 5-6 times per week=5.5, and once or more a day=7). We then categorized these meat intake frequencies into three or four categories to create approximately equal-sized groups (see Supplementary Methods S1 for additional detail).

Participants recruited after 2009, as well as participants who provided UK Biobank with an email address and agreed to be re-contacted, additionally filled out the Oxford WebQ⁹, an online 24-hour recall questionnaire. Participants were asked to select how many portions of each food item they consumed over the previous 24-hours, enabling calculation of mean grams per/day by multiplying frequencies of consumption by standard portion sizes. Similar foods were then grouped together into meat types to match the touchscreen dietary questionnaire. We then assigned the mean WebQ intakes in participants who had completed at least three WebQs to each touchscreen category (see Supplementary Methods S1 for additional detail).

Assessment of health outcomes

The main outcomes of interest in this study were incident cases of 25 common conditions. The conditions selected were those identified as the 25 leading, well-defined causes of non-
cancerous hospital admission in this cohort based on the primary International Classification of Diseases (ICD) 10 diagnosis codes recorded during admission. Some of commonest causes of hospital admission in this cohort (e.g. nausea or heartburn) were not considered to be separate conditions, because they were not well-defined and/or were likely to be associated with a diverse range of underlying conditions. Moreover, although diabetes was not among the 25 most common primary diagnoses associated with admission, it is a common secondary reason for admission and therefore any diagnosis of diabetes was included among the 25 common conditions examined. (See supplementary Table S1 for selected conditions and relevant diagnosis and procedure codes.)

Participant information on cause-specific in-patient hospital admissions and deaths (primary cause for all outcomes except diabetes which also included underlying cause) was obtained through linkage to the NHS Central Registers. For participants in England, Hospital Episode Statistics (HES) and information on date and cause of death were available until the 31st of March 2017; for participants in Scotland, the Scottish Morbidity Records and information on date and cause of death were available until the 31st of October 2016; and for participants in Wales, the Patient Episode Database and information on date and cause of death were available until the 29th of February 2016. We also obtained information on cancer registrations (including date and cancer site) from the NHS Central Registers. (See Supplementary Methods S2 and Supplementary Table S1 for information on exclusion, diagnosis and procedure codes).

**Exclusions**

Of the 503 317 recruited participants, 28 319 were excluded due to study withdrawals, prevalent cancer (except non-melanoma skin cancer, ICD-10 C44) prior to recruitment, or because their genetic sex differed from their reported gender, resulting in a maximal study
sample of 474 998 (94%). Participants with a relevant diagnosis or procedure prior to recruitment, ascertained through the touchscreen questionnaire, nurse-guided interviews, and hospital admission data were excluded for each respective analysis (see Supplementary Table S1 for details about the exclusions for each outcome). Participants who did not report their meat intake in the touchscreen questionnaire or reported ‘prefer not to say’ or ‘don’t know’ were classified as missing and excluded for the respective exposure analyses (See Supplementary Figure S1 for participant flowchart and supplementary Tables S6-10 for total numbers for each exposure and outcome).

**Statistical analysis**

We used Cox proportional hazards regression models to assess associations between meat consumption and risk for incident cases separately for each disease or condition, calculating trends using the mean meat intakes calculated using the WebQ questionnaires for each category from the touchscreen questionnaire and the trend test variables. Participants’ survival time in person-years was calculated from their age at recruitment until their age at hospital admission, death, loss to follow up, or administrative censoring. All analyses were stratified by sex, age at recruitment, and geographical region (Model 0). In Model 1, we estimated hazard ratios (HRs) and 95% confidence intervals (CIs) adjusted for ethnicity, Townsend deprivation index\(^\text{10}\), education, employment, smoking, alcohol consumption, and physical activity, and in women we additionally adjusted for menopausal status, hormone-replacement therapy, oral contraceptive pill use and parity. In Model 2, we further adjusted for total fruit and vegetable intake and cereal fibre intake score (calculated by multiplying the frequency of consumption of bread and breakfast cereal by the fibre content of these foods\(^\text{11}\)). For Model 3, we added adjustment for body mass index (BMI). Missing data for all covariates was minimal (<10%) and thus a ‘missing’ category was created for each covariate.
See Figures 1-4 footnotes and Supplementary Methods S3, for full adjustment description with definitions of categories.

**Sensitivity analyses**

To examine whether the associations between meat intake and risk of incidence for specific diagnoses could be affected by reverse causality or residual confounding by smoking, we repeated the analyses after excluding the first 4 years of follow-up and only in never smokers.

All analyses were conducted using STATA version 15.1 (Stata Corp LP, College Station, TX). All P values were two-sided and Bonferroni correction was used to allow for multiple testing (for 25 outcomes, P<0.002).

**Results**

**Baseline characteristics**

Table 1 shows baseline characteristics of participants by categories of red and processed meat intake. Around one-third of participants consumed red and/or processed meat once or more daily. On average, participants who consumed red and processed meat regularly (three or more times per week) were more likely to be men, older, of White European ethnicity, retired, have higher BMI, smoke and consume alcohol, consume less fruit and fibre and more poultry meat; they were also less likely to have attained a tertiary education, and among women to have three or more children, use oral contraceptives or hormone replacement therapy, or be postmenopausal compared with participants who consumed meat less than three times per week (P <0.001 for heterogeneity between meat intakes for all baseline characteristics). Participants who consumed higher amounts of red meat were more likely to consume higher amounts of processed and poultry meat (see Supplementary Table S3). The
characteristics in relation to poultry meat consumption were somewhat different (see Supplementary Table S5).

Risk analyses

Figures 1-4 present the numbers of incident cases for 25 common conditions and their HRs and 95% CIs per unit higher intake of meat for the multiple-adjusted model over an average follow-up of 8.0 years (standard deviation 1.0). Risks by categories of meat intake at baseline for Models 0-3 can be found in Supplementary Tables S6-10. Overall, many of the positive, associations were attenuated, and in some cases became null with the additional adjustment for BMI (Model 3). Here we describe the results for Model 3 that were robust to correction for multiple testing.

Red and processed meat

Red and processed meat intake was associated with a higher risk of ischaemic heart disease (IHD) (HR per 70 g/day higher intake =1.14, 95% CI 1.06-1.22), pneumonia (1.28, 1.15-1.41), diverticular disease (1.18, 1.10-1.26), colon polyps (1.09, 1.04-1.13) and diabetes (1.29, 1.19-1.40), and a lower risk of iron deficiency anaemia (IDA) (0.83, 0.75-0.92) (Figure 1).

Red meat

Red meat intake was associated with a higher risk of IHD (HR per 50 g/day higher intake =1.14, 95% CI 1.06, 1.23), pneumonia (1.18, 1.07-1.31), diverticular disease (1.15, 1.07-1.24) and diabetes (1.19, 1.10-1.30), and a lower risk of IDA (0.77, 0.69-0.86) (Figure 2).

Processed meat
Processed meat intake was associated with a higher risk of IHD (HR per 20 g/day higher intake =1.09, 95% CI 1.04-1.15), pneumonia (1.22, 95% CI 1.13-1.31), diverticular disease (1.11, 1.05-1.16), colon polyps (1.07, 95% CI 1.04-1.10) and diabetes (1.24, 1.17-1.32) (Figure 3).

**Poultry meat**

Poultry meat intake was associated with a higher risk of diverticular disease (HR per 30 g/day higher intake =1.09, 95% CI 1.04-1.16), gastro-oesophageal reflux disease (GERD) (1.14, 1.06-1.23), gastritis and duodenitis (1.10, 1.04-1.16), and diabetes (1.13, 1.06-1.20), and a lower risk of IDA (0.80, 0.73-0.87) (Figure 4).

**Sensitivity analysis**

Associations were similar when excluding the first 4 years of follow-up and in never smokers (Supplementary Figures S2-6). However, we did note a positive association between red and processed meat intake (combined) and haemorrhagic stroke (HR per 70 g/day higher intake =1.49, 95% CI 1.07-2.08) in participants diagnosed after four or more years of follow-up; and that the associations between red meat intake and diabetes risk, and processed meat intake and IHD risk, were null in never smokers.

**Discussion**

In this large, prospective cohort of nearly 0.5 million UK adults, we observed that after allowing for multiple testing higher consumption of red and processed meat combined was associated with higher risks of IHD, pneumonia, diverticular disease, colon polyps, and diabetes, and higher consumption of poultry meat was associated with higher risks of GERD, gastritis and duodenitis, diverticular disease, and diabetes. Differences in BMI across the categories of meat consumption appear to account for some of the increased risks. We also
observed inverse associations between higher intakes of red and poultry meat and IDA, which were minimally affected by adjustment for BMI.

**Circulatory diseases**

Similar to our findings, a recent meta-analysis of prospective studies\textsuperscript{12} and a recent prospective study from the Pan-European EPIC cohort which included over 7000 IHD cases\textsuperscript{13} reported positive associations between red meat and processed meat consumption and risk of IHD. For stroke, previous meta-analyses of prospective studies\textsuperscript{14,15} and a recent prospective study from the EPIC cohort\textsuperscript{16} both reported null associations for red and processed meat intake and haemorrhagic stroke; this is consistent with our main findings but not with our findings in participants diagnosed after four or more years of follow-up; though this might be a chance finding due to shorter follow-up. Processed meats contain high amounts of sodium\textsuperscript{17}, a risk factor for high blood pressure\textsuperscript{18}, which is a causal risk factor for IHD and stroke\textsuperscript{19}. Furthermore, processed meat is a major dietary source of saturated fatty acids (SFAs) which can increase low-density lipoprotein (LDL) cholesterol, an established causal risk factor for IHD\textsuperscript{20}.

**Respiratory disease**

Higher consumption of red and processed meat was associated with a higher risk of pneumonia; to the best of our knowledge these associations have not been shown previously. It is possible that hospital admission for pneumonia is a marker for co-morbidity and overall frailty\textsuperscript{21}, therefore residual confounding might operate (see further discussion on residual confounding below). It is also possible that the observed association might reflect a causal link, for example related to the high availability of iron in red and processed meat (see further discussion below in relation to anaemia). Excess iron has been found to be associated with a
higher risk of infection\textsuperscript{22}; and increased availability of iron for invading bacterial species and other pathogens\textsuperscript{23}.

**Digestive diseases**

Few prospective studies have examined risk for diverticular disease\textsuperscript{24,25}, but consistent with our findings the Health Professionals Follow-up Study (HPFS) observed increased risks of incident diverticulitis with higher consumption of red and processed meat\textsuperscript{24}. The HPFS did not observe an association for poultry meat, but had much lower power than the current study. Meat consumption might affect the risk of diverticular disease via the microbiome, and there is some evidence that meat intake might alter microbial community structure and change the metabolism of bacteria\textsuperscript{26}.

A recent meta-analysis of prospective studies reported that red and processed meat consumption was positively associated with the risk of colorectal adenomas\textsuperscript{27}, which is consistent with our findings for colon polyps. Red meat is a source of heme iron and processed meat usually contains nitrite and nitrates; these can promote the formation of $N$-nitroso compounds\textsuperscript{28}, which are mutagenic and have been associated with a higher risk of colorectal adenomas\textsuperscript{29}.

To our knowledge, this is the first prospective study of meat consumption and risk of GERD and gastritis and duodenitis. We found a positive association between poultry meat intake and GERD risk, whereas the available cross-sectional evidence suggests a null association for meat (total)\textsuperscript{30-33}. We also found a positive association between poultry meat consumption and risk of gastritis and duodenitis. *Helicobacter pylori*, a bacteria that increases the risk of gastritis\textsuperscript{34}, has been previously detected in raw poultry meat\textsuperscript{35}. Therefore, it is possible that the observed association might relate to inappropriate handling or cooking of poultry meat, but additional research is needed.
Other diseases

We found an inverse association between the consumption of red and processed meat combined, red meat, and poultry meat and risk of IDA. Some previous evidence from prospective studies supports these findings, and has also shown a positive association between red meat and total meat consumption and indicators of body iron stores. Moreover, previous cross-sectional work from the UK Biobank has shown that people who did not consume meat were more likely to be anaemic. This association is likely related to the high availability of heme iron in meat, which is more easily absorbed than non-heme iron (found in plant sources).

Similar to our findings, meta-analyses of prospective cohort studies have consistently reported a positive association between red and processed meat consumption and risk of diabetes. We also found a positive association between poultry meat consumption and risk of diabetes, which has been reported in some but not all prospective studies. The positive association observed for meat consumption and diabetes might relate to heme iron intake and greater iron storage in the body. In high amounts, iron, a pro-oxidant, can promote the formation of hydroxyl radicals that may attack the pancreatic beta cells, thereby impairing insulin synthesis and excretion.

Possible role of BMI

In the present study, most of the positive associations between meat consumption and health risks were substantially attenuated after adjusting for BMI, suggesting that BMI was a strong confounder or possible mediator for many of the meat and disease associations; BMI was highest in participants who consumed meat most frequently, and BMI is an important risk factor for many of the diseases examined (e.g., diabetes). Moreover, the associations which
remain after adjustment for BMI might still be partly due to residual confounding, because BMI is not a perfect measure of adiposity.

Strengths and limitations

This is as far as we are aware the first outcome-wide study of meat intake and risk of 25 common conditions (other than cancer). Additional strengths of this study include the large size of the cohort, its prospective design, and wide array of included confounders. This allowed us to investigate a large number of common conditions while simultaneously controlling for confounding, and thus avoid outcome selection bias. Additionally, we used national record linkage to ascertain information on disease incidence. Nevertheless, some potential methodological issues should be considered when interpreting our findings. Some measurement error would have occurred while measuring meat consumption at baseline; however, we reduced the likely effect of random error and short-term variation in diet by using the repeated 24-hour recall WebQ data and applying corrected intakes to each category of the baseline intakes. Additionally, multiple testing might have led to some spurious findings; however, we addressed this by using Bonferroni correction. Another consideration is the use of hospital records for incident case ascertainment. Some conditions might only require hospital use at later stages (e.g. diabetes), and therefore some admissions might reflect prevalent and/or more severe cases. Finally, given the observational nature of this study, it is possible that there is still unmeasured confounding, residual confounding and reverse causality. For instance, in analyses restricted to never smokers, some of the adjusted risk estimates were lower than in the main analysis (e.g. for red meat intake and diabetes and for processed meat intake and IHD), suggesting that even after adjustment for smoking there may be residual confounding. However, most of our results were largely similar after excluding participants who smoked or formerly smoked, and the first four years of follow-up.
Conclusions

Our findings from this large, prospective study of British adults show that red and poultry meat consumption is associated with a lower risk of IDA. Meat consumption is also associated with higher risks of several common conditions, at least partly accounted for by BMI; and additional research is needed to evaluate whether these differences in risk reflect causal relationships.
Acknowledgements

This research has been conducted using the UK Biobank Resource under application number 24494. We thank all participants, researchers and support staff who make the study possible.
References

1. Bouvard V, Loomis D, Guyton KZ, et al. Carcinogenicity of consumption of red and processed meat. *Lancet Oncol.* 2015;16:1599-1600.

2. Public Health England. *The Eatwell Guide.* London, UK: Public Health England; 2016.

3. Knuppel A, Papier K, Fensom GK, et al. Meat intake and cancer risk: prospective analyses in UK Biobank. *medRxiv.* 2019:19003822.

4. World Cancer Research Fund; American Institute for Cancer Research. *World Cancer Research Fund; American Institute for Cancer Research. Meat, fish and dairy products and the risk of cancer. Continuous Update Project Expert Report.* 2018.

5. Etemadi A, Sinha R, Ward MH, et al. Mortality from different causes associated with meat, heme iron, nitrates, and nitrites in the NIH-AARP Diet and Health Study: population based cohort study. *Bmj.* 2017;357:j1957.

6. Williamson PR, Gamble C, Altman DG, Hutton JL. Outcome selection bias in meta-analysis. *Stat Methods Med Res.* 2005;14:515-524.

7. VanderWeele TJ. Outcome-wide Epidemiology. *Epidemiology.* 2017;28:399-402.

8. Fry A, Littlejohns TJ, Sudlow C, et al. Comparison of Sociodemographic and Health-Related Characteristics of UK Biobank Participants With Those of the General Population. *Am J Epidemiol.* 2017;186:1026-1034.

9. Greenwood DC, Hardie LJ, Frost GS, et al. Validation of the Oxford WebQ Online 24-Hour Dietary Questionnaire Using Biomarkers. *Am J Epidemiol.* 2019;188:1858-1867.

10. Townsend P, Phillimore P, Beattie A. *Health and deprivation: inequality and the North.* Routledge; 1988.

11. Bradbury KE, Young HJ, Guo W, Key TJ. Dietary assessment in UK Biobank: an evaluation of the performance of the touchscreen dietary questionnaire. *J Nutr Sci.* 2018;7:e6.

12. Bechthold A, Boeing H, Schwedhelm C, et al. Food groups and risk of coronary heart disease, stroke and heart failure: A systematic review and dose-response meta-analysis of prospective studies. *Crit Rev Food Sci Nutr.* 2019;59:1071-1090.

13. Key TJ, Appleby PN, Bradbury KE, et al. Consumption of Meat, Fish, Dairy Products, and Eggs and Risk of Ischemic Heart Disease. *Circulation.* 2019;139:2835-2845.

14. Chen GC, Lv DB, Pang Z, Liu QF. Red and processed meat consumption and risk of stroke: a meta-analysis of prospective cohort studies. *Eur J Clin Nutr.* 2013;67:91-95.

15. Kaluza J, Wolk A, Larsson SC. Red meat consumption and risk of stroke: a meta-analysis of prospective studies. *Stroke.* 2012;43:2556-2560.

16. Tong TYN, Appleby PN, Key TJ, et al. The associations of major foods and fibre with risks of ischaemic and haemorrhagic stroke: a prospective study of 418 329 participants in the EPIC cohort across nine European countries. *Eur Heart J.* 2020.

17. Micha R, Michas G, Mozaffarian D. Unprocessed red and processed meats and risk of coronary artery disease and type 2 diabetes--an updated review of the evidence. *Curr Atheroscler Rep.* 2012;14:515-524.

18. He FJ, MacGregor GA. Effect of modest salt reduction on blood pressure: a meta-analysis of randomized trials. Implications for public health. *J Hum Hypertens.* 2002;16:761-770.

19. Rosendorff C, Lackland DT, Allison M, et al. Treatment of hypertension in patients with coronary artery disease: A scientific statement from the American Heart Association, American College of Cardiology, and American Society of Hypertension. *J Am Soc Hypertens.* 2015;9:453-498.

20. Mensink Ronald. *Effects of saturated fatty acids on serum lipids and lipoproteins: a systematic review and regression analysis.* World Health Organisation; 2016.

21. McDonald HI, Nitsch D, Millett ER, Sinclair A, Thomas SL. New estimates of the burden of acute community-acquired infections among older people with diabetes mellitus: a retrospective cohort study using linked electronic health records. *Diabet Med.* 2014;31:606-614.
22. Ganz T, Nemeth E. Iron homeostasis in host defence and inflammation. *Nat Rev Immunol.* 2015;15:500-510.
23. Cassat JE, Skaaer EP. Iron in infection and immunity. *Cell host & microbe.* 2013;13:509-519.
24. Cao Y, Strate LL, Keeley BR, et al. Meat intake and risk of diverticulitis among men. *Gut.* 2018;67:466-472.
25. Crowe FL, Appleby PN, Allen NE, Key TJ. Diet and risk of diverticular disease in Oxford cohort of European Prospective Investigation into Cancer and Nutrition (EPIC): prospective study of British vegetarians and non-vegetarians. *Bmj.* 2011;343:d4131.
26. David LA, Maurice CF, Carmody RN, et al. Diet rapidly and reproducibly alters the human gut microbiome. *Nature.* 2014;505:559-563.
27. Zhao Z, Yin Z, Hang Z, Zhang C, Zhao Q. Association between red and processed meat intake and colorectal adenoma incidence and recurrence: a systematic review and meta-analysis. *Oncotarget.* 2018;9:32373-32382.
28. Gamage SMK, Dissabandara L, Lam AK, Gopalan V. The role of heme iron molecules derived from red and processed meat in the pathogenesis of colorectal carcinoma. *Crit Rev Oncol Hematol.* 2018;126:121-128.
29. Ward MH, Cross AJ, Divan H, et al. Processed meat intake, CYP2A6 activity and risk of colorectal adenoma. *Carcinogenesis.* 2007;28:1210-1216.
30. Cela L, Kraja B, Hoti K, et al. Lifestyle characteristics and gastroesophageal reflux disease: a population-based study in Albania. *Gastroenterol Res Pract.* 2013;2013:936792.
31. Nam SY, Park BJ, Cho YA, et al. Different effects of dietary factors on reflux esophagitis and non-erasive reflux disease in 11,690 Korean subjects. *J Gastroenterol.* 2017;52:818-829.
32. Zheng Z, Nordenstedt H, Pedersen NL, Lagergren J, Ye W. Lifestyle factors and risk for symptomatic gastroesophageal reflux in monozygotic twins. *Gastroenterology.* 2007;132:87-95.
33. El-Serag HB, Satia JA, Rabeneck L. Dietary intake and the risk of gastro-oesophageal reflux disease: a cross sectional study in volunteers. *Gut.* 2005;54:11-17.
34. Van Hecke T, Van Camp J, De Smet S. Oxidation during digestion of meat: interactions with the diet and helicobacter pylori gastritis, and implications on human health. *Comprehensive Reviews in Food Science and Food Safety.* 2017;16:214-233.
35. Quaglia NC, Dambrosio A. Helicobacter pylori: A foodborne pathogen? *World J Gastroenterol.* 2018;24:3472-3487.
36. Thomson CA, Stanaway JD, Neuhausser ML, et al. Nutrient intake and anemia risk in the women's health initiative observational study. *J Am Diet Assoc.* 2011;111:532-541.
37. Wittenbecher C, Muhlenbruch K, Kroger J, et al. Amino acids, lipid metabolites, and ferritin as potential mediators linking red meat consumption to type 2 diabetes. *Am J Clin Nutr.* 2015;101:1241-1250.
38. Cade JE, Moreton JA, O'Hara B, et al. Diet and genetic factors associated with iron status in middle-aged women. *Am J Clin Nutr.* 2005;82:813-820.
39. Galan P, Yoon HC, Preziosi P, et al. Determining factors in the iron status of adult women in the SU.VI.MAX study. *Supplementation en Vitamines et Mineraux Antioxydants.* *Eur J Clin Nutr.* 1998;52:383-388.
40. Rigas AS, Sorensen CJ, Pedersen OB, et al. Predictors of iron levels in 14,737 Danish blood donors: results from the Danish Blood Donor Study. *Transfusion.* 2014;54:789-796.
41. Tong TYN, Key TJ, Gaiteskell K, et al. Hematological parameters and prevalence of anemia in white and British Indian vegetarians and nonvegetarians in the UK Biobank. *Am J Clin Nutr.* 2019.
42. Cook JD. Adaptation in iron metabolism. *Am J Clin Nutr.* 1990;51:301-308.
43. Aune D, Ursin G, Veierod MB. Meat consumption and the risk of type 2 diabetes: a systematic review and meta-analysis of cohort studies. *Diabetologia.* 2009;52:2277-2287.
44. Ericson U, Hindy G, Drake I, et al. Dietary and genetic risk scores and incidence of type 2 diabetes. *Genes Nutr.* 2018;13:13.

45. Pan A, Sun Q, Bernstein AM, et al. Red meat consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *Am J Clin Nutr.* 2011;94:1088-1096.

46. Talaei M, Wang Y-L, Yuan J-M, Pan A, Koh W-P. Meat, dietary heme iron, and risk of type 2 diabetes mellitus: the Singapore Chinese Health Study. *American journal of epidemiology.* 2017;186:824-833.

47. Feskens EJ, Sluik D, van Woudenbergh GJ. Meat consumption, diabetes, and its complications. *Curr Diab Rep.* 2013;13:298-306.

48. Kurotani K, Nanri A, Goto A, et al. Red meat consumption is associated with the risk of type 2 diabetes in men but not in women: a Japan Public Health Center-based Prospective Study. *Br J Nutr.* 2013;110:1910-1918.

49. Bao W, Rong Y, Rong S, Liu L. Dietary iron intake, body iron stores, and the risk of type 2 diabetes: a systematic review and meta-analysis. *BMC Med.* 2012;10:119.

50. Kim Y, Keogh J, Clifton P. A review of potential metabolic etiologies of the observed association between red meat consumption and development of type 2 diabetes mellitus. *Metabolism.* 2015;64:768-779.
Table 1. Baseline characteristics of participants by red and processed meat intake in UK Biobank (n=467,754*).

| Characteristic | 0-1 times/week | 2 times/week | 3-4 times/week | ≥5 times/week |
|----------------|----------------|--------------|---------------|--------------|
| Mean (SD) or n (%) | N=44 021 | N=160 073 | N=140 678 | N=122 982 |
| **Sociodemographic** | | | | |
| Sex, n (%) | | | | |
| Women | 31 319 (71.1) | 101 750 (63.6) | 71 681 (51.0) | 47 657 (38.8) |
| Men | 12 702 (28.9) | 58 323 (36.4) | 68 997 (49.0) | 75 325 (61.2) |
| Age (years), mean (SD) | 54.9 (8.2) | 56.5 (8.0) | 56.4 (8.1) | 56.5 (8.2) |
| Ethnicity, n (%) | | | | |
| White | 38 453 (87.4) | 151 731 (94.8) | 134 513 (95.6) | 116 818 (95.0) |
| Asian or Asian British | 3 468 (7.9) | 2 914 (1.8) | 2 245 (1.6) | 1 897 (1.5) |
| Black or Black British | 886 (2.0) | 2 607 (1.6) | 1 685 (1.2) | 2 047 (1.7) |
| Mixed Race/Other | 997 (2.3) | 3 232 (1.5) | 1 807 (1.3) | 1 774 (1.4) |
| Unknown | 217 (0.5) | 498 (0.3) | 428 (0.3) | 446 (0.4) |
| Townsend deprivation, n (%) | | | | |
| Most affluent (mean -4.7) | 7 037 (16.0) | 32 848 (20.5) | 29 803 (21.2) | 24 666 (20.1) |
| 2 (mean -3.3) | 7 525 (17.1) | 32 746 (20.5) | 29 079 (20.7) | 24 304 (19.8) |
| 3 (mean -2.1) | 8 341 (18.9) | 32 738 (20.5) | 28 325 (20.1) | 24 343 (19.8) |
| 4 (mean -0.1) | 10 146 (23.0) | 31 755 (19.8) | 27 447 (19.5) | 24 096 (19.6) |
| Most deprived (mean 3.8) | 10 910 (24.8) | 29 771 (18.6) | 25 871 (18.4) | 25 448 (20.7) |
| Unknown | 62 (0.1) | 215 (0.1) | 153 (0.1) | 152 (0.1) |
| Qualification, n (%) | | | | |
| College/university degree/NVQ | 28 492 (64.7) | 96 077 (60.0) | 82 367 (58.6) | 72 438 (58.9) |
| National examination at ages 17-18 | 2 491 (5.7) | 8 708 (5.4) | 7 795 (5.5) | 6 626 (5.4) |
| National examination at age 16 | 6 321 (14.4) | 27 682 (17.3) | 24 134 (17.2) | 19 676 (16.0) |
| Other/unknown | 6 717 (15.3) | 27 606 (17.2) | 26 382 (18.8) | 24 242 (19.7) |
| Employment, n (%) | | | | |
| In paid employment | 27 652 (62.8) | 93 968 (58.7) | 81 645 (58.0) | 70 102 (57.0) |
| Pension | 10 229 (23.2) | 48 220 (30.1) | 42 698 (30.4) | 37 181 (30.2) |
| Not in paid employment | 5 556 (12.6) | 16 487 (10.3) | 15 236 (10.8) | 14 563 (11.8) |
| Unknown | 584 (1.3) | 1 398 (0.9) | 1 099 (0.8) | 1 136 (0.9) |
| **Physical measurements** | | | | |
| BMI (kg/m²), mean (SD) | 25.9 (4.7) | 27.1 (4.7) | 27.6 (4.8) | 28.1 (4.9) |
| **Lifestyle** | | | | |
| Smoking, n (%) | | | | |
| None | 26 347 (59.9) | 90 449 (56.5) | 76 686 (54.5) | 62 688 (51.0) |
| Former | 13 964 (31.7) | 54 799 (34.2) | 48 534 (34.5) | 43 270 (35.2) |
| Current <15 cigarettes/day | 1 297 (2.9) | 4 581 (2.9) | 4 247 (3.0) | 4 074 (3.3) |
| Current ≥15 cigarettes/day | 1 030 (2.3) | 4 825 (3.0) | 6 015 (4.3) | 7 623 (6.2) |
| Current, amount unknown | 1 213 (2.8) | 4 876 (3.0) | 4 727 (3.4) | 4 914 (4.0) |
| Unknown | 170 (0.4) | 543 (0.3) | 469 (0.3) | 413 (0.3) |
| Physical activity level, n (%) | | | | |
| Low <10 excess METs | 7 770 (17.7) | 24 716 (15.4) | 21 860 (15.5) | 20 458 (16.6) |
| Moderate 10-<50 excess METs | 22 380 (50.8) | 80 041 (50.0) | 68 197 (48.5) | 58 007 (47.2) |
| High ≥ 50 excess METs | 12 406 (28.2) | 49 710 (31.1) | 45 470 (32.3) | 39 708 (32.3) |
| Unknown | 1 465 (3.3) | 5 606 (3.5) | 5 151 (3.7) | 4 809 (3.9) |
| Alcohol intake, n (%) | | | | |
| non-drinkers | 6 814 (15.5) | 19 867 (12.4) | 14 469 (10.3) | 10 862 (8.8) |
| <1g/d | 14 743 (33.5) | 57 212 (35.7) | 43 228 (30.7) | 31 588 (25.7) |
| 1-<10g/d | 7 985 (18.1) | 36 199 (22.6) | 31 682 (22.5) | 25 627 (20.8) |
| 10-<20g/d | 6 740 (15.3) | 34 046 (21.3) | 41 069 (29.2) | 46 545 (37.8) |
| 20+g/d | 7 503 (17.0) | 11 939 (7.5) | 9 611 (6.8) | 7 791 (6.3) |
| Unknown | 236 (0.5) | 810 (0.5) | 619 (0.4) | 569 (0.5) |
| **Diet** | | | | |
| Fruit & vegetable intake (s/day), mean (SD) | 5.59 (3.19) | 4.89 (2.54) | 4.50 (2.45) | 4.33 (2.50) |
| Fruit & vegetable intake categories, n (%) | | | | |
| <3 servings/day | 5 486 (12.5) | 25 992 (16.2) | 29 853 (21.2) | 29 895 (24.3) |
| 3-<4 servings/day | 6 014 (13.7) | 27 540 (17.2) | 27 245 (19.4) | 25 094 (20.4) |
| 4-<6 servings/day | 14 692 (33.4) | 58 168 (36.3) | 48 946 (34.8) | 40 319 (32.8) |
≥6 servings/day  
Unknown  
Cereal fibre intake (g), mean (SD)  
Poultry meat, n (%)  
0-1 times/week  
2 times/week  
≥3 times/week  
Unknown  
Menopausal status, n (%)  
Premenopausal  
Postmenopausal  
Unknown  
Parity, n (%)  
0 births  
1 - 2 births  
≥3 births  
Unknown  
HRT use, n (%)  
Never  
Past  
Current  
Unknown  
OCP use, n (%)  
Never  
Past  
Current  
Unknown  

The \(\chi^2\) test was used to compare the distribution between meat intakes for all categorical variables. Analysis of variance (ANOVA) was used to compare the means between meat intakes. The \(P\)-heterogeneity between meat intakes was \(<0.001\) for all variables. All dietary data come from the touchscreen questionnaire. *See supplementary Figure S1. BMI: Body mass index, HRT: hormone replacement therapy, OCP: oral contraceptive pill use, NVQ: national vocational qualification, s/day: servings/day.
### Disease subgroup

| Disease subgroup                          | Total n | Cases | HR (95% CI) per 70g/day | P trend |
|-------------------------------------------|---------|-------|-------------------------|---------|
| **Circulatory disease**                   |         |       |                         |         |
| Ischaemic heart disease                   | 430 726 | 13 120| 1.14 (1.06, 1.22)       | <0.001  |
| Atrial fibrillation and flutter           | 430 726 | 4742  | 0.87 (0.78, 0.98)       | 0.020   |
| Total stroke                              | 430 726 | 5330  | 1.14 (1.03, 1.28)       | 0.015   |
| Ischaemic stroke                          | 430 726 | 2338  | 1.22 (1.03, 1.44)       | 0.020   |
| Haemorrhagic stroke                       | 430 726 | 939   | 1.09 (0.85, 1.41)       | 0.478   |
| Venous thromboembolism                    | 457 413 | 3751  | 1.06 (0.93, 1.21)       | 0.383   |
| Varicose veins                            | 445 617 | 2633  | 0.93 (0.81, 1.08)       | 0.339   |
| Haemorrhoids                              | 448 133 | 8297  | 1.07 (0.98, 1.16)       | 0.125   |
| **Respiratory disease**                   |         |       |                         |         |
| Pneumonia                                 | 459 321 | 6350  | 1.28 (1.15, 1.41)       | <0.001  |
| **Digestive disease**                     |         |       |                         |         |
| Gastro-oesophageal reflux disease         | 439 868 | 7010  | 0.95 (0.87, 1.04)       | 0.284   |
| Gastritis and duodenitis                  | 451 009 | 11 365| 0.97 (0.91, 1.04)       | 0.412   |
| Inguinal hernia                           | 440 769 | 8020  | 0.98 (0.90, 1.07)       | 0.722   |
| Noninfective enteritis and colitis        | 453 628 | 6235  | 1.02 (0.92, 1.12)       | 0.731   |
| Diverticular disease                      | 455 294 | 12 816| 1.18 (1.10, 1.26)       | <0.001  |
| Colon polyps                              | 446 060 | 37 400| 1.09 (1.04, 1.13)       | <0.001  |
| Gallbladder disease                       | 448 394 | 8914  | 1.02 (0.95, 1.11)       | 0.551   |
| **Joint disorder**                        |         |       |                         |         |
| Osteoarthritis                            | 417 187 | 18 080| 0.97 (0.91, 1.02)       | 0.240   |
| **Genitourinary disease**                 |         |       |                         |         |
| Kidney stones                             | 460 570 | 2444  | 1.01 (0.86, 1.17)       | 0.944   |
| Urinary tract infection                   | 460 001 | 5205  | 1.05 (0.94, 1.16)       | 0.399   |
| Enlarged prostate                         | 205 696 | 3539  | 1.01 (0.88, 1.15)       | 0.938   |
| Female genital prolapse                   | 239 660 | 6083  | 1.06 (0.97, 1.17)       | 0.207   |
| **Other diseases**                        |         |       |                         |         |
| Uterine fibroids                          | 181 791 | 9258  | 0.98 (0.92, 1.06)       | 0.636   |
| Iron deficiency anaemia                   | 462 115 | 4719  | 0.83 (0.75, 0.92)       | <0.001  |
| Diabetes                                  | 442 752 | 9571  | 1.29 (1.19, 1.40)       | <0.001  |
| Carpal tunnel syndrome                    | 458 502 | 5048  | 1.06 (0.95, 1.18)       | 0.295   |
| Cataracts                                 | 425 982 | 16 114| 0.92 (0.87, 0.98)       | 0.007   |
| Cellulitis                                | 463 622 | 3409  | 1.00 (0.88, 1.15)       | 0.968   |

**Figure 1. Risk of 25 common conditions per 70 grams higher daily intake of red and processed meat**

Stratified for sex, age group and region and adjusted for age (underlying time variable), ethnicity (4 groups where possible: White, Asian or Asian British, Black or Black British, Mixed race or other, unknown), deprivation (Townsend index quintiles, unknown), qualification (College or university degree/vocational qualification, National examination at ages 17-18, National examination at age 16, other/unknown), employment (in paid employment, receiving pension, not in paid employment, unknown), smoking (never, former, current <15 cigarettes/day, current ≥15 cigarettes/day, current unknown amount of cigarettes/day, unknown), physical activity (<10 excess METs per/week, 10-<50 excess METs per/week, ≥50 excess METs per/week, unknown), alcohol intake (none, < 1 g/day, 1-<10 g/day, 10-<20 g/day, ≥20 g/day, unknown), total fruit and vegetable intake (< 3 servings/day, 3-<4 servings/day, 4-<6 servings/day, ≥6 servings/day, unknown), cereal fibre score (sex-specific quintiles, unknown), BMI (sex-specific quintiles, unknown), in women: menopausal status (pre-, postmenopausal, unknown), HRT (never, past, current, unknown), OCP use (never, past, current, unknown), and parity (nulliparous, 1-2, ≥3, unknown). BMI: Body mass index, HRT: hormone replacement therapy, OCP: oral contraceptive pill. P trend in bold: P value robust to Bonferroni correction (P<0.002).
Figure 2. Risk of 25 common conditions per 50 grams higher daily intake of red meat
Stratified for sex, age group and region and adjusted for age (underlying time variable), ethnicity (4 groups where possible: White, Asian or Asian British, Black or Black British, Mixed race or other, unknown), deprivation (Townsend index quintiles, unknown), qualification (College or university degree/vocational qualification, National examination at ages 17-18, National examination at age 16, other/unknown), employment (in paid employment, receiving pension, not in paid employment, unknown), smoking (never, former, current <15 cigarettes/day, current ≥ 15 cigarettes/ day, current unknown amount of cigarettes/day, unknown), physical activity (<10 excess METs per/week, 10-<50 excess METs per/week, ≥50 excess METs per/week, unknown), alcohol intake (none, < 1 g/day, 1-<10 g/day, 10-<20 g/day, ≥20 g/day, unknown), total fruit and vegetable intake (< 3 servings/day, 3-< 4 servings/day, 4-< 6 servings/day, ≥ 6 servings/day, unknown), cereal fibre score (sex-specific quintiles, unknown), BMI (sex-specific quintiles, unknown), in women: menopausal status (pre-, postmenopausal, unknown), HRT (never, past, current, unknown), OCP use (never, past, current, unknown), and parity (nulliparous, 1-2, ≥ 3, unknown). BMI: Body mass index, HRT: hormone replacement therapy, OCP: oral contraceptive pill. P trend in bold: P value robust to Bonferroni correction (P<0.002).

| Disease subgroup                  | Total n | Cases | HR (95% CI) per 50g/day | P trend |
|----------------------------------|---------|-------|-------------------------|---------|
| **Circulatory disease**          |         |       |                         |         |
| Ischaemic heart disease          | 431241  | 13134 | 1.14 (1.06, 1.23)       | <0.001  |
| Atrial fibrillation and flutter  | 431241  | 4746  | 0.85 (0.75, 0.95)       | 0.006   |
| Total stroke                     | 431241  | 5341  | 1.03 (0.93, 1.16)       | 0.555   |
| Ischaemic stroke                 | 431241  | 2344  | 1.02 (0.86, 1.21)       | 0.830   |
| Haemorrhagic stroke              | 431241  | 941   | 1.05 (0.81, 1.36)       | 0.700   |
| Venous thromboembolism           | 457982  | 3759  | 1.04 (0.91, 1.18)       | 0.609   |
| Varicose veins                   | 446083  | 2636  | 0.94 (0.81, 1.09)       | 0.430   |
| Haemorrhoids                     | 448688  | 8306  | 1.06 (0.98, 1.16)       | 0.167   |
| **Respiratory disease**          |         |       |                         |         |
| Pneumonia                        | 459898  | 6367  | 1.18 (1.07, 1.31)       | 0.001   |
| **Digestive disease**            |         |       |                         |         |
| Gastro-oesophageal reflux disease| 440403  | 7023  | 0.96 (0.87, 1.05)       | 0.384   |
| Gastritis and duodenitis         | 451556  | 11380 | 0.94 (0.88, 1.01)       | 0.093   |
| Inguinal hernia                  | 441332  | 8029  | 1.00 (0.91, 1.10)       | 0.982   |
| Noninfective enteritis and colitis| 454193 | 6241  | 0.99 (0.90, 1.09)       | 0.836   |
| Diverticular disease             | 455856  | 12829 | 1.15 (1.07, 1.24)       | <0.001  |
| Colon polyps                     | 446613  | 37430 | 1.06 (1.02, 1.11)       | 0.003   |
| Gallbladder disease              | 448958  | 8930  | 1.02 (0.94, 1.11)       | 0.645   |
| **Joint disorder**               |         |       |                         |         |
| Osteoarthritis                   | 417674  | 18095 | 0.96 (0.90, 1.01)       | 0.133   |
| **Genitourinary disease**        |         |       |                         |         |
| Kidney stones                    | 461149  | 2450  | 0.98 (0.84, 1.15)       | 0.807   |
| Urinary tract infection          | 460564  | 5216  | 1.06 (0.95, 1.19)       | 0.285   |
| Enlarged prostate                | 205848  | 3548  | 1.01 (0.87, 1.16)       | 0.924   |
| Female genital prolapse          | 239963  | 6070  | 1.05 (0.95, 1.15)       | 0.376   |
| **Other diseases**               |         |       |                         |         |
| Uterine fibroids                 | 182008  | 9266  | 1.01 (0.94, 1.09)       | 0.750   |
| Iron deficiency anaemia          | 462687  | 4728  | 0.77 (0.69, 0.86)       | <0.001  |
| Diabetes                         | 443267  | 9595  | 1.19 (1.10, 1.30)       | <0.001  |
| Carpal tunnel syndrome           | 459074  | 5055  | 1.06 (0.95, 1.18)       | 0.317   |
| Cataracts                         | 426474  | 16142 | 0.93 (0.87, 0.99)       | 0.015   |
| Cellulitis                        | 464204  | 3414  | 0.92 (0.80, 1.05)       | 0.199   |

Red meat intake range: 0.7 to 1.3
Figure 3. Risk of 25 common conditions per 20 grams higher daily intake of processed meat
Stratified for sex, age group and region and adjusted for age (underlying time variable), ethnicity (4 groups where possible: White, Asian or Asian British, Black or Black British, Mixed race or other, unknown), deprivation (Townsend index quintiles, unknown), qualification (College or university degree/vocational qualification, National examination at ages 17-18, National examination at age 16, other/unknown), employment (in paid employment, receiving pension, not in paid employment, unknown), smoking (never, former, current <15 cigarettes/day, current > 15 cigarettes/day, current unknown amount of cigarettes/day, unknown), physical activity (<10 excess METs per/week, 10-<50 excess METs per/week, ≥ 50 excess METs per/week, unknown), alcohol intake (none, < 1 g/day, 1-<10 g/day, 10-<20 g/day, ≥20 g/day, unknown), total fruit and vegetable intake (< 3 servings/day, 3-< 4 servings/day, 4-< 6 servings/day, ≥ 6 servings/day, unknown), cereal fibre score (sex-specific quintiles, unknown), BMI (sex-specific quintiles, unknown), in women: menopausal status (pre-, postmenopausal, unknown), HRT (never, past, current, unknown), OCP use (never, past, current, unknown), and parity (nulliparous, 1-2, ≥ 3, unknown). BMI: Body mass index, HRT: hormone replacement therapy, OCP: oral contraceptive pill. P trend in bold: P value robust to Bonferroni correction (P<0.002).

| Disease subgroup                     | Total n | Cases | HR (95% CI) per 20g/day | Ptrend |
|--------------------------------------|---------|-------|-------------------------|--------|
| **Circulatory disease**              |         |       |                         |        |
| Ischaemic heart disease              | 435 200 | 13 309| 1.09 (1.04, 1.15)       | 0.001  |
| Atrial fibrillation and flutter      | 435 200 | 47 96 | 0.96 (0.87, 1.03)       | 0.244  |
| Total stroke                         | 435 200 | 54 18 | 1.09 (1.01, 1.18)       | 0.032  |
| Ischaemic stroke                     | 435 200 | 23 83 | 1.15 (1.02, 1.30)       | 0.021  |
| Haemorrhagic stroke                  | 435 200 | 955   | 1.03 (0.86, 1.24)       | 0.759  |
| Venous thromboembolism               | 462 362 | 38 18 | 1.00 (0.99, 1.20)       | 0.076  |
| Varicose veins                       | 450 378 | 26 59 | 0.93 (0.84, 1.04)       | 0.202  |
| Haemorrhoids                         | 452 988 | 84 09 | 1.00 (0.94, 1.07)       | 0.959  |
| **Respiratory disease**              |         |       |                         |        |
| Pneumonia                            | 464 301 | 65 03 | 1.22 (1.13, 1.31)       | <0.001 |
| **Digestive disease**                |         |       |                         |        |
| Gastro-oesophageal reflux disease    | 444 569 | 71 13 | 0.95 (0.89, 1.01)       | 0.123  |
| Gastritis and duodenitis             | 455 830 | 11 53 | 1.01 (0.96, 1.07)       | 0.659  |
| Inguinal hernia                      | 446 600 | 8 109 | 1.01 (0.95, 1.08)       | 0.769  |
| Noninfecitive enteritis and colitis  | 458 560 | 6 33 | 1.00 (0.93, 1.07)       | 0.949  |
| Diverticular disease                 | 460 224 | 12 97 | 1.11 (1.05, 1.16)       | <0.001 |
| Colon polyps                         | 450 872 | 37 89 | 1.07 (1.04, 1.10)       | <0.001 |
| Gallbladder disease                  | 453 271 | 9 051 | 1.01 (0.95, 1.07)       | 0.749  |
| **Joint disorder**                   |         |       |                         |        |
| Osteoarthritis                       | 421 561 | 18 314| 1.00 (0.96, 1.04)       | 0.947  |
| **Genitourinary disease**            |         |       |                         |        |
| Kidney stones                        | 465 579 | 24 80 | 0.99 (0.88, 1.11)       | 0.804  |
| Urinary tract infection              | 464 967 | 5 299 | 1.03 (0.95, 1.11)       | 0.487  |
| Enlarged prostate                    | 208 097 | 3 590 | 1.05 (0.95, 1.15)       | 0.372  |
| Female genital prolapse              | 242 022 | 6 122 | 1.03 (0.96, 1.11)       | 0.426  |
| **Other diseases**                   |         |       |                         |        |
| Uterine fibroids                     | 183 488 | 9 359 | 1.00 (0.94, 1.05)       | 0.885  |
| Iron deficiency anaemia              | 467 116 | 4 800 | 0.97 (0.89, 1.05)       | 0.428  |
| Diabetes                             | 447 363 | 9 791 | 1.24 (1.17, 1.32)       | <0.001 |
| Carpal tunnel syndrome               | 463 466 | 5 144 | 1.02 (0.95, 1.11)       | 0.555  |
| Cataracts                            | 430 369 | 16 333| 0.96 (0.92, 1.01)       | 0.113  |
| Cellulitis                           | 468 659 | 3 470 | 1.03 (0.93, 1.14)       | 0.545  |

0.7 1 1.3

Processed meat intake
Figure 4. Risk of 25 common conditions per 30 grams higher daily intake of poultry meat
Stratified for sex, age group and region and adjusted for age (underlying time variable), ethnicity (4 groups where possible: White, Asian or Asian British, Black or Black British, Mixed race or other, unknown), deprivation (Townsend index quintiles, unknown), qualification (College or university degree/vocational qualification, National examination at ages 17-18, National examination at age 16, other/unknown), employment (in paid employment, receiving pension, not in paid employment, unknown), smoking (never, former, current <15 cigarettes/day, current > 15 cigarettes/day, current unknown amount of cigarettes/day, unknown), physical activity (<10 excess METs per/week, 10-<50 excess METs per/week, ≥ 50 excess METs per/week, unknown), alcohol intake (none, < 1 g/day, 1-<10 g/day, 10-<20 g/day, ≥20 g/day, unknown), total fruit and vegetable intake (< 3 servings/day, 3-< 4 servings/day, 4-< 6 servings/day, ≥ 6 servings/day, unknown), cereal fibre score (sex-specific quintiles, unknown), BMI (sex-specific quintiles, unknown), in women: menopausal status (pre-, postmenopausal, unknown), HRT (never, past, current, unknown), OCP use (never, past, current, unknown), and parity (nulliparous, 1-2, ≥ 3, unknown). BMI: Body mass index, HRT: hormone replacement therapy, OCP: oral contraceptive pill. P trend in bold: P value robust to Bonferroni correction (P<0.002).

| Disease subgroup                | Total n | Cases | HR (95% CI) per 30g/day | P trend |
|--------------------------------|---------|-------|-------------------------|---------|
| **Circulatory disease**        |         |       |                         |         |
| Ischaemic heart disease        | 435 349 | 13 299| 1.07 (1.01, 1.13)       | 0.017   |
| Atrial fibrillation and flutter| 435 349 | 4794  | 1.09 (0.99, 1.19)       | 0.069   |
| Total stroke                   | 435 349 | 5422  | 1.04 (0.96, 1.14)       | 0.309   |
| Ischaemic stroke               | 435 349 | 2388  | 1.00 (0.88, 1.13)       | 0.986   |
| Haemorrhagic stroke            | 435 349 | 957   | 1.08 (0.89, 1.32)       | 0.430   |
| Venous thromboembolism         | 462 525 | 3818  | 1.0 (0.91, 1.12)        | 0.819   |
| Varicose veins                 | 450 551 | 2661  | 1.00 (0.88, 1.13)       | 0.969   |
| Haemorrhoids                   | 453 148 | 8416  | 1.06 (0.99, 1.14)       | 0.078   |
| **Respiratory disease**        |         |       |                         |         |
| Pneumonia                      | 464 469 | 6505  | 1.01 (0.93, 1.09)       | 0.823   |
| **Digestive disease**          |         |       |                         |         |
| Gastro-oesophageal reflux disease | 444 713 | 7121  | 1.14 (1.06, 1.23)       | <0.001  |
| Gastritis and duodenitis        | 455 989 | 11 535| 1.10 (1.04, 1.16)       | 0.002   |
| Inguinal hernia                 | 445 779 | 8111  | 1.01 (0.94, 1.08)       | 0.873   |
| Noninfective enteritis and colitis | 458 721 | 6332  | 1.03 (0.95, 1.11)       | 0.516   |
| Diverticular disease            | 460 380 | 12 983| 1.06 (1.04, 1.16)       | 0.011   |
| Colost polyps                   | 451 036 | 37 860| 1.04 (1.01, 1.07)       | 0.016   |
| Gallbladder disease             | 453 438 | 9055  | 1.08 (1.01, 1.15)       | 0.030   |
| **Joint disorder**             |         |       |                         |         |
| Osteoarthritis                 | 421 706 | 18 304| 1.07 (1.02, 1.12)       | 0.003   |
| **Genitourinary disease**      |         |       |                         |         |
| Kidney stones                   | 465 748 | 2483  | 1.13 (0.99, 1.28)       | 0.066   |
| Urinary tract infection         | 465 142 | 5302  | 0.96 (0.88, 1.05)       | 0.385   |
| Enlarged prostate              | 208 119 | 3592  | 1.02 (0.92, 1.13)       | 0.671   |
| Female genital prolapse         | 242 167 | 6127  | 1.05 (0.97, 1.14)       | 0.234   |
| **Other diseases**             |         |       |                         |         |
| Uterine fibroids               | 183 585 | 9365  | 1.01 (0.95, 1.08)       | 0.786   |
| Iron deficiency anaemia        | 467 277 | 4796  | 0.80 (0.73, 0.87)       | <0.001  |
| Diabetes                       | 447 515 | 9799  | 1.13 (1.06, 1.20)       | <0.001  |
| Carpal tunnel syndrome         | 463 624 | 5146  | 1.02 (0.94, 1.12)       | 0.591   |
| Cataracts                      | 430 530 | 16 350| 0.96 (0.91, 1.01)       | 0.089   |
| Cellulitis                     | 468 830 | 3464  | 1.02 (0.92, 1.14)       | 0.696   |

0.7 1 1.3
Poultry meat intake