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Red meat and processed meat intake and risk of colorectal cancer: a population-based case control study

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Abstract

Objectives—To examine the association between red meat subtypes intake and risk of colorectal cancer among Jewish and Arabs populations in a unique Mediterranean environment.

Methods—The Molecular Epidemiology of Colorectal Cancer study (n=10,026) is a prospective population-based case-control study in northern Israel. Participants were interviewed in-person about their dietary intake and lifestyle using a questionnaire that included a food-frequency questionnaire.

Results—Red meat consumption in Israel was found to be especially low in the Jewish population (1.29±1.45 servings/week) but higher in Arabs (3.0±1.98 servings/week) (P <0.001). Beef was the most commonly consumed red meat by Jews (1.15/1.29 servings per week, 89%), and proportionally less so by Arabs (2.00/3.00, 67%). Processed meat consumption (mostly pork-free), was lower among Arabs (0.9±1.56 servings/week) compared to Jews (1.97±2.97 servings/week) (P <0.001). The adjusted odds of CRC per one serving/week of red meat was 1.05 (95% CI, 1.01-1.08) in Jews, and 0.94 (0.88-1.01) in Arabs. Compared to no consumption, beef consumption was associated with OR=0.96 (0.86-1.07) in Jews and 0.94 (0.61-1.45) in Arabs; lamb consumption with OR=1.28 (1.10-1.5) and 1.01 (0.75-1.37), pork consumption with OR=1.44 (1.24-1.67) and 1.07 (0.73-1.56), and processed meat consumption with OR=1.22 (1.10-1.35) and 1.04 (0.82-1.33) in Jews and Arabs, respectively.

Conclusions—Overall red meat consumption was weakly associated with CRC risk, significant only for lamb and pork but not for beef regardless of tumor location. Processed meat was associated with mild CRC risk.

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Keywords

colorectal cancer; processed meat; red meat; beef; pork; lamb

Introduction

Colorectal cancer (CRC) is the third most common cancer worldwide, accounting for 1.36 million new cases and 694,000 deaths worldwide in 2012 [1]. Western lifestyle and dietary factors may be responsible for the high incidence of CRC in industrialized countries and for the rapidly increasing rates in some countries undergoing economic transition [2,3]. It has been estimated that as high as 70% (range 50-80%) of CRC deaths could be avoided by dietary change [4]. A study from Alberta estimated that about 12% of CRC in 2012 were attributable to red and processed meat intake [5].

The potential role of red meat and processed meat intake in CRC risk has been the subject of scientific debate. A consensus statement issued in 2011 by the World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR) concluded that there was convincing evidence to support a positive association between intakes of red and processed meat and CRC [6]. However, a recently published comprehensive meta-analysis concluded that red meat intake does not appear to be an independent predictor of CRC [7].

Most of the previous studies were conducted in North America, Western Europe and certain Asian countries [7]. Data are lacking from countries following a Mediterranean diet and countries with low intake of fresh red meat and processed meat. Israel is a Mediterranean country with an overall low Intake of fresh red meat, especially among the Jewish population, and extremely low pork consumption, fresh or processed, due to religious and cultural prohibitions against pork consumption in Jewish and Muslim traditions. Further, the overall red meat intake and the proportion of the various meat subtypes (beef, lamb, and pork) differ significantly between Jews and Arabs in Israel. This study is aimed at assessing the association between red meat, processed meat and CRC risk using data from a large Mediterranean population-based study.

Material and Methods

Participants

The Molecular Epidemiology of Colorectal Cancer (MECC) study is an ongoing population-based case-control study of incident CRC in northern Israel [8,9]. Recruitment to the MECC Study started March 31, 1998, and all consecutive patients diagnosed with CRC residing in a geographically defined area of northern Israel at time of diagnosis were eligible to participate in this study. CRC-free controls were randomly selected from the same source population with the use of the Clalit Health Services (CHS) register. CHS is the largest health care provider in Israel and covers more than half of the population in Israel. Health care coverage in Israel is mandatory and is provided by four groups akin to not-for-profit health maintenance organizations. Thus, all study participants (patients and controls) had a similar health insurance plan and similar access to health services, including prevention and

cancer screening. Controls were individually matched on year of birth, sex, ethnicity (Jews vs. Arabs) and residence (primary care clinic). Participants provided IRB-approved written informed consent at the time of enrollment and were interviewed in-person by trained interviewers to obtain information about their dietary intake and lifestyle using a questionnaire that includes a semi-quantitative food frequency questionnaire (FFQ) modified and validated for the Israeli diet [10].

The study questionnaire includes demographic information, personal and family history of cancer and relevant diseases, education and health habits including smoking, alcohol consumption, physical activity, height and weight, reproductive history, hormonal and drug exposures and a detailed nutritional component. Total energy and fiber intake, dietary folate, calcium and vitamin D and other dietary components were calculated from the food frequency questionnaire.

Specifically for this study red meat was defined as unprocessed beef, lamb or pork meat, and processed meat was defined as meat that has been transformed through salting, curing, smoking, fermentation, or other processes and might contain red meat and/or poultry such as sausages, hotdogs, salami, and pastrami [11].

For this analysis we excluded 414 participant with excessive missing items in the FFQ (< 150 of the 178 requested items) and participants with implausibly low or high energy intake (<600 or >4000 kcal/day). We also excluded 221 non-Jewish/non-Arab participants.

Statistical analysis—Student *t* tests for continuous variable and chi-square tests for categorical variable were used to compare baseline characteristics between cases and controls and between Jews and Arabs. Logistic regression was used to assess the association between meat intake and CRC risk. Red meat consumption was both studied as a single entity and separately as beef, lamb or pork. Intake was tested as a continuous variable as well as quartiles of consumption and was compared to non-consumers according to the frequency of use of the various meat subtypes. Multivariate logistic regression models were adjusted for age, sex, BMI (<25, 25-30, >30 kg/m^2), first degree family history for CRC, smoking (never, former, current), education (≤12 years vs. >12 years), sports activity (yes vs. no), total energy intake, fibers, calcium, vitamin D, and folate intake, alcohol intake (any vs. none), vegetable consumption (≥ 3 vs. <3 serving/day), fruit consumption (≥ 3 vs. <3 serving/day), regular aspirin intake (daily low dose for at least 1 year), and intake of each meat subtype was mutually adjusted for the other meats intake.

For a limited period of time CRC cases were enrolled in the study without matched controls; as a result the number of cases is higher than the number of controls. Therefore an unconditional model was employed with matching variables (age, sex) included in the model and with stratification by ethnicity due to the major differences in consumption patterns between Jews and Arabs.

All statistical analyses were performed using SPSS Statistics package v. 23.0 (IBM, New York, NY). For all analyses, $P < 0.05$ for the 2-tailed tests was considered to be statistically significant.

Results

A total of 10,026 participants were included in the study. Of them 8,615 were Jews (4,615 cases and 4,000 controls), and 1,411 were Arabs (857 cases and 554 controls). The demographic, clinical and nutritional characteristics of cases and controls stratified by ethnic group (Jews and Arabs) are presented in Table 1.

Fresh red meat consumption, mostly of beef, was higher in Arab controls, with 3.0 ± 1.98 servings/week, than in Jewish controls with 1.29 ± 1.45 servings/week (P <0.001) (Table 2). Lamb consumption was also higher in Arab controls (0.90 ± 1.03 servings/week) than in Jews (0.06 ± 0.25) (P <0.001), and fresh pork consumption was extremely low in both groups. Processed meat was consumed significantly more frequently by Jewish controls (1.97 ± 2.97 servings/week) than by Arab controls (0.9 ± 1.56 servings/week) (P <0.001) (Table 2).

Red and processed meat intake and CRC risk in Jews

Using meat intake as a continuous variable; the adjusted OR for increase in one serving per week of all red meats was 1.05 (95% CI, 1.01-1.08). While the CRC risk was not elevated for beef consumption, OR=1.01 (0.97-1.05), it was significantly increased for lamb, OR=1.46 (1.20-1.79) and pork, OR=1.21 (1.07-1.35) and was very mild for one additional serving of processed meat (usually pork free), OR=1.02 (1.0-1.03) (Table 3).

Among Jews, 23.2% reported no intake of red meats and 32% reported no intake of processed meats at all, allowing us to compare non-consumers to consumers. The adjusted CRC risk for any red meat was 1.03 (95% CI, 0.93-1.16), and differed between beef intake OR=0.96 (0.86-1.07), lamb intake OR=1.28 (1.10-1.50), pork intake OR=1.44 (1.24-1.67), and processed meat OR=1.22 (1.10-1.35) (Table 4).

Assessing the association by comparing highest to lowest quartiles of meat intake yielded an OR=1.13 (95% CI, 0.98-1.31) for all red meat intake, OR=0.95 (0.82-1.11) for beef intake, and OR=1.21 (1.06-1.38) for processed meat intake (supplementary Table S1). The variance of lamb and pork intake was low among Jews; therefore classification into quartiles was not applicable (Table 2 and supplementary Table S1).

Red and processed meat intake and CRC Risk in Arabs

The adjusted risks for CRC of an increase of one serving/week of overall red meat consumption, beef consumption, lamb consumption or pork consumption were all not associated with significant increase in the Arab population in our study; OR=0.94 (95% CI, 0.88-1.01), OR=0.88 (0.81-0.96), OR= 1.02 (0.91-1.16), OR=1.15 (0.89-1.48), respectively. The risk associated with processed meat consumption was also not increased (OR=0.99 (0.91-1.07)) (Table 3).

Compared to no intake, the adjusted OR was 1.34 (95% CI, 0.69-2.62) for overall red meat intake, 0.94 (0.61-1.45) for beef, 1.01 (0.75-1.37) for lamb, 1.07 (0.73-1.56) for pork, and 1.04 (0.82-1.33) for processed meat (Table 4).

Assessing the association with quartiles of meat intake was applicable only for the total consumption of red meats, and for beef intake due to the low variance of the other red meat subtype intake among Arabs (Table 2 and supplementary Table S1). Compared to the lowest quartile of intake, the odds of CRC for those in the highest quartile was 0.69 (95% CI, 0.47-1.01) for overall red meats intake, and 0.65 (0.45-0.93) for beef intake (supplementary Table S1).

Tumor location

Anatomical sub-site data of CRC was available for 4392 (95.2%) Jewish cases and 805 (93.9%) CRC cases among Arabs. The risk estimates of red meats and processed meats consumption were similar for right colon, left colon and rectal tumors, among Jews and among Arabs. Lamb and pork consumption seem to have some stronger association specifically with the right colon, but none of the associations reached statistical significance (Table 5 and supplementary Table S2).

Discussion

Our study of the association between red and processed meat and colorectal cancer risk, conducted in a country with low overall meat consumption and minimal pork products consumption, demonstrates only weak associations with risk of CRC. Beef, pork, lamb, and processed meat consumption were examined independently, and there was no evidence of a meaningful association between beef consumption and risk of colorectal cancer, whereas modest risk was associated with lamb, pork, and processed meats.

Previous studies have shown conflicting results with regards to the association between red meat and processed meat intake and CRC risk ranging from no effect, positive association, and negative association [12-17]. Studies that examined red unprocessed and processed meats separately, detected stronger and more consistent associations between processed meat and CRC [10,17]. A consensus statement issued in 2007 by the WCRF and AICR concluded that red meat and processed meat are “convincing” risk factors for CRC [6]. The WCRF and AICR reconfirmed their recommendations in 2011 based on a meta-analysis that showed a significant association between red meat and CRC; RR=1.10 (95% CI, 1.00-1.21), and between processed meat intake and CRC; RR=1.17 (95% CI, 1.09-1.5), for the highest intake compared to the lowest intake [18]. However, a comprehensive meta-analysis published in 2015 showed that red meat had a weak and non-significant association with CRC; RR=1.05 (95% CI, 0.98-1.12) for the highest intake compared to the lowest intake [7]. The authors concluded that red meat intake does not appear to be an independent risk factor for CRC [7]. More recently, in October 2015, the International Agency for Research on Cancer (IARC) classified processed meat intake as Group I carcinogen and red meat intake as Group 2A (probable) carcinogen [10].

The EPIC study, similar to our finding, identified lamb and pork but not beef intake as significantly associated with CRC risk [15]. A Danish study, while finding no association between overall red meat intake and CRC risk, reported pork intake to be associated with increased risk of rectal cancer, lamb intake with increased risk of colon cancer, and beef intake with decreased risk of rectal cancer [12].

Cancers arising in the proximal colon, distal colon, and rectum arise from different embryonic tissue, and each has distinct clinical behavior and risk factor profiles, likely relating to important differences in molecular cancer pathways [16, 19]. Red meat and processed meat may have a different impact on the development of the various CRC sites [13,14,17,20]. We carefully examined risks of red meat consumption in our large, population-based study and found no significant differences by tumor location.

There may be subtle differences in risk estimates of red meat consumption in Jews and Arabs that are difficult to discern in our large population-based study. For example, among Arabs we observed a significant, modestly reduced odds ratio of 0.88 (95% CI, 0.81-0.96) for beef consumption in a fully adjusted model, whereas there was no association in Jews OR=1.01 (95% CI, 0.97-1.05). Whether these differences are meaningful is open to discussion, but what is clear is that there is no evidence of increased risk of colorectal cancer from beef consumption in any population in Israel.

Various compounds with carcinogenic potential could explain associations between meat and colon cancer, including heme iron, heterocyclic amines (HCAs), polycyclic aromatic hydrocarbons (PAHs), and nitrites and nitrates [13,21].

Our study has the strengths of its large size and the detailed information in a population-based set-up. This allowed us to analyze the differences by type of meat intake while controlling for many relevant potential confounders. However, due to the observational nature of the study we cannot exclude the possibility of residual confounding which given the weak associations identified may have a large impact on the effect estimate. Observational studies, by their nature, are susceptible to recall bias since cases may have reported past meat consumption differently than controls if meat was perceived to be risk factor for colorectal cancer. Measurement errors associated with FFQs could also lead to non-differential misclassification of respondent into dietary exposure categories, thereby attenuating risk estimates.

In summary, we identified only weak associations between overall red meat and processed meat intake and CRC risk in this low-consumption population, with evidence supporting the hypothesis that lamb and pork consumption, even at low levels may be more relevant as risk factors for colorectal cancer than beef.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1

Distribution of demographic, clinical, and nutritional characteristics in cases and controls stratified by ethnic group

Characteristic	Jews		Arabs	
	Cases (n=4,615)	*Controls (n=4,000)*	*Cases (n=857)*	*Controls (n=554)*
Age (years)	70.1 ± 11.5	71.7 ± 11.3	61.0 ± 13.2	64.0 ± 13.3 **
Sex				
Males	2429 (52.7%)	2089 (52.2%)	451 (52.7%)	300 (54.2%)
Females	2184 (47.3%)	1911 (47.8%)	404 (47.3%)	254 (45.8%)
Education				
≤ 12 years	2636 (57.4%)	2383 (59.6%)	754 (88.3%)	487 (88.1%) **
> 12 years	1959 (42.6%)	1613 (40.4%)	100 (11.7%)	66 (11.9%)
Sport activity				
Any	1440 (31.4%)	2089 (52.2%)	125 (14.6%)	88 (15.9%) **
Family history for CRC (1st degree relative)	630 (13.8%)	354 (8.9%)	128 (15.1%)	32 (5.8%) *
Body mass index (BMI)				
< 25 Kg/m^2	1404 (32.5%)	1378 (36.4%)	236 (28.9%)	172 (31.8%) *
25-30 Kg/m^2	1780 (41.2%)	1569 (41.4%)	329 (40.3%)	222 (41.0%)
≥ 30 Kg/m^2	1135 (26.3%)	842 (22.2%)	251 (30.8%)	147 (27.2%)
Smoking				
Never	2700 (58.8%)	2184 (54.6%)	523 (61.2%)	310 (56.1%) **
Former	1528 (33.3%)	1298 (32.5%)	192 (22.5%)	110 (19.9%)
Current	365 (7.9%)	515 (12.9%)	139 (16.3%)	133 (24.1%)
Alcohol consumption				
Any	1419 (31.0%)	1521 (38.1%)	128 (15.0%)	74 (13.4%) **
Aspirin use (daily low dose at least one year)	1048 (22.9%)	1352 (33.9%)	190 (22.2%)	174 (31.4%)
Vegetables consumption				
≥ 3 servings/wk	3547 (88.9%)	3983 (86.3%)	775 (90.4%)	515 (93.0%) *
Fruits consumption				
≥ 3 servings/wk	1499 (32.6%)	1611 (40.3%)	196 (23.0%)	129 (23.3%) **
Energy intake (Kcal/day)	1704 ± 561	1738 ± 517	1843 ± 581	1794 ± 576 **
Fibers intake (gr/day)	14.2 ± 6.3	15.6 ± 6.4	12.7 ± 5.3	13.3 ± 6.5 **

Characteristic	Jews		Arabs	
	Cases (n=4,615)	*Controls (n=4,000)*	*Cases (n=857)*	*Controls (n=554)*
Calcium intake (mg/day)	742 ± 313	757 ± 303	675 ± 278	649 ± 277**
Vitamin D intake (mcg/day)	2.8 ± 1.4	2.9 ± 1.5	2.7 ± 1.3	2.5 ± 1.4**
Folate intake (mcg/d)	263 ± 106	267 ± 101	278 ± 92	280 ± 96*

*P < 0.05 for comparison between Jewish controls and Arab controls

**P < 0.001 for comparison between Jewish controls and Arab controls

Table 2

Distribution of red meat and processed meat consumption in cases and controls stratified by ethnic group

	Jews		Arabs	
	Cases (n=4,615)	***Controls (n=4,000)***	***Cases (n=857)***	***Controls (n=554)***
Red meat (all types)				
Mean ± SD	1.43 ± 1.63	1.29 ± 1.45	2.94 ±2.07	3.00 ± 1.98 *
Median (IQR)	0.98 (0.49-1.96)	0.98 (0.49-1.96)	2.45 (1.47-3.99)	2.45 (1.47-3.99)
Beef				
Mean ± SD	1.22 ± 1.40	1.15 ± 1.30	1.87 ± 1.54	2.00 ± 1.62 *
Median (IQR)	0.98 (0.49-1.47)	0.98 (0-1.47)	1.47 (0.98-2.49)	1.47 (0.98-3.01)
Lamb				
Mean ± SD	0.09 ± 0.31	0.06 ± 0.25	0.94 ± 1.02	0.90 ± 1.03 *
Median (IQR)	0 (0-0)	0 (0-0)	0.49 (0.49-0.98)	0.49 (0.49-0.98)
Pork				
Mean ± SD	0.13 ± 0.47	0.09 ± 0.39	0.14 ± 0.51	0.11 ± 0.43
Median (IQR)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Processed meat				
Mean ± SD	2.20 ± 3.41	1.97 ± 2.97	0.96 ± 1.80	0.90 ± 1.56 *
Median (IQR)	0.98 (0-2.94)	0.98 (0-2.94)	0.49 (0-1.47)	0 (0-1.47)

* $P < 0.001$ for comparison between meat consumption in Jewish controls and Arab controls

Table 3

Crude, age adjusted and multivariate* odds ratios for the association between increase in one serving/week of red meat, red meat subtypes, and processed meats with the risk of colorectal cancer, stratified by ethnic group in Israel

Jews	**Crude OR†**	**Age adjusted OR†**	**Multivariate* adjusted OR†**
Red meat (all types)	1.06 (1.03-1.09)	1.05 (1.03-1.08)	1.05 (1.01-1.08)
Beef	1.04 (1.01-1.07)	0.99 (0.98-0.99)	1.01 (0.97-1.05)
Lamb	1.58 (1.32-1.88)	1.50 (1.26-1.79)	1.46 (1.20-1.79)
Pork	1.28 (1.14-1.42)	1.27 (1.14-1.42)	1.21 (1.07-1.35)
Processed meat	1.02 (1.01-1.04)	1.02 (1.01-1.04)	1.02 (1.0-1.03)
Arabs			
Red meat (all types)	0.99 (0.94-1.04)	0.98 (0.93-1.03)	0.94 (0.88-1.01)
Beef	0.95 (0.89-1.01)	0.93 (0.87-1.0)	0.88 (0.81-0.96)
Lamb	1.04 (0.93-1.15)	1.04 (0.93-1.15)	1.02 (0.91-1.16)
Pork	1.16 (0.91-1.47)	1.17 (0.92-1.49)	1.15 (0.89-1.48)
Processed meat	1.02 (0.96-1.09)	1.0 (0.94-1.07)	0.99 (0.91-1.07)

*adjusted for age, sex, BMI (<25, 25-30, >30 kg/m^2), family history for CRC (first degree relative), smoking (never, former, current), education (≤12 years vs. >12 years), sport activity (yes vs. no), total energy intake, fibers, calcium, vitamin D, and folate intake, alcohol intake (any vs. none), vegetables consumption (≥ 3 vs. <3 serving/day), fruit consumption (≥ 3 vs. <3 serving/day), regular aspirin intake (daily low dose for at least 1 year), and intake of each meat type was mutually adjusted for other meats intake

†OR for increase in one serving/week

Table 4

Crude, age adjusted and multivariate* odds ratios for the association of red meat, red meat subtypes, and processed meats with the risk of colorectal cancer stratified by ethnic group in Israel

Jews	Cases/controls	Crude OR†	Age adjusted OR†	Multivariate* adjusted OR†
Red meat (all)				
None	1020/977	Reference	Reference	Reference
Any	3595/3023	1.14 (1.03-1.26)	1.11 (1.0-1.23)	1.03 (0.92-1.16)
Beef				
None	1128/1049	Reference	Reference	Reference
Any	3487/2951	1.10 (1.0-1.21)	1.07 (0.97-1.18)	0.96 (0.86-1.07)
Lamb				
None	4019/3649	Reference	Reference	Reference
Any	594/349	1.55 (1.34-1.78)	1.47 (1.28-1.70)	1.28 (1.10-1.50)
Pork				
None	3934/3599	Reference	Reference	Reference
Any	672/397	1.55 (1.36-1.77)	1.54 (1.35-1.76)	1.44 (1.24-1.67)
Processed meat				
None	1364/1393	Reference	Reference	Reference
Any	3251/2607	1.27 (1.16-1.39)	1.25 (1.15-1.37)	1.22 (1.10-1.35)
Arabs				
Red meat (all)				
None	26/21	Reference	Reference	Reference
Any	831/533	1.26 (0.70-2.26)	1.26 (0.70-2.27)	1.34 (0.69-2.62)
Beef				
None	73/50	Reference	Reference	Reference
Any	784/503	1.07 (0.73-1.56)	1.01 (0.69-1.48)	0.94 (0.61-1.45)
Lamb				
None	170/109	Reference	Reference	Reference
Any	687/445	0.99 (0.76-1.30)	0.99 (0.75-1.29)	1.01 (0.75-1.37)
Pork				
None	747/489	Reference	Reference	Reference
Any	108/65	1.09 (0.78-1.51)	1.12 (0.81-1.56)	1.07 (0.73-1.56)
Processed meat				
None	419/290	Reference	Reference	Reference
Any	438/264	1.15 (0.93-1.42)	1.07 (0.86-1.33)	1.04 (0.82-1.33)

[*] adjusted for age, sex, BMI (<25, 25-30, >30 kg/m^2), family history for CRC (first degree relative), smoking (never, former, current), education (≤12 years vs. >12 years), sport activity (yes vs. no), total energy intake, fibers, calcium, vitamin D, and folate intake, alcohol intake (any vs. none), vegetables consumption (≥ 3 vs. <3 serving/day), fruit consumption (≥ 3 vs. <3 serving/day), regular aspirin intake (daily low dose for at least 1 year), and intake of each meat type was mutually adjusted for other meats intake

[†] OR for any consumption versus none

Table 5

Crude, age adjusted and multivariate* odds ratios for the association between increase in one serving/week of red meat, red meat subtypes, and processed meats with the risk of colorectal cancer stratified by ethnic group in Israel and by tumor site

Right colon			
Jews *# of cases 1510*	**Crude OR†**	**Age adjusted OR†**	**Multivariate* adjusted OR†**
Red meat (all types)	1.04 (1.0-1.09)	1.05 (1.01-1.09)	1.04 (0.99-1.09)
Beef	1.02 (0.97-1.06)	1.02 (0.98-1.07)	0.99 (0.94-1.05)
Lamb	1.54 (1.25-1.89)	1.60 (1.29-1.97)	1.75 (1.36-2.26)
Pork	1.19 (1.04-1.35)	1.19 (1.04-1.36)	1.15 (1.0-1.33)
Processed meat	1.02 (1.01-1.04)	1.03 (1.01-1.04)	1.01 (0.99-1.04)
Arabs *# of cases 224*			
Red meat (all types)	0.98 (0.91-1.06)	0.97 (0.90-1.05)	0.96 (0.87-1.06)
Beef	0.93 (0.84-1.03)	0.92 (0.83-1.02)	0.87 (0.76-0.99)
Lamb	1.06 (0.92-1.23)	1.06 (0.91-1.23)	1.09 (0.92-1.29)
Pork	1.21 (0.88-1.66)	1.21 (0.88-1.66)	1.23 (0.86-1.76)
Processed meat	0.97 (0.87-1.08)	0.96 (0.86-1.07)	0.98 (0.86-1.12)
Left colon			
Jews *# of cases 1858*	**Crude OR†**	**Age adjusted OR†**	**Multivariate* adjusted OR†**
Red meat (all types)	1.07 (1.03-1.10)	1.05 (1.02-1.09)	1.05 (1.01-1.10)
Beef	1.03 (0.99-1.08)	1.02 (0.98-1.07)	1.01 (0.96-1.06)
Lamb	1.42 (1.16-1.74)	1.34 (1.09-1.63)	1.30 (1.02-1.65)
Pork	1.34 (1.19-1.51)	1.35 (1.19-1.52)	1.26 (1.10-1.43)
Processed meat	1.03 (1.01-1.04)	1.03 (1.01-1.04)	1.02 (1.0-1.04)
Arabs *# of cases 339*			
Red meat (all types)	0.97 (0.91-1.04)	0.96 (0.90-1.03)	0.92 (0.84-1.01)
Beef	0.93 (0.85-1.02)	0.91 (0.83-1.0)	0.85 (0.75-0.95)
Lamb	1.04 (0.91-1.18)	1.04 (0.91-1.18)	1.03 (0.88-1.20)
Pork	1.12 (0.84-1.50)	1.13 (0.84-1.51)	1.15 (0.84-1.58)
Processed meat	1.02 (0.94-1.10)	0.99 (0.92-1.08)	0.96 (0.86-1.08)
Rectum			
Jews *# of cases 1024*	**Crude OR†**	**Age adjusted OR†**	**Multivariate* adjusted OR†**
Red meat (all types)	1.07 (1.02-1.12)	1.05 (1.01-1.10)	1.06 (1.0-1.11)
Beef	1.05 (1.0-1.11)	1.04 (0.98-1.09)	1.02 (0.96-1.09)
Lamb	1.54 (1.24-1.92)	1.43 (1.14-1.78)	1.55 (1.19-2.01)
Pork	1.18 (1.01-1.38)	1.17 (1.0-1.38)	1.10 (0.92-1.32)
Processed meat	1.02 (1.0-1.04)	1.02 (1.0-1.04)	1.01 (0.98-1.03)

Right colon			
Jews *# of cases 1510*	**Crude OR†**	**Age adjusted OR†**	**Multivariate* adjusted OR†**
Arabs *# of cases 242*			
Red meat (all types)	0.99 (0.92-1.07)	0.98 (0.91-1.05)	0.93 (0.84-1.02)
Beef	0.96 (0.88-1.06)	0.95 (0.86-1.04)	0.87 (0.77-0.99)
Lamb	1.01 (0.87-1.17)	1.0 (0.86-1.16)	1.01 (0.84-1.20)
Pork	1.18 (0.88-1.60)	1.21 (0.89-1.63)	1.11 (0.78-1.58)
Processed meat	1.07 (0.98-1.16)	1.04 (0.96-1.13)	1.05 (0.94-1.16)

*adjusted for age, sex, BMI (<25, 25-30, >30 kg/m^2), family history for CRC (first degree relative), smoking (never, former, current), education (≤12 years vs. >12 years), sport activity (yes vs. no), total energy intake, fibers, calcium, vitamin D, and folate intake, alcohol intake (any vs. none), vegetables consumption (≥ 3 vs. <3 serving/day), fruit consumption (≥ 3 vs. <3 serving/day), regular aspirin intake (daily low dose for at least 1 year), and intake of each meat type was mutually adjusted for other meats intake

†OR for increase in one serving/week