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Original Research

Do low-fat foods alter risk of colorectal cancer from processed meat?

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B S T R C T

Objectives: We investigated potential causes of the high incidence rate of colorectal cancer (CRC) in New Zealand.
Study design: A national population-based case-control study of 806 cases and 1025 controls was conducted to determine the risk factors for CRC in this population.
Methods: Information about family history of CRC, ethnicity, diet, school milk consumption, exercise, and height and weight at age 20 years were collected by a self-administered questionnaire from cases and controls.
Results: Response rates were 84 for cases and 65 for controls. Increasing preference for low-fat food alternatives was associated with reducing odds ratios (OR) for CRC (P_{trend} 0.001) with a considerably reduced OR of always versus never choosing low-fat food alternatives (OR 0.39, 95 con dence interval 0.26, 0.58). Increased consumption of dairy products or milk was associated with reduced risk of CRC. Belonging to the male gender, having a rst degree relative with CRC, and increasing consumption of processed meat, lamb, pork, and bread were associated with elevated risks of CRC. The increased risk from consumption of processed meat was not evident in subjects who regularly or always preferred low-fat food.
Conclusions: A preference for low-fat food may ameliorate an increased risk of CRC from the consumption of processed meat.

Introduction

New Zealand has very high incidence rates of colorectal cancer (CRC).[1] However, these rates vary considerably by generation. In those born from about 1940 to 1956 the age-speci c rates are up to 55 lower than those of earlier generations.[2,3] The change in risk between generations indicates that environmental factors acting during pregnancy, childhood, or adolescence are likely to be major determinants of risk of CRC in adulthood. Adenomas of the colon and rectum, precursors of CRC, begin to develop in young adulthood, their prevalence increases up to about 60 years of age,[4 7] and the risk of CRC is greatly reduced by their removal.[8 10] This suggests that factors affecting adenoma development in youth probably contribute to the generation-speci c risks of CRC observed, and adult exposures may be associated with promotion of adenoma to invasive carcinoma rather than the development of adenoma.

Adult obesity, height, consumption of processed meat, and alcohol have been found to be associated with an increased risk, whereas increased physical activity is found to be associated with a decreased risk of CRC.[11] In addition, adult consumption of whole-grain foods, high ber foods, dairy products, and calcium supplementation are associated with a decreased risk of CRC, and the consumption of red meat is associated with an increased risk of CRC.[11] The regular use of low-dose aspirin[12] has also been associated with a decreased risk of CRC. Calcium supplementation has been also shown to reduce the risk of adenoma in adults.[13,14]

Our previous study[3] focussed on exposures in childhood that could have altered the risk of CRC, but we were unable to separately assess adult risk factors. In that study, risk of CRC decreased with increased consumption of school milk.[3] This second national case-control study was conducted to assess the risk of CRC from both adult exposures and school milk consumption.

Methods

Case and control subjects aged 30 74 years were approached by post to give consent and complete a questionnaire. For non-

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responders, a second questionnaire was sent and, if no reply was received, the questionnaire was completed by telephone interview with trained interviewers. At the same time as our study, a bowel screening pilot for people aged 50 74 years was being conducted in the Waitemata District Health Board (WDHB) region. To minimise screening detection bias,[15] only those residing outside the WDHB region were included in the study.

Cases

The New Zealand Cancer Registry forwarded records of all 1121 New Zealand residents aged 30 74 years diagnosed with adenocarcinoma of the colon and rectum between November 1, 2013 and October 31, 2014. Patients were excluded if they had carcinoma of the appendix, no available histology report con rming adenocarcinoma of the colon or rectum, or for whom Cancer Registry records indicated a previous diagnosis of CRC. Approval to approach the patients was sought from their doctors.

Controls

The subjects were randomly selected from the electoral roll and invited to participate between July 2013 and November 2014. Electoral registration in New Zealand is compulsory and over 97 of adults aged 35 years or more are listed on the electoral roll.[16] Control subjects without CRC were asked the same questions about CRC risk factors as cases.

Data collection

A questionnaire was posted to subjects with a reply-paid envelope for its return. The questionnaire inquired about previous illnesses, family history of cancer, adult diet in the previous 12 or more months, vigorous exercise suf cient to cause breathlessness or an increased heart rate, smoking, alcohol consumption (available for only 61 of subjects), history of screening tests for CRC, school milk consumption, and sociodemographic characteristics. Information about school milk consumption was sought in the same manner as in our previous study.[3] The study hypotheses were not disclosed to participants.

De nition of terms

A positive family history of CRC was de ned as a self-report of a sibling or parent with CRC. Educational attainment was de ned as the highest quali cation gained and was categorised into ve categories (none, basic vocational, intermediate vocational, advanced vocational, and degree or diploma). Self-identi ed ethnicity was sought using the same question as the population census whereby people can select several ethnic groups. Each respondent was then categorised into one of four ethnic groups using the priority algorithm used by the Ministry of Health (Maori rst, then ‘Paci c people , ‘other , then New Zealand European ethnic groups).

Questions from a previous national nutrition survey about usual servings of meats, vegetables, fruit, dairy products, and bread were used to assess adult diet up to 12 months before invitation.[17] Thus only information about diet before diagnosis was sought. Daily servings of beef, lamb, pork, and processed meat were combined to estimate daily servings of red meat. As reporting a high number of servings of any particular food item might have been associated with a preference to report a high number of servings overall, adjustment of the results for the total number of servings across all foods was also undertaken.

The numbers of half-pint bottles consumed at school per week and the annual total amount of milk consumed (categorized into none, 1 to 799, 800 to 1199, 1200 to 1599, 1600 to 1799, and 1800 or more half-pint bottles per year [bottle-years]) were estimated from the reported number of half-pint bottles drunk per week and the age at starting and stopping school milk consumption. Subjects were also asked if they followed a special diet for religious reasons, allergies, diabetes, or vegetarianism and to specify any other dietary restrictions. The frequency of choosing low-fat food alternatives was also reported. Body mass index at age 20 years (BMI-20) was calculated and categorised into quintile ranges from self-reported height and weight at age 20 years.

Data on self-reported exercise (exercise that was vigorous enough to cause breathlessness or a faster heart rate) up to 12 months before invitation to participate were collected using questions from a previously validated questionnaire.[18,19] All analyses were also conducted separately for men and women and appreciable differences in the results were reported.

Statistical analysis

For exposures of interest with a population prevalence of 10 and true odds ratio (OR) for disease in exposed subjects relative to unexposed subjects of 1.5, a sample size of 807 patients with CRC and 1009 controls provided a probability (power) of 0.80 to reject the null hypothesis that this OR equals 1.[20] The mean time between diagnosis and case responses was subtracted from the date of completion of the control questionnaire. This created a reference date for controls comparable with the date of diagnosis of the cases. Age on this reference date was used for controls. ORs and con - dence intervals (CIs) were calculated using multivariable unconditional logistic regression.[21] The age at diagnosis for cases, or the age at the reference date for controls, was categorised into 5-year age-groups. Multivariable regression models included 5-year age-group, sex, ethnicity, family history of CRC, and residence in the Auckland District Health Board (ADHB) region. These are labeled the main effects in the analysis. Ordinal variables with many categories were tted as continuous variables to assess trends in OR by the level of exposure. A quadratic term was included if it improved model t.

For examination of rst degree interactions, exposures were coded into 3 categories, to avoid cells with few subjects, and assessed using the likelihood ratio test. When data for any variable in the regression model were missing, the record was excluded from the analysis. All *P*-values are 2 sided with values less than 0.05 indicative of statistical signi cance.

Results

Cancer Registry policy meant that information was provided to the study team three or more months after the patient's diagnosis. One-hundred and four patients died before the study team could contact them, and 13 had language dif culties that prevented participation. Twenty-seven cases were excluded after data collection because they had previous CRC or no longer resided in New Zealand. Of the remaining 956 eligible patients, 17 were too ill to participate, 120 were unable to be traced, 2 declined the invitation to participate, and for 11 their doctor declined permission.

Fifty-one controls were found to be living overseas, previously had CRC, or had language dif culties preventing their participation. A further 15 died before invitation. Of the 1590 eligible controls, 162 declined the invitation, 363 could not be traced, and 13 were too ill to participate.

Overall, 84 of eligible cases and 65 of eligible controls completed the questionnaire. Of these, 96 of cases and 94 of controls responded by mail, and 4 of cases and 6 of controls completed the questionnaire by telephone interview. The mean

time between diagnosis and case response was 6.3 months. After interview, one control was older than 74 years on their reference date and thus excluded. The responses of the 806 cases and 1025 controls were analyzed.

The median ages at the reference date for cases and controls were 66.2 years and 63.7 years, respectively.

The adjusted OR for CRC for women compared with men was 0.62 (95 CI 0.51, 0.76) (Table 1). People who reported a brother, sister, mother, or father with a diagnosis of CRC had an increased risk of CRC (OR 1.72, 95 CI 1.35, 2.20). Maori had a reduced OR and Paci c people an increased OR for CRC compared with New Zealand Europeans, but these ORs were not statistically signi cant. Residence in the ADHB region was associated with a statistically signi cant increase in the occurrence of CRC (OR 2.46, 95 CI 1.78, 3.40). For residents younger than 50 years of age in the ADHB region, that is, outside the age range for bowel screening, the adjusted OR for CRC was 1.79 (95 CI 0.66, 4.86) (data not shown). Greater postprimary education was associated with a decreased occurrence of CRC (P_{trend} 0.043), but this trend was not present among women (P_{trend} 0.638) (data not shown). No statistically signi cant associations were found between CRC and being born in New Zealand, or with a history of ulcerative colitis or Crohn disease.

Few people never consumed dairy products and, overall, decreasing ORs for CRC were found with increasing consumption of dairy products (P_{trend} 0.007), which excluded milk but included cheese, cream, sour cream, yoghurt, ice cream, and dairy-based dips (Table 2). Those reporting either no dairy consumption or the highest category of consumption showed lower ORs for CRC than those reporting intermediate levels of consumption. A statistically signi cant quadratic trend in ORs for CRC and categories of increasing dairy consumption was found ($P_{quadratic\ trend}$ 0.002). The overall and quadratic trends were similar for men and women but only statistically signi cant for men. Increasing consumption of milk was associated with a statistically signi cant linear reduction in ORs for CRC (P_{trend} 0.010), but no statistically signi cant change in risk of CRC was found with increasing cheese consumption.

In New Zealand, children start school on their 5th birthday, and historical records of participation in the school milk program indicate that about 88 of school children drank the school milk provided.[22] For respondents in our study starting school from 1942 to 1967, participation in school milk programs was 83 for cases and 80 for controls. For those starting school after the government milk-in-schools program ceased in 1967, participation was 15 for cases and 27 for controls. Eight-hundred and one cases (99.4) and 1021 controls (99.6) reported drinking milk at school. No statistically signi cant reduction in the occurrence of CRC from ever having drunk school milk (OR 0.98, 95 CI 0.76, 1.26) or bottle-years of consumption was observed.

There were statistically signi cant increases in the OR for CRC with increasing consumption of processed meat (P_{trend} 0.001) (Table 3) with a 25 (95 CI 12 , 39) increase for each category of increasing consumption (data not shown). However, this trend was not statistically signi cant for women (P_{trend} 0.168). Few participants consumed processed meat 7 or more times a week but this consumption was associated with a considerably increased risk of CRC (OR 8.57, 95 CI 2.50, 29.4). The association between risk of CRC and consumption of processed meat was not appreciably altered by adjustment for red meat consumption, total servings of food, BMI at age 20 years, or a history of vigorous exercise. Exclusion of vegetarians did not appreciably alter the results (data not shown). There was a 21 (95 CI 7 , 36) and a 14 (95 CI 1 , 28) increase in risk of CRC with increasing frequency of servings of lamb (P_{trend} 0.002) and pork (P_{trend} 0.036), respectively. No statistically signi cant overall increase in risk was found with consumption of beef, game, sh, or poultry, but an increased risk from an increased consumption of game (P_{trend} 0.049) and poultry (P_{trend} 0.011) was observed for women.

Increasing consumption of bread per week was associated with a statistically signi cant increase in the occurrence of CRC

Table 1
Odds ratios for characteristics of cases and controls.

Characteristics	Number of cases	Number of controls	Adjusted OR for colorectal cancer[a]	95 CI
Sex				
Male	467	481	1.00	
Female	339	544	0.62	0.51, 0.76
Family history of colorectal cancer				
No	616	865	1.00	
Yes	190	160	1.72	1.35, 2.20
Ethnicity				
NZ European	702	875	1.00	
Maori	55	80	0.87	0.60, 1.28
Paci c	16	14	1.10	0.50, 2.44
Other	33	56	0.69	0.43, 1.11
Resident in ADHB				
No	684	953	1.00	
Yes	122	72	2.46	1.78, 3.40
Education				
No post, primary school quali cation		214	231	1.00
Basic vocational quali cation	125	168	0.91	0.67, 1.24
Intermediate vocational quali cation	57	111	0.57	0.39, 0.85
Advanced vocational quali cation	266	318	0.87	0.67, 1.13
Degree or diploma	133	188	0.69	0.50, 0.94
Total	795	1016	Ptrend 0.043	
History of ulcerative colitis or Crohn disease				
No	787	1004	1.00	
Yes	19	21	1.12	0.58, 2.16
Born in New Zealand (NZ)				
No	142	195	1.00	
Yes	663	821	1.15	0.87, 1.51

CI, con dence interval; OR, odds ratio; ADHB, Auckland District Health Board; CRC, colerectal cancer.
[a] Adjusted, where appropriate, by 5-year age-group, sex, ethnicity, family history of CRC, and residence in the ADHB region in logistic regression.

Table 2
Association between CRC and milk, cheese, and dairy consumption.

Consumption of dietary items	Number of cases	Number of controls	Adjusted odds ratio for colorectal cancer[a]	95 CI
Dairy[b]				
Never	19	42	1.00	
1 per week	189	223	2.00	1.10, 3.64
1 2 per week	243	230	2.55	1.40, 4.63
3 4 per week	169	223	1.80	0.98, 3.28
5 6 per week	107	171	1.54	0.83, 2.85
7+ per week	76	135	1.34	0.71, 2.53
Total	803	1024	P_{trend} 0.007	
			$P_{quadratic\ trend}$ 0.002	
Milk[c]				
Never	103	105	1.00	
1 per week	132	136	0.99	0.68, 1.44
1 2 per week	121	158	0.80	0.55, 1.16
3 4 per week	118	151	0.77	0.52, 1.12
5 6 per week	116	174	0.65	0.45, 0.95
7+ per week	213	292	0.73	0.52, 1.03
Total	803	1016	P_{trend} 0.010	
Cheese[d]				
Never	35	25	1.00	
1 per week	91	94	0.79	0.42, 1.45
1 2 per week	270	160	1.33	0.75, 2.37
3 4 per week	271	173	1.22	0.68, 2.17
5 6 per week	101	89	0.82	0.44, 1.53
7+ per week	36	20	1.42	0.65, 3.12
Total	804	561	P_{trend} 0.674	
School milk				
No	205	238	1.00	
Yes	596	783	0.98	0.76, 1.26
Bottle-years of milk at school				
none	205	238	1.00	
1-799	98	188	0.72	0.51, 1.02
800-1199	95	141	0.86	0.60, 1.23
1200-1599	179	211	1.12	0.81, 1.53
1600-1799	86	107	0.92	0.62, 1.34
1800+	82	80	1.09	0.73, 1.64
Total	745	965	P_{trend} 0.262	

CI, con dence interval; OR, odds ratio; ADHB, Auckland District Health Board; CRC, colerectal cancer.
[a] Logistic regression with adjustment for 5-year age-group, sex, ethnicity, family history of CRC, and residing in the ADHB region.
[b] Excludes milk but includes cheese, cream cheese, cream, sour cream, yoghurt, ice cream, and dairy-based dips.
[c] Excludes soya milk.
[d] Cheese was an item added to the control questionnaire after recruitment began and includes cream cheese.

(P_{trend} 0.003) (Table 4). However, this trend was not statistically signi cant for women (P_{trend} 0.070). Both fruit consumption less than once per week and the highest category of consumption showed lower ORs for CRC than intermediate categories, and a statistically signi cant quadratic relationship ($P_{quadratic\ trend}$ 0.006) overall was observed. Fruit consumption 3 4 times per week, compared with less than once a week, had an adjusted OR of 1.50 (95 CI 0.95, 2.38). However, neither the trend (P_{trend} 0.792) nor the quadratic relationship ($P_{quadratic\ trend}$ 0.649) was statistically signi cant for women. The reduction in risk of CRC associated with increased servings of vegetables was not statistically signi cant. There was no statistically signi cant association between CRC and being vegetarian in the past 20 years (OR 1.04, 95 CI 0.62, 1.72) or at age 18 years (OR 1.05, 95 CI 0.42, 2.63) (data not shown). There was no statistically signi cant difference between cases and controls in total servings of food (OR 1.012, 95 CI 0.99, 1.03) (data not shown). The ORs associated with dietary items were not appreciably altered after additional adjustment for total servings of food, BMI at age 20 years, or level of education. Increasing frequency of choosing low-fat food showed a statistically signi cant reduction in risk of CRC (P_{trend} 0.001) (Table 4), and this was not appreciably altered with adjustment for BMI at age 20 years or a history of vigorous exercise.

Considerable effect modi cation from low-fat food preferences occurred for the risk of CRC associated with the consumption of processed meat (P 0.018). Using the single reference category of never or rarely choosing low-fat food and having less than one serving of processed meat a week, the effect modi cation is shown in Table 5. For those who regularly or always chose low-fat food, no dose-response effect on risk of CRC from increasing consumption of processed meat was observed. The dose-response relationship of the consumption of processed meat with risk of CRC was only statistically signi cant for those who never or rarely preferred low-fat food and was similar for men and women (men: P_{trend} 0.002; women: P_{trend} 0.031).

A history of frequent exercise resulting in breathlessness or an increased heart rate was associated with reduced risk of CRC (OR 0.64, 95 CI 0.52, 0.78). An increased risk of CRC was observed for current smokers (OR 1.27, 95 CI 1.04, 1.56) but not for past smokers (OR 0.96, 95 CI 0.65, 1.42). For the subjects for whom information about alcohol consumption was available, the risk of CRC for 'ever versus never consuming alcohol was not statistically signi cant (OR 1.27, 95 CI 0.72, 2.24). No trend in risk with increased consumption of alcohol was observed.

Discussion

This national population-based case-control study found increasing consumption of processed meat, lamb, pork, and bread, as well as a family history of CRC, belonging to the male gender, and residence in the ADHB region to be associated with an increased occurrence of CRC in New Zealand. The relationship of risk to

Table 3
Association between CRC and meat consumption.

Number of servings	Number of cases	Number of controls	Adjusted odds ratio for colorectal cancer[a]	95 CI
Processed meat				
Never	54	105	1.00	
1 per week	324	463	1.43	0.98, 2.08
1 2 per week	290	337	1.68	1.15, 2.47
3 4 per week	103	91	2.15	1.35, 3.40
5 6 per week	18	23	1.62	0.78, 3.39
7+ per week	14	4	8.57	2.50, 29.4
Total	803	1023	P_{trend} 0.001	
Lamb				
Never	54	93	1.00	
1 per week	255	381	1.21	0.82, 1.79
1 2 per week	393	442	1.57	1.07, 2.31
3 4 per week	82	96	1.45	0.91, 2.33
5+ per week	19	11	3.12	1.32, 7.37
Total	803	1023	P_{trend} 0.002	
Pork				
Never	59	91	1.00	
1 per week	344	475	1.10	0.76, 1.60
1 2 per week	330	378	1.36	0.93, 1.98
3 4 per week	55	60	1.42	0.85, 2.37
5+ per week	18	21	1.29	0.60, 2.75
Total	806	1025	P_{trend} 0.036	
Beef				
Never	25	46	1.00	
1 per week	69	113	1.28	0.70, 2.33
1 2 per week	347	434	1.65	0.96, 2.83
3 4 per week	286	335	1.76	1.02, 3.04
5 6 per week	64	82	1.46	0.78, 2.71
7+ per week	11	12	2.19	0.80, 5.99
Total	802	1022	P_{trend} 0.073	
Game				
Never	464	594	1.00	
1 per week	302	387	0.94	0.77, 1.16
1+ per week	40	44	1.17	0.74, 1.87
Total	806	1025	P_{trend} 0.987	
Poultry				
Never	35	41	1.00	
1 per week	125	163	0.90	0.53, 1.52
1 2 per week	454	585	0.89	0.55, 1.45
3 4 per week	163	207	0.92	0.55, 1.53
5 6 per week	19	23	0.83	0.37, 1.86
7+ per week	5	5	1.45	0.35, 5.95
Total	801	1024	P_{trend} 0.974	
Fish				
Never	25	36	1.00	
1 per week	221	311	1.08	0.61, 1.90
1 2 per week	468	534	1.30	0.75, 2.26
3 4 per week	70	116	0.92	0.49, 1.72
5+ per week	22	28	1.06	0.47, 2.38
Total	806	1025	P_{trend} 0.855	

CI, con dence interval; OR, odds ratio; ADHB, Auckland District Health Board; CRC, colerectal cancer.
[a] Logistic regression with adjustment for 5-year age-group, sex, ethnicity, family history of CRC, and residence in the ADHB region.

increased servings of processed meat, lamb, pork, and bread was more pronounced for men than women, while an increased risk of CRC was found with increased consumption of game or poultry for women. Adult milk consumption, consumption of dairy products, and choosing low-fat food alternatives, all were protective for CRC.

The study included all histologically con rmed cases of CRC in New Zealand over a prede ned time period. Cases came from the entire population through statutory noti cation of cancer by pathology laboratories. Response rates for both cases and controls were relatively high, minimising the possible effects of selection bias. Exposure information bias was avoided because neither participants nor telephone interviewers were told the hypotheses under study.

Historically, the ADHB region had lower than average incidence rates of CRC, so the increased OR for CRC for this region was unexpected. Increased detection of CRC by screening among those 50-74 years of age in the ADHB region may have occurred due to publicity surrounding the pilot bowel screening study of the same age group in the adjacent health board region. When the analysis was restricted to cases and controls younger than 50 years of age, the excess risk of CRC in residents of the ADHB was reduced. To minimise possible screening effects, adjustment for residence in the ADHB region, or otherwise, was included in all analyses.

Over decades, various aspects of diet have been associated with risk of CRC. The effects of individual food items, micronutrients, and types of diet have all been separately assessed. A protective effect from the consumption of fresh fruit and vegetables and increased physical exercise has been widely reported for many years, so we cannot exclude the possibility that some cases may have modi ed their behaviour since the onset of their illness[23] and reported current rather than past exposure. However, for the increased risk of CRC, we found that increased processed meat consumption,

Table 4
Risk of CRC from the consumption of bread, fruit, and vegetables and vegetarianism or choosing low-fat foods.

Number of servings or food preference	Number of cases	Number of controls	Adjusted odds ratio for CRC[a]	95 CI
Bread				
1 per day	74	160	1.00	
1 2 per day	327	419	1.53	1.10, 2.12
3 4 per day	304	345	1.68	1.20, 2.35
5 6 per day	82	82	1.80	1.16, 2.81
7+ per day	17	14	2.48	1.11, 5.53
Total	804	1020	P_{trend} 0.003	
Fruit				
1 per week	45	66	1.00	
1 2 per week	106	99	1.46	0.90, 2.39
3 4 per week	155	155	1.50	0.95, 2.38
5 6 per week	174	199	1.30	0.83, 2.05
7+ per week	325	505	1.02	0.67, 1.56
Total	805	1024	P_{trend} 0.052	
			$P_{quadratic\ trend}$ 0.006	
Vegetables per week[b]				
3 per week	9	24	1.00	
3 4 per week	10	64	0.28	0.09, 0.90
5 6 per week	31	146	0.39	0.15, 1.04
7+ per week	56	370	0.38	0.15, 0.96
Total	106	604	P_{trend} 0.336	
Vegetables per day[b]				
1 per day	30	20	1.00	
1 2 per day	297	165	1.05	0.57, 1.95
3 4 per day	235	142	1.09	0.58, 2.03
5 6 per day	74	48	0.94	0.47, 1.91
7+ per day	61	45	0.96	0.47, 1.96
Total	697	420	P_{trend} 0.686	
Vegetarian in past 20 years				
No	772	978	1.00	
Yes	32	39	1.04	0.62, 1.72
Total	804	1017		
Low-fat				
Never	141	131	1.00	
Rarely	139	122	1.02	0.72, 1.46
Sometimes	219	238	0.84	0.61, 1.15
Regularly	243	385	0.59	0.43, 0.79
Always	61	147	0.39	0.26, 0.58
Total	803	1023	P_{trend} 0.001	

CI, con dence interval; OR, odds ratio; ADHB, Auckland District Health Board; CRC, colerectal cancer.
[a] Logistic regression with adjustment for 5-year age-group, sex, ethnicity, family history of CRC, and residing in the ADHB region.
[b] After the study began categories of servings of vegetables were changed from weekly to daily, so some participants only recorded servings per week and others reported servings per day.

Table 5
Odds ratios[a] (95 CI) for effect modi cation of association of CRC with processed meat and low-fat food preference.

Low-fat preference	Number of servings of processed meat			
	1 per week	1-2 per week	3+ per week	Adjusted OR[b]
Both sexes				
Never or rarely	1.00[c]	1.71 (1.15, 2.54)	2.73 (1.60, 4.68)	1.00
Sometimes	1.01 (0.68, 1.49)	1.43 (0.94, 2.19)	1.46 (0.86, 2.49)	0.84 (0.64, 1.09)
Regularly or always	0.80 (0.57, 1.11)	0.69 (0.47, 1.01)	0.81 (0.47, 1.40)	0.55 (0.43, 0.69)
Adjusted OR[d]	1.00	1.20 (0.96, 1.49)	1.53 (1.13, 2.08)	
Men				
Never or rarely	1.00[c]	1.39 (0.83, 2.31)	2.84 (1.48, 5.45)	1.00
Sometimes	0.85 (0.48, 1.49)	1.21 (0.68, 2.14)	1.26 (0.64, 2.50)	0.75 (0.53, 1.06)
Regularly or always	0.62 (0.38, 1.02)	0.59 (0.35, 0.97)	0.94 (0.47, 1.88)	0.47 (0.35, 0.65)
Adjusted OR[d]	1.00	1.19 (0.88, 1.60)	1.87 (1.26, 2.76)	
Women				
Never or rarely	1.00[c]	2.56 (1.30, 4.97)	1.77 (0.57, 5.47)	1.00
Sometimes	1.21 (0.69, 2.13)	1.84 (0.96, 3.51)	1.71 (0.70, 4.17)	1.01 (0.67, 1.53)
Regularly or always	1.02 (0.63, 1.65)	0.85 (0.47, 1.54)	0.49 (0.18, 1.32)	0.67 (0.46, 0.97)
Adjusted OR[d]	1.00	1.28 (0.92, 1.77)	0.95 (0.59, 1.65)	

CI, con dence interval; OR, odds ratio; ADHB, Auckland District Health Board; CRC, colerectal cancer.
[a] Logistic regression with adjustment for 5-year age-group, sex when both sexes included, ethnicity, family history of CRC, and residing in the ADHB region.
[b] Adjusted for 5-year age-group, sex when both sexes included, ethnicity, family history of CRC, and residing in the ADHB region, and categories of servings of processed meat.
[c] Reference category.
[d] Adjusted for 5-year age-group, sex when both sexes included, ethnicity, family history of CRC, and residing in the ADHB region, and categories of low-fat preference.

various forms of red meat consumption, and the protective effect of increased milk consumption and vigorous exercise have also been identi ed in a meta-analysis of prospective studies.[24 26] The effect modi cation from low-fat food preferences on the dose-response relationship of processed meat consumption and CRC risk was unexpected. However, choosing low-fat foods may not represent a low-fat diet. Whether decreased consumption of fat inhibits an increased risk of CRC from the consumption of processed meat requires further investigation.

The microbial flora and the host reaction to it are a major influence on the chemical environment of the cellular lining of the colorectum, and many aspects of diet also influence the products of microbial fermentation, thus potentially influencing colorectal carcinogenesis. Advances in technology now enable more detailed examination of the carcinogenic potential of these interactions. If the microbiome is a key component in CRC risk and is appreciably changed by fat consumption, it is feasible that dietary risk may be influenced by fat consumption.[27]

As in this study, a meta-analysis of prospective studies has found the risk of CRC to be non-linearly related to fruit consumption.[28] The meta-analysis also found a non-linear association between vegetable consumption and risk of CRC; however, no statistically signi cant quadratic trend for vegetable consumption was found in our study. The linear association of increasing risk of CRC with increasing consumption of processed meat and various forms of red meat found in a meta-analysis of prospective studies[24] was also found in our study.

Our observed protective effect of milk and dairy consumption, but not cheese consumption, was consistent with a recent meta-analysis.[25] As in our earlier study,[3] the reported prevalence of school milk consumption matched historical records of participation, but in this study, school milk consumption was not associated with a reduced occurrence of CRC. Our observation of a statistically signi cant increasing occurrence of CRC with increasing bread consumption was similar in magnitude to a previous study.[29] Increasing consumption of dietary ber and whole grains is associated with a reduced risk of CRC.[30] In addition, while some heterogeneity between studies does exist, a meta-analysis of carbohydrate consumption in prospective studies did not nd a statistically signi cant increase in risk of CRC with increasing carbohydrate consumption.[31]

Overall, the results of our study were consistent with the results of meta-analyses of prospective and population-based case-control studies.[24 26,28,32] The results of the study will enable calculation of the proportional contribution of each dietary risk and protective factor to the incidence of CRC for men and women in New Zealand to improve the targeting and ef ciency of CRC health promotion and prevention activities, as well as the development of individual risk calculations for clinical use and targeted screening programmes. The multitude of risk and protective factors for CRC and their interactions suggests that country-speci c identi cation of their relative contribution to the incidence of CRC may be needed.

Author statements

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Ethical approval

All procedures involving research study participants were approved by the Health and Disability Ethics Committee of New Zealand. Written informed consent was obtained from all subjects/patients.

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Competing interests

The authors have no competing interests in this research.

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