

# Association between Diet-related Behaviour and Risk of Colorectal Cancer: A Scoping Review

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Individual dietary patterns may be influenced by diet-related behaviours, which may eventually play a significant role in contributing to colorectal cancer risk. As nearly half of colorectal cancer cases can be prevented through diet and lifestyle modification, in this study, we aimed to present an overview of the literature on diet-related behaviour and its effect on colorectal cancer risk among adults. Articles published from 2011 until July 2021 were selected. Out of the 1,198 articles retrieved, 25 were analyzed. There were 16 case-control studies, and nine of them were cohort studies. As a finding, the instruments used in this review were food frequency questionnaires (n = 23), followed by a semi-structured interview (n = 1), and diet records (n = 1). We demonstrated that unhealthy diet-related behaviours are linked to an increased risk of colorectal cancer in adults and those food frequency questionnaires or food records are common instruments used to collect diet-related behaviours. This article imparts the research trends and directions of colorectal cancer risk factors and shows that diet-related behaviour varies and changes over time.

**Key Words** Colorectal neoplasms, Feeding behavior, Cooking method, Eating

## INTRODUCTION

According to the World Health Organisation, cancer is the world's leading cause of death and is responsible for an estimated 10 million deaths in 2020 [1]. Cancer was responsible for approximately one in every six deaths globally. About 70% of cancer deaths occur in countries with low and medium incomes, and the mortality rate is also projected to increase in numbers by the year 2040 [2,3]. Colorectal cancer (CRC), which refers to both cancer of the colon and the rectum, is one of the most common types of cancer worldwide, accounting for 10% of worldwide cancer incidence with 9.4% cancer mortality [4]. Aside from dietary habits, other factors, such as age, lifestyle, and nutritional status, have a significant impact on the incidence of CRC [5,6].

CRC is thought to develop from colorectal adenoma, a benign and non-cancerous tumour that later progresses to become a precursor for the malignant and invasive form of adenocarcinoma; colorectal adenoma and sporadic CRC share common risk factors [7]. It may take many years for the progression from a non-cancerous form to a cancerous

one [8]. The formation of colorectal adenocarcinomas can be classified into three patterns: sporadic, hereditary, and familial [9]. The non-hereditary risk factors, such as dietary and lifestyle behaviours and exposure to environmental genotoxins, are linked to the onset of sporadic CRC. In contrast, hereditary and familial CRC are linked with inherited mutations of certain genes and their interaction with environmental risk factors [10].

Nowadays, the study of the risks of CRC is becoming an important research focus since most of the risk factors are modifiable and preventable [11]. Dietary habits and related behaviours can significantly alter nutrient composition, such as changes in patterns of energy, macronutrients, and micronutrients, which can lead to the development of some cancers [12]. The majority of studies on CRC risk factors have been conducted in Western countries, but studies in Malaysia are lacking and need to be explored more in depth. Local studies show that males having a high percentage of body fat, smoking, and having a history of cancer in the family, are inclined to have an increased risk of CRC [13].

In addition, high fat and calorie intake and red meat con-

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sumption exceeding 100 g per day increase the risk of colorectal adenoma [13]. The determination of dietary patterns is important to know because the nutrients from different types of foods consumed together will affect the individual's health. Compared to determining the intake of food types one by one, the determination of dietary patterns will provide a better quality and more comprehensive profiles of a diet [14]. Thus, dietary patterns should be determined and analysed to improve the ability to assess stronger effects as a result of the cumulative effects of nutritional characteristics and allow the evaluation of interactions between synergistic components [15].

It has previously been observed that the type of meat, cooking method, and temperature influence the amount and types of carcinogens [16]. Red meat intake and smoking are significantly associated with increased CRC risk [17]. The cooking process of meat can produce carcinogens, such as heterocyclic aromatic amines and polycyclic aromatic hydrocarbons. Similarly, processed meat products, such as cured and smoked meat, may also contain carcinogenic chemicals like N-nitroso compounds and polycyclic aromatic hydrocarbons formed through meat processing [18]. While the role of dietary patterns assessed by principal component analysis has also been increasingly evaluated, there is a paucity of data on food consumption behaviour. There are increasing reports suggesting that the need for diet-related behaviours could potentially lead to significant changes in limiting the risk of CRC. Obesity has been linked to increasing and varying snacking on unhealthy foods, cooking methods, meal frequency, and food type intake [19,20]. Due to the detrimental effects that poor dietary decisions have on general health, particular attention should be paid to these alterations as they may increase cardiometabolic risks [19,21]. Thus, in this review, we conducted a comprehensive analysis of food consumption behaviour considering meal frequency, food intake, and types of cooking methods.

## MATERIALS AND METHODS

This scoping review was conducted on diet-related behaviour and the risk of CRC among adults following Arksey and O'Malley's [22] framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines [23]. The five stages that were applied are described below.

### Identifying the research questions

As mentioned previously, the purpose of this study is to present an overview of the literature on diet-related behaviour among adults with CRC. The research question was identified to direct the review and determine the relevant studies. Thus, this scoping review was intended to answer the following research questions:

1. What are the instruments used to identify diet-related

behaviour among adults with CRC?

2. What diet-related behaviours are prominent due to their effect on CRC risk in adults?

## Identifying relevant studies

### 1) Search terms

Relevant studies published between January 2011 and July 2021 were identified for this scoping review. We intended to find evidence for five years; however, due to limited data, we expanded our search to ten years. The Population, Concept, and Context (PCC) in Table 1A below was used to guide at this stage based on the following mnemonic PCC, where the target population of this scoping review was adults with CRC and their diet-related behaviour. The MEDLINE Medical Subject Headings for key terms related to diet-related behaviour and CRC were carefully analyzed by two reviewers (NMABM and RS). Thus, these are the search terms used in this scoping review: ("Diet behaviour" OR "Food consumption" OR "meal timing" OR "dietary habit" OR "Dietary intake" OR "Diet" OR "Cooking methods") AND ("Behaviour" OR "habit" OR "Practices") for food consumption behaviour and ("Colorectal Cancer" OR "Colorectal neoplasm" OR "colon cancer" OR "rectal cancer" OR "bowel cancer").

The inclusion criteria for the articles were as follows: 1) full-text articles from peer-reviewed journals and 2) a retrospective study aimed at understanding diet-related behaviour in CRC patients. Retrospective studies were selected to determine the effect of their dietary behaviour before subjects were diagnosed with CRC. Studies were excluded if they did not fit into one of these categories. In addition, any review articles and all other secondary sources were excluded from the study to make sure that only analysis of primary data was performed.

### 2) Databases

Three databases were queried in this review: PubMed (EMBASE), Science Direct, and the Cochrane Database of Systematic Reviews. We believe that these three search databases would collect relevant journals in the field of interest. In summary, 1,471 articles were retrieved using the above keywords and databases.

### Study selection

With guidelines from PRISMA-ScR any duplicated titles were removed (n = 273), leading to 1,198 articles to be considered. After these articles were reviewed by NMAM and RS, about 1,173 of them were excluded due to the study population

**Table 1A.** Table of population, concept, and context

Population	Adults
Concept	Diet-related behaviour
Context/Outcome	Adults with colorectal cancer

**Table 1B.** Characteristics, instrument, and outcome of the selected studies

Author (year), country	Study design	Instrument	Objective	No. of participants, mean age	Outcomes
Joshi et al. (2015) [26], North America	Population-based case-control study	FFQ, retrospective	A comprehensive analysis of red meat and poultry consumption, considering cooking practices, estimated levels of heterocyclic amines, tumor location, and tumor molecular characteristics	3,364 CRC cases, 1,806 unaffected siblings, 136 unaffected spouses, and 1,620 unaffected population-based controls, aged 59.4 ± 11.4 yr	Positive association with CRC for pan-fried beefsteak, which was stronger among tumor mismatch repair proficiency deficient cases. A positive association between diets high in oven-broiled short ribs or spareribs and CRC risk and an inverse association with grilled hamburgers.
Tabatabaei et al. (2011) [25], Australia	Population-based case-control study	FFQ, retrospective	Investigated the association between meat consumption and cooking practices and the risk of CRC	567 incident CRC cases and 713 controls, aged 41–80 yr	The amount of red baked meat consumed had a statistically significant inverse trend of association with CRC. The protective trends for red pan-fried meat were also borderline statistically significant.
Khan et al. (2015) [41] Pakistan	Population-based case-control	Structured questionnaire, retrospective	To examine associations of dietary practices, addictive behavior and bowel habits in developing CRC among patients in a low-resource setup	74 CRC patients and 148 controls, aged 41.47 ± 15.47 yr	All the dietary practices showed protective effect for CRC except for high fat diet. Individuals consuming high fats diet had 98% higher risk of CRC as compared to those who avoid using such diets.
Angelo et al. (2016) [44] Brazil	Population-based case-control	Semi-quantitative FFQ (SQFFQ), retrospective	To investigate the role of the dietary pattern on the risk of SCA in Brazil	169 patients with SCA and 101 controls, aged 29–87 yr	Individuals with higher intakes of beef, chicken, and pork had a 1.025, 1.069, and 1.121-fold increased risk of SCA when compared with controls.
Ashmore et al. (2013) [39], Pennsylvania, US	Population-based case-control	FFQ, retrospective	To evaluate the role of dietary iron, heme iron, and supplemental iron on CRC risk	1,196 incident CRC cases and 1187 healthy controls of both sexes, aged 64.2 ± 11.6 yr	Consumption of more than 18 mg/day of supplemental iron may increase risk for CRC. No significant associations between heme iron or total iron intake and CRC incidence.
Bahrami et al. (2019) [36], Iran	Hospital-based case-control study	SQFFQ, retrospective	To examine the relationship between dietary polyphenols' classes and individual polyphenol subclasses and also the risk of CRC and CRA	129 colorectal cancers, 130 colorectal adenoma cases and 240 healthy controls, aged 30–79 yr	A higher intake of total polyphenols, total flavonoids, total phenolic acids anthocyanin and flavanols was related to the decreased risk of CRC. The higher consumption of stilbenes was also inversely associated with the risk of CRA.
Hullings et al. (2020) [54], US	Cohort study	FFQ, prospective	Evaluated associations of whole grain and dietary fiber intake with CRC risk in the large National Institutes of Health - American Association of Retired Persons Diet and Health Study	478,994 US adults, aged 50–71 yr	Intakes of whole grains and fiber from grains, but not total intake of dietary fiber, were inversely associated with CRC risk, particularly rectal cancer

Table 1B. Continued

Author (year), country	Study design	Instrument	Objective	No. of participants, mean age	Outcomes
Takachi et al. (2011) [43], Japan	Cohort study	FFQ, prospective	Examined associations between the consumption of red and processed meat and the risk of subsite-specific CRC by gender in a large Japanese cohort	80,658 men and women aged 45–74 yr	Potentially carcinogenic heterocyclic amines are formed when muscle meats such as beef, pork, or fish are cooked at high temperatures and are a possible mechanism of the association between red meat and colon cancer. Higher consumption of red meat was significantly associated with a higher risk of colon cancer among women, but no association was found between the consumption of processed meat and CRC risk.
Theodoratou et al. (2014) [40], Scotland	Case-control study	SQFFQ, retrospective	Investigated the relationship between CRC and demographic, lifestyle, food, and nutrient risk factors	2,062 patients and 2,776 controls, aged 16–79 yr	High-energy snack foods, eggs, fruit/vegetable juice, sugar-sweetened beverages and white fish (associated with an increased CRC risk) and NSAIDs, coffee and magnesium (associated with a decreased CRC risk).
Wang et al. (2013) [38], Japan	Community-based case-control study	FFQ, retrospective	To investigate the associations between dietary intake of polyphenols and CRC	816 cases of CRC and 815 community-based controls, aged 20–74 yr	There was no measurable difference in total or tea polyphenol intake between cases and controls, but intake of coffee polyphenols was lower in cases than in controls. Decreased risk of CRC associated with coffee consumption.
Zhang et al. (2020) [57], China	Case-control study	FFQ, retrospective	Investigated the association between these dietary intakes and the risk of CRC in Guangdong	2,380 patients with CRC and 2,389 sex- and age-matched controls, aged 30–75 yr	Inverse associations of dietary vitamin D, calcium, total dairy products, and milk intakes with the risk of CRC were independent of sex and cancer site. Protective effects of high dietary vitamin D, calcium, and dairy.
Zhong et al. (2013) [42], China	Case-control study	FFQ, retrospective	To examine the associations of total fat and fatty acid intakes with the risk of CRC in Guangzhou	489 CRC cases were frequency matched to 976 controls, aged 30–75 yr	Total fat, saturated fat, monounsaturated fat, and n-6 polyunsaturated fat intakes were not related to the risk of colorectal cancer. However, increased consumption of n-3 polyunsaturated fat might reduce the risk.
Xu et al. (2016) [37], China	Case-control study	FFQ, retrospective	To evaluate associations of flavonoids intake from different dietary sources with CRC risk in a Chinese population	1,632 eligible CRC cases and 1,632 frequency-matched controls, aged	Anthocyanidins, flavanones and flavones intakes from total diet were found to be inversely associated with CRC risk. Flavonoids from vegetables and fruits, may be linked with the reduced risk of colorectal cancer.

**Table 1B.** Continued

Author (year), country	Study design	Instrument	Objective	No. of participants, mean age	Outcomes
Vogtmann et al. (2013) [55], Shanghai	Cohort study	FFQ, prospective	To evaluate the association of fruit and vegetable consumption with the risk of CRC among Chinese men	61,274 male participants aged 40–74 yr	Fruit intake was generally inversely associated with the risk of colorectal cancer, whereas vegetable consumption was largely unrelated to risk among middle-aged and older Chinese men.
Sinha et al. (2012) [58], US	Cohort study	FFQ, prospective	Evaluated coffee and tea intakes (caffeinated and decaffeinated) in relation to colon (proximal and distal) and rectal cancers	489,706 men and women who completed a baseline, aged 50–71 yr	Coffee was inversely associated with colon cancer, particularly proximal tumours.
Perrigue et al. (2013) [28], US	Cohort study	FFQ, prospective	Association between eating frequency and CRC in a large, prospective cohort study, and explored whether this relationship was modified by sex, coffee consumption, or dietary glycaemic load	67,912 western Washington residents aged 50–76 yr	Weak inverse association observed between eating frequency and CRC is consistent with findings from other prospective studies. In age- and sex-adjusted models, eating frequency was inversely associated with CRC risk ( <i>P</i> trend = 0.001), with eating 4 or more times per day associated with a 28%–38% reduction in CRC risk compared with eating fewer than 3 times per day (HR for eating 4 times/d).
Michels et al. 2020 [34], US	Cohort study	FFQ, prospective	To examine the role of yogurt consumption on CRC incidence and mortality.	83,054 women and 43,269 men, aged 30–55 yr	Frequency of yogurt consumption was associated with a reduced risk of proximal colon cancer with a long latency period. No significant inverse trend was observed for CRC mortality.
Mekary et al. (2012) [29], US	Cohort study	FFQ, prospective	To examine association between eating frequency and colorectal cancer	34,968 US men, aged 40–75 yr	There was an implied protective association between increased eating frequency of healthy meals and CRC risk and in men with factors associated with higher insulin sensitivity.
Lee et al. (2017) [56], Korea	Case-control study	SQFFQ, retrospective	To investigate the relationship between the colors of vegetables and fruits and the risk of CRC in Korea.	923 CRC patients and 1,846 controls	High total intake of vegetables and fruits was strongly associated with a reduced risk of CRC in women and a similar inverse association was observed for men.
Kontou et al. (2013) [30], Greece	Case-control study	FFQ, retrospective	To investigate the association between dietary behaviours and CRC in the context of the Mediterranean diet.	250 cases with newly diagnosed CRC 63 ± 12 and 250 controls	The higher the daily number of meals, the lower the likelihood of having CRC, coffee drinking was associated with higher likelihood of having CRC, the use of non-stick cookware was positively associated with CRC.

Table 1B. Continued

Author (year), country	Study design	Instrument	Objective	No. of participants, mean age	Outcomes
Abu Mweis et al. (2015) [33], Jordan	Case-control study	FFQ, retrospective	Examining the association between food groups (including grains, fruits, vegetables, milk, meat, and legumes) and CRC risk in Jordan.	CRC patients (n = 167) and matched controls (n = 240)	Direct associations were found for grains, white bread, and chicken, whereas an inverse relation was reported for whole bread.
Kim et al. (2019) [35], Korea	Case-control study	SQFFQ, retrospective	Examined whether increased green tea intake was associated with a decreased risk of CRC and how the risk of CRC was altered by the protective effect of green tea consumption and five health-related factors	2,742 participants (922 cases, 56.6 ± 9.7 yr and 1,820 controls, 56.1 ± 9.1 yr)	High green tea consumption was associated with a decreased risk of CRC, with or without considering lifestyle factors. However, moderate green tea consumption increased the risk of CRC among ever-smokers, ever-drinkers, and the high-inflammatory diet group. Increased consumption of green tea might be helpful to reduce the risk of CRC in those with an unhealthy lifestyle.
de Batlle et al. (2018) [27], Spain	Multicase-control study	FFQ, retrospective	To investigate the association between meat consumption and cooking practices and the risk of CRC in a population-based case-control study	1,671 CRC cases, 67 ± 11 and 3,095 controls, 63 ± 12 yr	Rare-cooked red and total meat preference is associated with low risk of CRC among meat consumers. Griddle-grilling and barbecuing meat could be associated with increased CRC risk and stewing, and oven-baking could increase the risk of white, but not red, meat.
Bakken et al. (2018) [32], Norway	Cohort study	FFQ, prospective	To examine the association between milk intake and risk of CRC, colon cancer and rectal cancer among women	81,675 women	Weak inverse association between milk intake and risk of colon cancer among women.
Bakken et al. (2016) [31], Norway	Cohort study	FFQ, prospective	To investigate the association between whole-grain bread consumption and CRC incidence among Norwegian women	78,254 women	No association between whole-grain bread consumption and CRC was found among the women in the Norwegian Women and Cancer Study.

CRA, colorectal adenomas; CRC, colorectal cancer; FFQ, food frequency questionnaires; SQFFQ, Semi-quantitative FFQ; SCA, sporadic colorectal adenocarcinoma; US, United States.

involving animals, in vitro or in vivo studies, bioactive components, and an irrelevant population. Only 25 articles were finally included in the review. The methodological quality of individual studies was not conducted, as this is not a compulsory step in scoping reviews [24].

### Charting the Data

At this stage, all of the selected data extracted from the journal databases were organised in Microsoft Excel. The extracted data include the author(s), publication year, country, study design, objectives, type of instrument used, and the findings. We presented the data in four separate tables under

the results section of this review.

### Collating, summarising, and reporting results

Under Arksey and O'Malley's [22] framework, the last stage was to categorise the relevant findings based on the research questions and focus on diet-related behaviour among adults with CRC. The flow diagram for this scoping review has been summarised in Appendix 1.



## RESULTS

### Characteristics of the selected studies

Following Arksey and O'Malley's [22] framework and the inclusion criteria outlined above, the literature search found 25 relevant studies (Table 1B). As mentioned in the methods section, the study on food consumption behaviour and the incidence of CRC was still limited, which led to extending the scope of the target population. The sample size of participants involved ranged from 222 to 478,994. Meanwhile, the age range of participants was between 16 and 87 years old. The studies comprised nine cohort studies and 16 case-control studies. Among the 25 articles, seven were from the United States, four were from China, two each from Japan, Korea, and Norway, and one each from Australia, Pakistan, Brazil, Iran, Scotland, Greece, Spain, and Jordan. All the studies recruited participants from hospital and community-based settings.

### Instruments used to identify diet-related behaviour

Most of the studies used a food frequency questionnaire (FFQ) (n = 23); two used a semi-quantitative food frequency questionnaire, and one used a structured questionnaire (Table 1B). All the information on dietary intake was collected via questionnaire, and 16 studies were retrospective, while nine were prospective. The settings of these studies included hospital-based and community populations. Some articles studied a single type of dietary intake, while others tackled multiple dietary intakes and types of cooking methods.

Studying diet-related behaviour and the incidence of CRC requires reliable and valid methods for the assessment of diet-related behaviour. Nineteen of the reported questionnaires dealt with food frequency, five were semi-quantitative, and one was structured. The purpose of most dietary methods was to obtain information on nutrient intake, although some were also concerned with information about food groups

**Table 2.** Outcome of cooking method and association with risk of CRC

Diet-related behaviour	Author (year), country	Instrument	Association	Outcomes
Cooking method	Takachi et al. (2011) [43], Japan	FFQ, prospective	Positive	Cooking muscle meat at high temperature
	Joshi et al. (2015) [26], North America	FFQ, retrospective		Pan-fried beefsteak/sausage/spam/ham
	de Batlle et al. (2018) [27], Spain	FFQ, retrospective		Oven-broiled short ribs or spareribs Griddle-grilled/barbecued meat was associated with an increased CRC risk Rare-cooked meat preference was associated with low risk of CRC in red and total meat Stewing and oven-baking of white meat were associated with increased CRC risk
	Joshi et al. (2015) [26], North America	FFQ, retrospective	Inverse association	Higher frequency of grilled/barbecued hamburgers
	Tabatabaei et al. (2011) [25], Australia	FFQ, retrospective	No association	No association for red baked meat and red pan-fried meat

CRC, colorectal cancer; FFQ, food frequency questionnaires.

**Table 3.** Outcome of meal frequency and association with risk of CRC

Diet-related behaviour	Author, (year), country	Instrument	Association	Outcomes
Meal frequency	Perrigue et al. (2013) [28], US	FFQ, prospective	Inverse association	Higher eating frequency was associated with statistically significantly lower risk for colon cancer
	Mekary et al. (2012) [29], US	FFQ, prospective		Higher eating frequency among participants who had high insulin sensitivity, were physically active, and were lean (body mass index < 25)
	Kontou et al. (2013) [30], Greece	FFQ, retrospective		Higher the daily number of meals, the lower the likelihood of having CRC
	Mekary et al. (2012) [29], US	FFQ, prospective	No association	Highest eating frequency category (5–8 times/d) with the reference category (3 times/d), the authors found no evidence of an increased risk of CRC

FFQ, food frequency questionnaires; US, United States; CRC, colorectal cancer.

or specific food items. In few instances, the dietary method was concerned only with collecting data on food groups or items. Some used a semi-quantitative questionnaire to grasp a better idea of diet-related behaviour, as the FFQ may not capture it.

### Diet-related behaviour

This review identified three different diet-related behaviours in these studies. They include (a) cooking methods (Table 2), (b) meal frequency (Table 3), and (c) food intake (Table 4). Three studies investigate the type of cooking method that increases the risk of CRC among adults. The majority of participants preferred barbecued meat, followed by pan-fried meat, and microwaved meat was the least preferred [25]. However, Joshi et al. [26] reported that pan-fried beefsteak, sausage, spam, ham, or bacon (especially among tumour mismatch repair proficiency) and a diet high in oven-broiled short ribs or spareribs had a strong positive association with the risk of CRC. Apparently, those who preferred their hamburgers well-done or very well-done had a 27% higher chance of developing CRC (95% confidence interval, 0.95–1.69) than those who preferred their hamburgers rare or medium-done, but none of these differences were significant [25]. Interestingly, a preference for rare-cooked meat was associated with a lower risk of CRC in both red and total meat [27].

Two cohort studies focused on the association between meal frequency and the CRC risk [28,29]. One study found that eating four or more times a day lowered the CRC risk by 28 to 38% as compared to eating fewer than three times a day [30]. This was supported by Kontou et al. [30]: the higher the daily meal frequency, the lower the likelihood of having CRC after adjusting for age, sex, body mass index (BMI), physical activity status, smoking habits, and family history of CRC. In contrast, a study conducted by Mekary et al. [29] believed that an increase in meal frequency, increased snack frequency, or breakfast pattern had no association with the incidence of CRC. There was no evidence of an increased risk of CRC when the highest meal frequency (6–8 times a day) was compared with the reference category of three times a day [29].

It has been reported that dietary vitamin D, calcium-rich dairy products, whole grains, and fibre were shown to be protective against CRC risk [31–34]. A case-control study conducted in Korea reported an association between green tea intake and the risk of CRC [35]. According to this study, moderate green tea intake elevated the risk of CRC; however, the risk was reduced when a higher amount of green tea was consumed [35]. Polyphenols are mostly found in a wide variety of plants, food, and beverages including green tea, and their protective effect on CRC risk is related to their antioxidant, anti-atherosclerotic, anti-inflammatory, and anti-cancer properties [36–38]. Furthermore, Ashmore et al. [39] discovered that a supplemental iron intake of more than 18 mg/d may increase the risk for CRC in a study on the associ-

ation of dietary and supplemental iron and CRC. However, no significant associations were observed for dietary iron, total iron, or heme iron intakes.

Aside from sugar-sweetened beverages, poor dietary behaviour indicated by high-energy snacks food, which is defined as high-sugar foods, including pudding and desserts; chocolates, nuts, and crisps; and biscuits, cakes, and high-fat foods, was positively associated with the risk of CRC [40,41]. Meanwhile, Theodoratou et al. [40] also found that individuals with a high BMI were associated with an increased CRC risk, even when consuming a high intake of fruit or vegetable juices (fresh or ready-to-drink juice). As for total fat and fatty acid intakes, [42] suggested that total fat, saturated fat, monounsaturated fat, and n-6 polyunsaturated fat intakes were not related to the risk of CRC. However, increased consumption of n-3 polyunsaturated fat might reduce the risk.

## DISCUSSION

Most of the articles reported a positive association between cooking methods and the risk of CRC. The current study found that cooking at high temperatures and long exposure to heat will result in the formation of a genotoxic agent, such as heterocyclic amines and polycyclic aromatic hydrocarbons, which are related to CRC formation. Therefore, cooking methods like grilling, barbecuing, pan-frying muscle meat, or cooking over a direct flame were found to have a positive association with CRC [27,28,43]. Takachi et al. [43] explained that meats like beef, pork [44], and fish produced carcinogens like heterocyclic amines when cooked at a high temperature, which relates to the possible mechanism associated with CRC. Tabatabaei et al. [25] agreed that relatively high temperatures affected mutagenic activity when they studied cooking methods and the level of doneness that can influence the content of by-products in meat.

Minimal studies have looked at the association between meal frequency and quality and the risk of CRC. Two studies have shown that higher meal frequency was associated with lower colon cancer risk among subjects with higher insulin sensitivity, a higher physical activity level, and a BMI below 25 kg/m<sup>2</sup> [28,29]. According to Kontou et al. [30], the higher the number of meals daily, the lower the likelihood of having CRC, because frequent meals have been linked with a better lifestyle and diet as well as better blood sugar control, whereas a lower number of meals (< 3 times daily) were associated with elevated visceral fat and insulin resistance, an increase in alcohol consumption, and lower leisure physical activity [45,46].

These current findings are in contrast to previous case-control studies where a positive association was seen between meal frequency and CRC risk [47,48]. In this review, we discovered a limitation in terms of meal frequency, where it is solely measured in how many meals per day participants consume, and not all studies consider whether it is a



**Table 4.** Outcome of type of food intake and association with risk of CRC

Diet-related behaviour	Author, (year) country	Instrument	Association	Outcomes
Polyphenols	Bahrami et al. (2019) [36], Iran	SQFFQ, retrospective	Inverse association	Higher intake total polyphenols, total flavonoids, total phenolic acids anthocyanin and flavanols
	Xu et al. (2016) [37], China	FFQ, retrospective.		All subclasses of flavonoids from vegetables and fruits
	Wang et al. (2013) [38], Japan	FFQ, retrospective	No association	Tea polyphenols and non-coffee polyphenols
	Xu et al. (2016) [37], China	FFQ, retrospective.		Tea flavonoids
Coffee	Kontou et al. (2013) [30], Greece	FFQ, retrospective	Positive association	Coffee drinking was associated with higher likelihood of having CRC
	Sinha et al. (2012) [58] US	FFQ, prospective	Inverse association	> 4 cups coffee lower risk of CRC
Green tea	Kim et al. (2019) [35], Korea	SQFFQ, retrospective	Positive association	Moderate green tea consumption increased the risk of CRC among ever-smokers, ever-drinkers, and the high-inflammatory diet group
			Inverse association	Increased consumption of green tea might be helpful to reduce the risk of CRC
Meat	Angelo et al. (2016) Brazil [44]	SQFFQ, retrospective	Positive association	Higher intake of chicken, beef, and pork
	Abu Mweis et al. (2015) [33], Jordan	FFQ, retrospective		Higher frequency of consumption of chicken
Supplement	Ashmore et al. (2013) [39], US	FFQ, retrospective	Positive association	More than 18 mg/d of supplemental iron
			Inversely associated	Dietary iron intake was inversely associated with CRC among women
Whole grains	Hullings et al. (2020) [54], US	FFQ, prospective	Inversely associated	High intakes of whole grains and fiber from grains, particularly rectal cancer
	Abu Mweis et al. (2015) [33], Jordan	FFQ, retrospective		Whole grains bread
	Bakken et al. (2018) [32], Norway	FFQ, prospective	No association	Whole-grain bread consumption and CRC
Fiber	Vogtmann et al. (2013) [55], Shanghai	FFQ, prospective	Inversely associated	Fruit intake was generally inversely associated with the risk of CRC
	Lee et al. (2017) [56], Korea	SQFFQ, retrospective		High total intake of vegetables and fruits
	Vogtmann et al. (2013) [55], Shanghai	FFQ, prospective	No association	Vegetable consumption was largely unrelated to risk among middle-aged and older Chinese men
High-energy snack foods	Theodoratou et al. (2014) [40], Scotland	SQFFQ, retrospective	Positive association	High-fat and high-sugar foods, including pudding and deserts; chocolates, nuts and cakes crisps; and biscuits
Beverages	Theodoratou et al. (2014) [40], Scotland	SQFFQ, retrospective	Positive association	High sugar sweetened beverages. High intake fruit/vegetable juices was associated with an increased CRC risk only in the high body mass index group
Dietary vitamin D, calcium, and dairy products	Zhang et al. (2020) [57], China	FFQ, retrospective	Inversely associated	Dietary vitamin D, calcium, total dairy products, and milk
	Bakken et al. (2018) [32], Norway	FFQ, prospective		Weak inverse association between milk intake and risk of colon cancer among women
Fat	Zhong et al. (2013) [42], China	FFQ, retrospective	No association	Total fat, saturated fat, monounsaturated fat, and n-6 polyunsaturated fat
Omega 3	Zhong et al. (2013) [42], China	FFQ, retrospective	Inversely associated	Increased consumption of n-3 polyunsaturated fat

FFQ, food frequency questionnaires; SQFFQ, Semi-quantitative FFQ; US, United States; CRC, colorectal cancer.

healthy balanced diet or vice versa. It is more practical and relevant to record the types of meals, nutrients, and portion sizes compared to meal frequency alone [49]. These findings should be interpreted with caution because our bodies' mechanisms interact differently with increasing or decreasing meal frequency, as it involves the concentration of bile acids secretions, serum glucose, and insulin levels, which may have a negative effect on cancer growth [50,51].

According to the World Cancer Research Fund, grains and their products, poultry, coffee, tea, omega-3 fatty acids, shellfish, and other seafood have limited to no conclusive evidence with regards to association with cancer [52]. Furthermore, consuming whole grains, dietary fibre, and dairy products is strongly associated with decreasing the risk of CRC [52]. A meta-analysis revealed a nonlinear inverse relationship between fruit and vegetable consumption and CRC [53]. Following the present results, previous studies have demonstrated an inverse to no association when examining whole grains, fibre, polyphenols, dietary vitamin D, calcium, and dairy products [32,33,35,54-58].

In a recent survey by the National Health and Morbidity Survey 2019, 95% of adults in Malaysia do not meet the recommended number of servings of fruits and vegetables a day and are taking less than that requirement. It is important to meet fruit and vegetable requirements as it will also provide therapeutic effects from natural compounds like polyphenols and aid in the prevention of diseases [59]. Polyphenols from natural sources are found to have a protective effect on cells against oxidative stress [60]. Some examples of foods and food materials that contain polyphenols include cereals and legumes (barley, corn, nuts, oats, rice, sorghum, wheat, beans, and pulses), oilseeds (rapeseed, canola, flaxseed, and olive seeds), fruits and vegetables, and beverages (fruit juices, tea, coffee, cocoa, beer, and wine) [61].

We included a range of diet-related behaviours (e.g., cooking methods, meal frequency, and food intake), which provided an opportunity to assess the effect of this factor on the risk of CRC. Some limitations need to be clarified in this review. Despite the fact that most studies used validated and reliable food frequency questionnaires or dietary intake questions, dietary intake was assessed using self- or parent-report, which was susceptible to measurement error and thus may have influenced the results. Researchers must look at the molecular level to dig into what diet-related behaviours cannot capture the risk of CRC in order to come up with more precise results for a dietary pattern guideline [62]. In terms of study design, some of the cohort and case-control studies included in the review were only conducted from 2011 until 2021 and may be subjected to selection bias and recall bias depending on the length of follow-up, sample size, and studied region.

We have shown in the present review that instruments used to collect diet-related behaviours are food frequency questionnaires or food records, and unhealthy diet-related behaviours are associated with an increased risk of CRC in

adults. Therefore, this article can be applied not only to CRC but also to case studies of cancer, and it is suitable to provide readers with wide-ranging information. Diet-related behaviour alone is not enough. Thus, biological markers seem to be substantial and can contribute greatly to the prediction of CRC.

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## CONFLICTS OF INTEREST

No potential conflicts of interest were disclosed.

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## APPENDIX

Appendix 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Review (PRISMA-ScR) flow diagram for new perspective on diet-related behavior and risk of colorectal cancer.

