RESEARCH ARTICLE

Dietary Patterns and Risk of Colorectal Cancer: A Systematic Review of Cohort Studies (2000-2011)

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Abstract

Objectives: This systematic review of cohort studies aimed to identify any association between specific dietary patterns and risk of colorectal cancer (CRC). Dietary patterns involve complex interactions of food and nutrients summarizing the total diet or key aspects of the diet for a population under study. **Methods and materials:** This review involves 6 cohort studies of dietary patterns and their association with colorectal cancer. An exploratory or *a posteriori* approach and a hypothesis-oriented or *a priori* approach were employed to identify dietary patterns. **Results:** The dietary pattern identified to be protective against CRC was healthy, prudent, fruits and vegetables, fat reduced/diet foods, vegetables/fish/poultry, fruit/wholegrain/dairy, healthy eating index 2005, alternate healthy eating index, Mediterranean score and recommended food score. An elevated risk of CRC was associated with Western diet, pork processed meat, potatoes, traditional meat eating, and refined grain pattern. **Conclusion:** The Western dietary pattern which mainly consists of red and processed meat and refined grains is associated with an elevated risk of development of CRC. Protective factors against CRC include a healthy or prudent diet, consisting of vegetables, fruits, fish and poultry.

Keywords: Systematic review - colorectal cancer - dietary pattern analysis - Western and healthy

Introduction

Colorectal cancer (CRC) is a multifactorial disease. CRC is the fourth most common form of cancer occurring worldwide. Colorectal cancer is more prevalent in North America, Argentina, Australia, New Zealand and parts of Europe, Japan, and Israel, and for this reason is commonly regarded as a western life-style disease. Although incidence and mortality are higher in western countries, yet majority of the world's cases of colorectal cancer occur outside of countries in which traditional western life-styles are dominant. The profile varies greatly in different populations, and the evidence suggests that this variation is mainly a consequence of different life-style and environmental factors, which should be amenable to preventive interventions. World population growth and ageing imply a progressive increase in the cancer burden; 15 million new cases and about 10 million new deaths are expected in 2020, even if current rates remain unchanged (Ganesh et al., 2009).

Dietary pattern can be defined as combinations of dietary components (food items, food groups, nutrients, or both) intended to summarize the total diet or the key aspects of the diet for the population under study (Randi et al., 2010). A dietary pattern approach may provide additional insights that take into account the combined effects of foods. People eat meals consisting of a variety of foods with complex combinations of nutrients, not isolated nutrients. Because of the complexity of diet, the traditional approach with a single nutrient may potentially be confounded by the interactions between food components that are likely to be interactive or synergistic. The overall dietary pattern that reflects many simultaneous dietary exposures may be an important complementary approach for elucidating relationships between diet and health (Kim et al., 2005). It is hoped that dietary pattern approach could capture the totality of dietary experience, including all the nutrient interactions, in a manner that studies of single nutrient or of individual foods cannot (Flood et al., 2008). This review aims to summarize the available information on the association between dietary pattern and the risk of CRC.

Materials and Methods

Study selection

An electronic literature search was conducted using an Ovid Medline. The literature search was restricted to human studies written in English language for the period of 2000 until 2011. The keywords or phrases used during the literature search were dietary pattern, dietary habit, diet, colorectal cancer, factor analysis and principal component analysis. References cited in certain papers and reviews were used to identify additional articles.

The following information was documented for each study listed in the review: authors of the study, location, outcome of the study, study design (cohort studies only), study population (number of cases, number of total

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subjects or controls, age range, years of follow-up), year of data collection, dietary pattern identified in each study, methods (principal component analysis, factor analysis, diet scores), and the name and composition of dietary pattern identified. The main results reported in tables (Table 2 and Table 3) for each of the study reviewed.

Dietary pattern identification methods

Three main approaches have been proposed to define dietary pattern in observational studies: 1) an exploratory or *a posteriori* approach, which empirically derives dietary pattern directly from the data; 2) a hypothesis-oriented or *a priori* approach, which relies on specific available evidence related to the disease under analysis; and 3) method called *reduced rank regression*, which combines characteristics of the exploratory and hypothesis-oriented approaches to dietary pattern (Randi et al., 2010). Four cohort studies out of 6 articles in this review used dietary pattern using *a posteriori* exploratory analyses (principal component factor analysis) and only 2 studies that used dietary scores and indexes defined *a priori* as proxies of dietary habits in the population under study.

Factor analysis is a variable consolidation technique designed to generate a small number of variables that will capture much of the information in a larger data set. In this way, factor analysis allows an investigator to reduce information on frequency of food intake among the members of a study population over the entire range of foods covered by a food-frequency questionnaire (FFQ) into 2 or 3 variables that capture the primary sources of variation in the reported diet. These variables, by identifying where the major sources of dietary variation lies, are one way of describing the main dietary patterns in that study population (Flood et al., 2008).

Meanwhile, hypothesis-oriented (a priori) relies upon scientific knowledge from previous investigations into health-promoting or disease-preventing diets. With this approach, researchers measure compliance with a preexisting diet quality index, current dietary guidelines, or a specific dietary pattern and assign diet scores that reflect the level of adherence (Miller et al., 2010). Four different categories of indexes have been identified: 1) nutrient adequacy or density scores, 2) variety or diversity scores, 3) food-group patterning scores, and 4) index-based summary scores. Some other types of scores involve a combination of dietary habits and lifestyle factors that are all associated with the disease under study (Randi et al., 2010).

Results

A total of 17 articles were gathered at initial literature search, whereby only 6 cohort studies were included in the review. The other 11 articles were excluded because 2 of the articles are related to dietary pattern and colorectal adenoma, 1 article is a review article, 2 articles are related to colon and rectal cancers separately and 6 articles were case control studies. The summary of the findings of each article are shown in Table 1 (6 cohort studies) with the dietary pattern identified in each study. The 6 cohort studies were published from the year 2000 till 2008. The

studies reviewed were conducted in Sweden (1 article), United States (3 articles), France (1 article) and Singapore (1 article).

Dietary assessment and dietary pattern identification methods

Information on the dietary pattern identification method, dietary composition and main results are documented in Table 2 and Table 3. In Table 2, 4 cohort studies used food frequency questionnaires (FFQ) as a method of data collection. Each study used principal component factor analysis (PCFA) as a method for dietary pattern identification. Dietary composition identified in all 4 studies were based on specific categories; *healthy*, western, drinkers, prudent, pork, processed meats, potatoes, traditional, meat-eaters, fat-reduced/diet foods, meat and potatoes, vegetable/fruit/soy and meat/dim sum.

Risk estimates for colorectal cancer

Varieties of dietary patterns were identified from 4 cohort studies in this review (Table 2). Among those identified were; healthy, western, drinker, prudent, vegetables and pork, processed meats, potatoes, traditional, meat eaters, dietary pattern using recommended food scores, healthy eating index, alternate healthy eating index, Mediterranean diet score, fruit and vegetables, diet foods and red meat, and potatoes patterns, meat-dim sum and vegetable-fruit-soy. Each study showed different results even they were using similar dietary pattern categories. In Swedish Mammography Cohort (SMC), it was documented that they did not find any strong, significant association between dietary pattern and colorectal cancer risk. However, they suggest a possibility that a "*healthy*" dietary pattern is protective among younger women.

Four dietary patterns; *healthy, Western, drinker* and *meat eaters* were identified in the European Prospective Investigation into Cancer and Nutrition (EPIC) in France. The *meat-eaters* pattern was positively associated with colorectal cancer risk; RR=1.58, 95%CI 0.98-2.53; p trend=0.02). Results from the study conducted by Flood et al. (2008) in United States also supported the result that dietary patterns are characterized by a low frequency of meat and potato consumption and frequent consumption of fruit and vegetables and fat-reduced foods are consistent with a decreased risk of colorectal cancer.

Singapore Chinese Health Study (SCHS), the only study from Asia concluded that neither individual nutrients or foods nor dietary patterns appear to be the underlying explanation for the rise in colorectal cancer among Singapore Chinese. This could be explained by the rise of Type 2 Diabetes Mellitus prevalence in Singapore that contributes to the rise of CRC risk in Singapore. Therefore, as a preventive strategy to reduce CRC incidence in Singapore Chinese population, factors associated with insulin resistance, such as visceral adiposity and physical inactivity, may be an appropriate targets.

Two studies used *a priori* methods in Table 3. The study by Mai et al. (2005) in the United States suggested that a dietary pattern reflecting a higher Recommended Food Score (RFS) was associated with decreased overall mortality in women, specifically for colon/rectum. These

Table 1. Summary of Cohort Studies of Dietary Pattern and Colorectal Cancer

Study	Location	Outcome	Sample size	Age (years)	Follow up (years)	Data collection period	Dietary pattern identified
Terry et al., 2001	Sweden	CRC	61,463 subjects (460 cases)/0.8%	40-74	9.6 (mean)	1987-1998	Healthy, Western and drinker dietary pattern
Mai et al., 2005	United States	CRC in women	37,135 (372 cases/1.0%)	61 (mean)	9.5 (mean)	1987-1998	Dietary pattern using Recommended Food Scores (RFS)
Kesse et al., 2006	France	CRC in women	67,312 CRC-free (172 CRC/0.3%)	40-65	7	1993-2000	Healthy, Western, Drinker, Meat eaters
Reedy et al., 2008	United States	CRC	492,382 (3,110 CRC/0.6%)	50-71	5	1995-2000	Healthy Eating Index- 2005, Alternate Healthy Eating Index, Mediterranean Diet Score, Recommended Food Score.
Flood et al., 2008	United States	CRC	492,382 (3110 CRC/0.6%)	50-71	5	1995-2000	Fruit and vegetables, Diet foods & Red meat and potatoes pattern.
Butler et al., 2008	Singapore	CRC	61,321 (961 CRC/1.6%)	45-74	10	1993-2005	Meat–dim sum & Vegetable–fruit–soy

*CRC: colorectal cancer

Table 2. Summary of Cohort Studies of Colorectal Cancer and Dietary Pattern Defined using the *a Posteriori* Method

Reference; Country; Study name	Questionnaire	Dietary pattern identification method	Dietary pattern composition	Main results
Terry et al., 2001; Sweden; SMC	FFQ	PCFA	**HEALTHY**: fruits and vegetables, fish and poultry, cereal and whole-grain breads, fruit juice, and low-fat dairy products; **WESTERN**: processed and red meats, soda and sweets, refined breads and potatoes, and high-fat dairy products; **DRINKERS**: wine, beer, and spirits.	**HEALTHY**: not associated with overall CRC; RR = 0.45 (95% CI: 0.23–0.88) for CRC for 5th versus 1st quintile among women aged <50 p = 0.03.
Kesse et al.,2006; France; EPIC France	FFQ	PCFA	**HEALTHY**: raw and cooked vegetables, legumes, fruit, yogurt, fresh cheese, breakfast cereals, sea products, eggs, and vegetable oils (olive oil and others) and low intakes of sweets; **WESTERN**: potatoes, pizzas and pies, sandwiches, sweets, cakes, cheese, cereal products, processed meat, eggs, and butter; **DRINKER**: sandwiches, snacks, coffee, processed meat, sea products, and alcoholic beverages and low intakes of soup and fruit; **MEAT-EATERS**: meat, poultry, and margarine.	**MEAT-EATERS**: RR = 1.58 (95% CI: 0.98–2.53) for CRC among women, p = 0.02.
Flood et al., 2008; USA; NIH-AARP Diet and Health	FFQ	PCFA by sex	**FRUIT & VEGETABLES**: fruit and vegetables; **FAT-REDUCED/DIET FOODS**: fat-reduced foods, diet foods, and lean meats; **MEAT AND POTATOES**: high-fat foods, red meats and potatoes	**FRUIT AND VEGETABLES**: RR = 0.81 (95% CI: 0.70–0.93) for CRC for 5th versus 1st quintile among men, p = 0.004; **FAT-REDUCED/DIET FOODS**: RR = 0.82 (95% CI: 0.72–0.94) for CRC among men, p = 0.001 and RR = 0.87 (95% CI: 0.71–1.07) among women, \p = 0.06; **MEAT AND POTATOES**: RR = 1.18 (95% CI: 1.02–1.35) for CRC among men, p= 0.14 and RR = 1.48 (95% CI: 1.20–1.83) among women, p = 0.0002.
Butler et al., 2008; Singapore; SCHS	FFQ	PCFA	**VEGETABLE/FRUIT/SOY**: vegetables, fruits, and soy foods; **MEAT/DIM SUM**: chicken, pork, fish, rice and noodle dishes, and preserved foods.	No specific dietary pattern identified

*CI, confidence interval; CRC, colorectal cancer; EPIC, European Prospective Investigation into Cancer and Nutrition; FFQ, food frequency

Table 3. Epidemiological Studies on Colorectal Cancer and Dietary Indexes (a priori methods)

Reference; Country; Study name	Ques-tion-naire	Dietary pattern composition [Index range]	Main results
Mai et al., 2005; United States; cohort study; BCDDP follow-up	FFQ	Recommended Food Score (RFS): 23 FFQ items: apples or pears; oranges; cantaloupes; orange or grapefruit juice; grapefruit; other fruit juices; dried beans; tomatoes; broccoli; spinach; mustard, turnip or collard greens; carrots or mixed vegetables with carrots; green salad; sweet potatoes, yams or other potatoes; baked or stewed chicken or turkey; baked or broiled fish; dark breads like whole wheat, rye, or pumpernickel; cornbread, tortillas and grits; high-fibre cereals, such as bran, granola or shredded wheat; cooked cereals; 2% milk and beverages with 2% milk; and 1% milk or skimmed milk.	RFS: not associated with CRC among women
Reedy et al., 2008; United States; cohort study; NIH-AARP Diet and Health	FFQ	Compare 4 indexes **Healthy Eating Index-2005;** scores 12 components for a total of 100 points (5). Six components—total grains; whole grains; total vegetables; dark-green vegetables, orange vegetables, and legumes; total fruit; and whole fruit—are worth 0–5 points; five components—milk; meats and beans; oils; saturated fat; and sodium—are worth 0–10 points; and one component—calories from solid fat, alcohol, and added sugar—is worth 0–20 points. **Alternate Healthy Eating Index scores**; 9 components for a total of 87.5 points (6–8). Eight components— vegetables, fruit, nuts and soy, white:red meat ratio, trans fat, polyunsaturated:saturated fat ratio, cereal fiber, and alcohol—are worth 0–10 points, and scores are evenly prorated on the basis of standards established previously. The multivitamin component is scored as either 7.5 points for regular intake of multivitamins or 2.5 points for intake less than every other day. **MDS**: 9 components (whole grains, vegetables, fruit, fish, legumes, and nuts: 1 point for intake at or greater than the sex-specific median; red and processed meat and the MFA:SFA ratio: 1 point for intake less than the sex-specific median; alcohol intake scored by predetermined cut-off points) [0–9]; **RFS**: 45 components (1 point for each of the 45 recommended foods consumed at least weekly in the following categories: 5 whole-grain bread/ cereal items, 18 vegetable items, 15 fruit items, 2 low-fat milk items, and 5 lean-meat items) [0–45].	Similar decreased of CRC risk observed in 4 indexes for men comparing the 5th quintile with the 1st quintile: **Healthy Eating Index-2005** (RR =0.72, 95% CI: 0.62, 0.83); **Alternate Healthy Eating Index** (RR= 0.70, 95% CI: 0.61, 0.81); **Mediterranean Diet Score** (RR = 0.72, 95% CI: 0.63, 0.83); **Recommended Food Score** (RR= 0.75, 95% CI: 0.65, 0.87). For women decreased CRC risk observed in **Healthy Eating Index-2005**, (RR= 0.80, 95% CI; 0.64, 0.98) although **Alternate Healthy Eating Index** results were similar (RR= 0.83, 95% CI; 0.66, 1.05)

*AHEI, Alternate Healthy Eating Index; BCDDP, Breast Cancer Detection Demonstration Project; CI, confidence interval; CRC, colorectal cancer; FFQ, food frequency questionnaire; MDS, Mediterranean diet score; NIH-AARP, National Institutes of Health – American Association of Retired

observations are consistent with the hypothesis that a high RFS dietary pattern, or associated lifestyle factors, might affect cancer progression and survival. While in the National Institutes of Health – American Association of Retired Persons (NIH-AARP) Diet and Health Study, index-based methods illustrate that dietary patterns consistent with given dietary guidelines are associated with a reduced risk of CRC in men and in women when measured with the *Healthy Eating Index-2005*.

Discussion

Diet has long been considered a causal factor in the mechanism of colorectal cancer. Diet can be studied in terms of nutrients, foods, and food groups. Nowadays, people have more choices on the variety of food available as the technology advanced. Due to the complex combination of nutrients and foods, it is impossible to investigate single food causing CRC. As has been documented in many journals, *Western* dietary pattern has

been associated with increased risk of CRC worldwide, while vegetables and fruits were the protective factor of CRC.

Mostly, the *Western* dietary pattern consisted of processed and red meat, high fat dairy products, fast food, refined grain, coffee, high sugar drink and high sugar dessert. The positive association between the meat eaters pattern and risk of CRC can be explained by an effect of red meat and processed meat on colorectal carcinogenesis. Mechanisms underlying such a relation involve their content of fat, heme iron, N-nitroso compounds, heterocyclic amines, and polycyclic aromatic hydrocarbons due to cooking at high temperature (Kesse et al., 2006). High consumption of fruits and vegetables has been documented to have inverse relationship with CRC. Prudent or healthy dietary pattern were used interchangeably, consisted of fruits and vegetables, whole grain, fish and poultry, legumes and soy products. Vegetables and fruits are rich in fiber, antioxidant vitamins, folic acid, carotenoids, and other phytochemical

compounds, which may yield beneficial properties and act in a synergic way against colorectal carcinogenesis (Kesse et al., 2006).

Most of the studies in this review, used *a posteriori* or the exploratory method to identify the dietary pattern such as factor analysis. Factor analysis, as a generic term, includes both principal component analysis and common factor analysis (Hu, 2002). Dietary pattern identified by the exploratory techniques are meant to reflect real dietary habits and are not based on known health effects of diet. As a consequence, the dietary patterns identified are not necessarily relevant for cancer risk and this can explain, at least in part, by the lack of association reported in some studies (Randi et al., 2010).

The dietary index approach, in contrast, is *a priori* because the indices are created on the basis of previous knowledge of a 'healthy' diet. The dietary index approach is limited by current knowledge and an understanding of the diet-disease relationship, and can be fraught with uncertainties in selecting individual component of the score and subjectivity in defining cut off points. Typically, dietary indices are constructed on the basis of prevailing dietary recommendations, some of which may not represent the best available scientific evidence (Hu, 2002).

The term 'dietary pattern' may differ from country to country worldwide. For example, the term *Western* dietary pattern may differ slightly in Western population and also in Asia population based on the food composition. The similar goes to *healthy* or *prudent* dietary pattern. Basically, it consisted of fruits, vegetables, whole grain, fish and poultry as the main source. This will lead to the problem of reproducibility across different populations.

There are several limitations related to the dietary pattern analysis used. Firstly, it is difficult to identify or establish a quantitative method to identify specific eating pattern (ie Mediterranean diet). Mediterranean diet is a well-established eating pattern worldwide. The dietary pattern may vary according to sex, ethnic group and socioeconomic status. Therefore, it is crucial to conduct the study in other population to see if it will replicate the same result. In dietary pattern analysis, it considers overall diet rather than single food or nutrient. Therefore, the result from the analysis cannot be interpreted based on the association of the dietary component and the observed disease risk. The finding should be interpreted together with the individual food analyses.

In conclusion, in this review, many of the studies supported CRC associated with *Western* dietary pattern, consisting mainly red and processed meat, and refined grains. The protective factors of CRC are healthy or prudent diet which composed of vegetables, fruits, fish and poultry. Information gathered from the dietary pattern could have important public health implication. Therefore, the public health division should take further action into translating the finding from the dietary pattern studies conducted worldwide into simple fact or lay-man term that can be digested by the public. By doing so, it will simplify the pathway for education and intervention for the public. As public showed awareness on their dietary pattern, it will be easier to implement healthy public transformation and thus reducing the chronic disease incidence especially cancer.

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