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Association between food availability and mortality due to colorectal cancer in the Americas

Relación entre la disponibilidad alimentaria y la mortalidad por cáncer colorrectal en América

Susana Buamden[1]

[1]*Bachelor's degree in Nutrition, Master's degree in Epidemiology, Health Policy and Management, Teaching assistant at Universidad de Buenos Aires, City of Buenos Aires, Argentina.* ✉

ABSTRACT With the aim of describing the association between food availability and the mortality rate due to colorectal cancer in the countries of the Americas in 2010, data provided by the International Agency for Research on Cancer and the Food and Agriculture Federation were analyzed in an ecological study. Great variability was observed except in caloric supply. Food availability was abundant for calories, total fats, animal fat, red meat and alcoholic beverages. Availability was critically low for fruits and vegetables in 80% of the countries. The countries with the highest colorectal cancer mortality rates were Uruguay, Barbados, Argentina and Cuba, while those with the lowest rates were Guatemala, Canada, Mexico and Honduras. The strongest relationships were found between colorectal cancer mortality rate and the availability of animal fat, red meat, alcoholic beverages and calories. No protective effect of availability of fruits and vegetables on the colorectal cancer mortality rate was found. It would be advisable to improve the records of tumor incidence and direct ways of evaluating diet to be analyzed in future studies instead of the data used here.

KEY WORDS Colorectal Neoplasms; Mortality; Diet; Food Supply; Risk Factor.

RESUMEN Con el objetivo de describir la relación entre la disponibilidad alimentaria y la tasa de mortalidad por cáncer colorrectal en los países de América en el año 2010, se analizaron datos provistos por la International Agency for Research on Cancer y la Food and Agriculture Organization mediante un estudio ecológico. Se observó una gran variabilidad excepto en disponibilidad calórica. La disponibilidad alimentaria fue abundante para calorías, grasas totales, grasa animal, carnes rojas y bebidas alcohólicas. Para frutas y vegetales fue crítica en un 80% de los países. Los países con más alta tasa de mortalidad por cáncer colorrectal fueron Uruguay, Barbados, Argentina y Cuba, y con las tasas más bajas fueron Guatemala, Canadá, México y Honduras. Las relaciones más fuertes se dieron entre la tasa de mortalidad por cáncer colorrectal y la disponibilidad alimentaria de grasa animal, carne roja, bebidas alcohólicas y calorías. No se encontró efecto protector de la disponibilidad alimentaria de frutas y vegetales sobre la tasa de mortalidad por cáncer colorrectal. Sería recomendable mejorar los registros de incidencia de tumores y de formas directas de evaluar la dieta para ser analizados en futuros estudios en lugar de los datos aquí utilizados.

PALABRAS CLAVES Neoplasias Colorrectales; Mortalidad; Dieta; Abastecimiento de Alimentos; Factor de Riesgo.

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INTRODUCTION

Colorectal cancer is a growing public health concern that increasingly affects the least developed countries. Although it has a genetic component, the influence of dietary patterns on its development has been extensively demonstrated. As the countries of the Americas adopt the dietary practices of developed countries, the growth of noncommunicable chronic diseases is now a matter of concern.

Within this context, the following questions arise: How does our dietary pattern influence the development of colorectal cancer? Do we triple mortality rates as we triple the recommendation of meat consumption? Can we apply the international recommendations without hesitation or should we analyze the situation before doing so? And also, what relationship do neighboring countries show in terms of food consumption and colorectal cancer mortality rate?

Following the traditional studies on diet and cancer, and in the light of the information available, it was decided to analyze diet in terms of food availability and colorectal cancer in connection with mortality rates.

The aim of this study was to contribute to the knowledge of the association between food availability in American countries and colorectal cancer mortality using a local approach considering that the current recommendations on diet and cancer are based on diets from countries of Europe, Asia, and North America, mainly. This research was carried out within the framework of the thesis entitled "Food availability and mortality rate due to colorectal cancer in Argentina and other countries of America in 2010"[1] to earn the Master's Degree in Epidemiology, Health Policy and Management, from the Instituto de Salud Colectiva, of the Universidad Nacional de Lanús.

Colorectal cancer

The global burden of cancer will have an increasing impact in the coming decades, as a result of the aging of the population due to higher life expectancy and a decrease in the birth rate observed. Colorectal cancer is the third most common type of cancer diagnosed in both men and women with global incidence rates of 14.7 per 100,000 (inhabitants) in women and 20.4 per 100,000 in men. Argentina exceeds the world average, with an incidence of colorectal cancer for the year 2008 of 16.7 per 100,000 in women and 25.3 per 100,000 in men.[2] According to Gualdrini and Iummato[3]:

> Global survival rates of CRC [colorectal cancer] are 60%, increasing to 90% when it is diagnosed at an early stage. In Argentina, it is diagnosed at advanced stages [...] Mortality from CRC reaches 11% due to malignant tumors, being one of the tumors with the highest incidence worldwide. Two out of every five cases of CRC in the world in 2008 occurred in less developed countries [...] Approximately 75% of CRCs are sporadic and occur in individuals without genetic predisposition or family history of CRC; therefore, dietary and environmental factors have been implicated in its etiology. Age is the main risk factor in this group of sporadic cases [...] Primary prevention aims to identify the risk factors in diet and lifestyle to try to modify them through the education of the population. Both diet and lifestyle, chemoprevention, and antioxidants may impact the different stages of CRC development, either before the onset of adenomas, during their growth, or in the process of transformation into cancer.[3] [Own translation]

Diet as a preventive factor

The possibility of preventing very frequent tumor localizations through changes in dietary habits, particularly, by eating fruits and vegetables (or their equivalent, vitamin supplements and other antioxidants in the diet) brought high hopes for cancer control in the 1980s.

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Members of Argentina's National Cancer Institute [*Instituto Nacional del Cáncer*] claim that, in view of the fact that environmental factors such as food, nutrition, and physical activity contribute to the development of the disease, it may be argued that cancer is preventable.

> Thus, high-calorie diets, high rates of processed meats, refined foods, fats, and alcohol, are associated with an increase in the risk of developing breast, prostate, and colon cancer, while a diet that includes important amounts of fruits and vegetables, with high content of micronutrients and fiber, is linked to a reduction of the risk of developing the disease.[4]

In 2011, a panel of experts from the World Cancer Research Fund (WCRF) drafted a report on diet, physical activity, and colorectal cancer, in which they examined the studies on the subject and provided guidance. In this report, it is stated that diet plays an important role in prevention and causation of cancer.[5]

In the WCRF report, it is established that physical activity and foods high on fiber (fruits and vegetables) are protective factors, whereas red meat consumption, processed meats, alcoholic beverages for men, abdominal fat, and the attained height in adulthood are considered convincing risk factors.

A daily increase of 100 grams of red meat per day would raise the risk of suffering from colorectal cancer by 12% and 17%, whereas an increase of 25 grams in the consumption of processed meats would raise this same risk by 49%.[5]

Recently, the World Health Organization (WHO) published a press report on red meats and cancer, in which it asserts that:

> After a comprehensive review of the published scientific literature, a Working Group composed of 22 experts from 10 countries, convened by the IARC (International Agency for Research on Cancer) Monographs Programme, classified the consumption of red meat as probably carcinogenic to humans. This statement is based on limited evidence that shows that red meat consumption causes cancer in humans, and strong mechanistic evidence that supports a carcinogenic effect. This association was mainly observed with colorectal cancer; however, other associations have also been observed with pancreatic and prostate cancer.[6]

Ways of measuring diet

The difficulties of the populations in gaining access to diets have led some epidemiologists to postulate that it is not possible to establish a dietary profile of a population.[7] The measurement of food intake in individuals and populations is carried out using different methods, which differ in the way of gathering information and also in the period of time covered. There is great controversy with regard to which one of these methods is more appropriate and which one reflects the actual food consumption in a population in a more reliable way. In fact, different reviews in relation to the subject conclude that there is not an entirely satisfactory method by itself, and the usefulness of each one will depend on the conditions in which it is applied, and the objectives of the measurement.[8]

Food availability represents the amount of food available per capita, and, although it does not reflect any differences in food access or actual consumption, it gives a general idea of the diet of the populations. It is obtained from the food balance sheets, which were first published by the Food and Agriculture Organization (FAO) in 1949, and are currently published every year. Food balance sheets are a balance (input-output ratio) of foods at the national level of the amount of a food item available for human consumption.[9]

Background of similar studies

Ecological correlation studies have been used traditionally to analyze diets and cancer

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in the populations.[7] These studies include food availability data of the countries to approach the diet and the mortality rates to measure cancer. Both measures are population-based and, overall, provide good quality information.

METHODS

In 2010, an ecological study was conducted with the aim of describing the association between food availability and mortality due to colorectal cancer in Argentina and other countries of the Americas.

Food availability data of 33 of the 34 countries of the Americas were gathered (except for Antigua and Barbuda, because of the lack of data): Argentina, Barbados, Belize, Bolivia, Brazil, Canada, Costa Rica, Colombia, Cuba, Chile, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Saint Lucia, Surinam, the Bahamas, the United States, Uruguay, and Venezuela.

Mortality due to colorectal cancer in men and women in 2010 was studied in 26 of the 34 countries of America (excluding those countries in which data were unreliable): Argentina, Barbados, Bolivia, Brazil, Canada, Costa Rica, Colombia, Cuba, Chile, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panamá, Paraguay, Peru, the Bahamas, the United States, Uruguay, and Venezuela. The association between food availability and mortality due to colorectal cancer was analyzed in these 26 countries.

In order to carry out this research study, data were collected from food balance sheets available at the FAO,[10] and mortality rates due to colorectal cancer available at the International Agency for Research on Cancer (IARC),[11] codes C18, C19, C20, and C21 of the International Classification of Diseases (ICD-10).

First, a description of the food availability associated with colorectal cancer was provided: calories, total fats, animal fat, red meat, alcoholic beverages, and fruits and vegetables. Food availability of processed meat was not described, despite being highly associated with colorectal cancer, due to the lack of reliable data. Then, mortality rates due to colorectal cancer were described, age-adjusted and by five-year age groups from 55 to 74 years. Finally, the association between food availability and mortality rate due to colorectal cancer was analyzed.

Food availability

In order to analyze food availability, food balance sheets provided by the FAO were used. These sheets provide information per capita and per year of kilocalories, total fats, and animal fat, according to each country. Moreover, the balance sheets provide information of food availability per capita per year. Availability of kilocalories, total fats, animal fat, red meat, alcohol, and fruits and non-starchy vegetables was compared per capita per country in 2010. These amounts were expressed as daily amounts in order to compare them with the guidelines.

In order to create the variable "availability of red meat per capita," the definition was taken from the WCRF and the following items were added up in the food balance sheet of the country for the year 2010: bovine meat, goat and lamb meat, pork, other types of meat, and viscera (chicken meat was excluded according to the definition of red meat).

Therefore, to analyze "food availability of fruit and vegetables per capita," non-starchy vegetables were added to the fruit item in the balance sheets.

To construct the variable "availability of alcohol per capita," the item "alcoholic beverages" in the balance sheets was considered, the amount per day per capita of each drink was calculated, and then, the content of ethanol in each drink was calculated for each drink. Finally, the amount of ethanol content in each drink was added up.

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Mortality rates due to colorectal cancer

Data were collected from the IARC and the WHO.[12] The age-standardized rate and specific rates by age from 55 to 74 years in five-year groups were used, with the aim of further deepening the analysis further. Both groups of rates were used because they provide supplementary data.

The age-standardized rate is a summary measure of the mortality rates of a population that considers that every population has the same age structure. Standardization is necessary to compare populations, as these differ in age, and age is an influential factor in the risk of dying due to cancer.

Correlation analysis

Spearman's correlation coefficient (rho) was used for the analysis of the associations between food availability and mortality rates. This statistical measure enables the creation of correlations when there are distant or extreme values, or even when the distribution of the variables is not consistent with a Gaussian bell curve or a normal distribution.[13]

> It is considered that correlation coefficients ranging from 0 to 0.25, or from 0 to -0.25 show low or null correlation, from 0.25 to 0.50 (or from -0.25 to -0.50) show a certain degree of correlation; from 0.50 to 0.75 (or from 0.50 to -0.75) show moderate correlation, and greater than 0.75 (or -0.75) show very good or excellent correlation.[13]

RESULTS

Food availability

The average of calorie availability in the Region of the Americas was 2665 kcal. (Colombia). The minimum value was observed in Bolivia (2168 kcal.) and the maximum in the US (3659 kcal.), followed by Canada (3397 kcal.), Brazil (3230 kcal.), Cuba (3159 kcal.), and Argentina (3157 kcal.). Half of the countries (interquartile range) exhibited calorie availabilities ranging from 2532 to 3014 kcal. (Table 1).

The average availability of total fats was 85 grams per capita per day. The US showed the maximum value of 161 grams per capita per day, followed by Canada, Brazil, and Argentina (149, 113, and 113 g/per capita/per day, respectively). Countries with the lowest fat availability were Haiti, Peru, and Bolivia (47, 47, and 48 grams per capita per day). The interquartile range was 61-94 grams (Table 1).

Countries with the highest animal fat availability were the US, Argentina, Canada, and The Bahamas (69, 68, 67, and 63 grams per capita per day, respectively). Countries with the lowest availability were Haiti, Peru, and Guatemala (10, 16, and 17 grams per capita per day, respectively). The average was 35 grams per capita per day, and the interquartile range was 27-54 (Table 2).

By analyzing the different variables related to food availability (caloric, total fats, and animal fat availability), the results showed that the distribution of calorie availability showed fewer variations (variation coefficient: 12.8%) than the distribution of total fat availability (variation coefficient: 33.2%)

Table 1. Statistics of the food availability variable in the countries of America, year 2010.

Food availability	Average	Interquartile range Q_1-Q_3	Coefficient of variation (%)
Caloric (kcal/per capita/per day)	2,665	2,532-3,041	12.8
Total fats (g/per capita/per day)	85	61-94	33.2
Animal fat	35	27-54	42.6
Red meat (g/per capita/per day)	94	41-128	55.6
Alcoholic beverages (g of ethanol/per capita/per day)	10	6-12	80.3
Fruits and vegetables (g/per capita/per day)	421	341-538	39.2

Source: Own elaboration based on data from the Food and Agriculture Organization[10].

Q_1= Quartile 1, lower limit of the interquartile range. Q_3= Quartile 3, upper limit of the interquartile range.

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and animal fat distribution (variation coefficient: 42.6%) (Table 1).

Red meat availability showed great variability in the countries under study, with a variation coefficient of 55.6%. The average was 94 grams per capita per day. Table 2 shows that the countries with the highest levels were Argentina (194 g), the US (190 g), Uruguay (162 g), Canada (155 g), The Bahamas (150 g), and Brazil (148 g). The countries with the lowest availability were Saint Kitts and Nevis (15 g), Guyana (19 g), Nicaragua (29 g), and Haiti (32 g) (Table 2). Interquartile range was 41-128 (Table 1).

The average of alcohol availability (measured in grams of ethanol) showed a great difference among countries. The country that showed the highest availability (the US: 20 grams of ethanol per day) showed almost seven times greater availability than the country that showed less availability (Guatemala: 3 grams of ethanol per day) (Figure 2).

The apparent consumption of fruits and non-starchy vegetables showed an important fluctuation among countries, with a variation coefficient of 39.2%. The countries with higher availability (Dominica and The Bahamas) showed almost seven times more availability than the country in the lowest rank (Nicaragua); although, in general, availability was low for most of the countries. Only seven countries reached full availability of fruits and vegetables (660 grams, which is the recommended amount plus 10%): Dominica, The Bahamas, Saint Vincent and the Grenadines, Belize, Cuba, Dominican Republic, and Canada, and only one country, the US, showed sufficient availability (660 grams, 100%) (Figure 3).

Mortality rate due to colorectal cancer

Standardized mortality rates due to colorectal cancer showed a similar behavior to age-specific rates, ranging from 55 to 74 years, with a great variability among countries, and a variation coefficient greater than 40% in all age groups studied.

Uruguay showed the highest mortality rate due to colorectal cancer, in all groups. Other countries that showed considerably higher rates than the rest were The Bahamas, Cuba, and the US. Barbados showed higher rates in almost every group studied, except in the 55 to 59-year-old group. Argentina ranked third in the standardized mortality rate due to colorectal cancer, and between the sixth and the seventh place in age-specific rates in the 55 to 74-year-old group. The countries with the lowest rates in all five-year periods studied were Guatemala, Canada, Mexico, and Haiti (Figure 4).

The age-adjusted mortality rate due to colorectal cancer showed an average of 6.5 per 100,000 inhabitants, and an interquartile range of 5.4-8.8. The countries with the highest rates were: Uruguay (16 per 100,000), Barbados (14 per 100,000), and Argentina (13 per 100,000). The countries with the lowest rates were: Guatemala and Canada (3 per 100,000), and Mexico (4 per 100,000).

By analyzing the rate categorized by age in the 55 to 74-year-old band, abrupt increases were observed as the age increased. The average value was 12.5 (deaths) per 100,000 in the 55 to 59-year-old band, to 21.5 per 100,000 in the following five-year period, then 31 per 100,000 in the 65 to 69-year-old band, and reaching 59 (deaths) per 100,000 in the age group ranging from 70 to 74-years.

Association between food availability and mortality due to colorectal cancer

The association between red meat availability and mortality rate due to colorectal cancer in the age-standardized rate was analyzed. A positive moderate association with a Spearman's correlation coefficient of 0.59 and a coefficient of determination of 0.29 were observed. Countries such as Uruguay and Argentina, with high availability of red meat and high age-standardized mortality rate due to colorectal cancer, countries with average availability and high rates, such as Barbados and Cuba, and countries with high

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Table 2. Daily food availability per capita, according to each country. America, 2010.

Country[1]	Calories (kcal/ per day)	Total fats (g/ per day)	Animal fat (g/ per day)	Fruits and vegetables (g/ per day)	Red meat (g/ per day)	Ethanol (g/ per day)
Argentina	3,157	113	68	388	194	13
Bahamas	2,584	95	63	1005	150	15
Barbados	3,060	94	51	538	89	9
Belize	2,839	73	41	815	60	11
Bolivia	2,168	48	33	284	94	4
Brazil	3,230	113	54	501	148	12
Canada	3,397	149	67	671	155	12
Chile	2,949	85	54	368	128	11
Colombia	2,665	78	32	461	68	7
Costa Rica	2,869	87	38	435	81	9
Cuba	3,159	64	33	739	98	9
Dominica	3,069	85	47	1119	83	10
Ecuador	2,450	100	52	558	96	4
El Salvador	2,524	58	27	341	36	5
United States	3,659	161	69	604	190	20
Granada	2,451	95	37	470	51	11
Guatemala	2,431	57	17	362	34	3
Guyana	2,623	54	24	317	19	6
Haití	2,169	47	10	240	32	9
Honduras	2,573	71	27	352	41	5
Jamaica	2,762	79	34	513	36	9
Mexico	3,041	91	45	421	103	7
Nicaragua	2,512	61	22	158	29	4
Panama	2,579	72	35	317	101	11
Paraguay	2,575	93	38	366	113	9
Peru	2,617	47	16	474	42	8
Dominican Republic	2,532	88	29	730	68	10
Saint Kitts and Nevis	2,499	84	42	263	15	8
Saint Vincent and the Grenadines	2,944	83	42	980	74	12
Saint Lucia	2,640	78	55	356	101	13
Surinam	2,804	81	27	423	61	10
Uruguay	2,955	88	54	384	162	12
Venezuela	2,906	88	36	340	103	13

Source: Own elaboration based on data from Food and Agriculture Organization.[10]

availability of red meat and low or medium rates, such as Canada and the US (Figure 5) were observed.

By associating the availability of ethanol and the age-standardized mortality rate due to colorectal cancer, a Spearman's correlation coefficient of 0.61 was obtained, meaning a moderate positive association. Most of the countries with high availabilities of alcohol showed high rates as well. Nevertheless, the US, the country with the highest availability, showed an average rate, and Canada, also with a high availability, showed one of the lowest rates.

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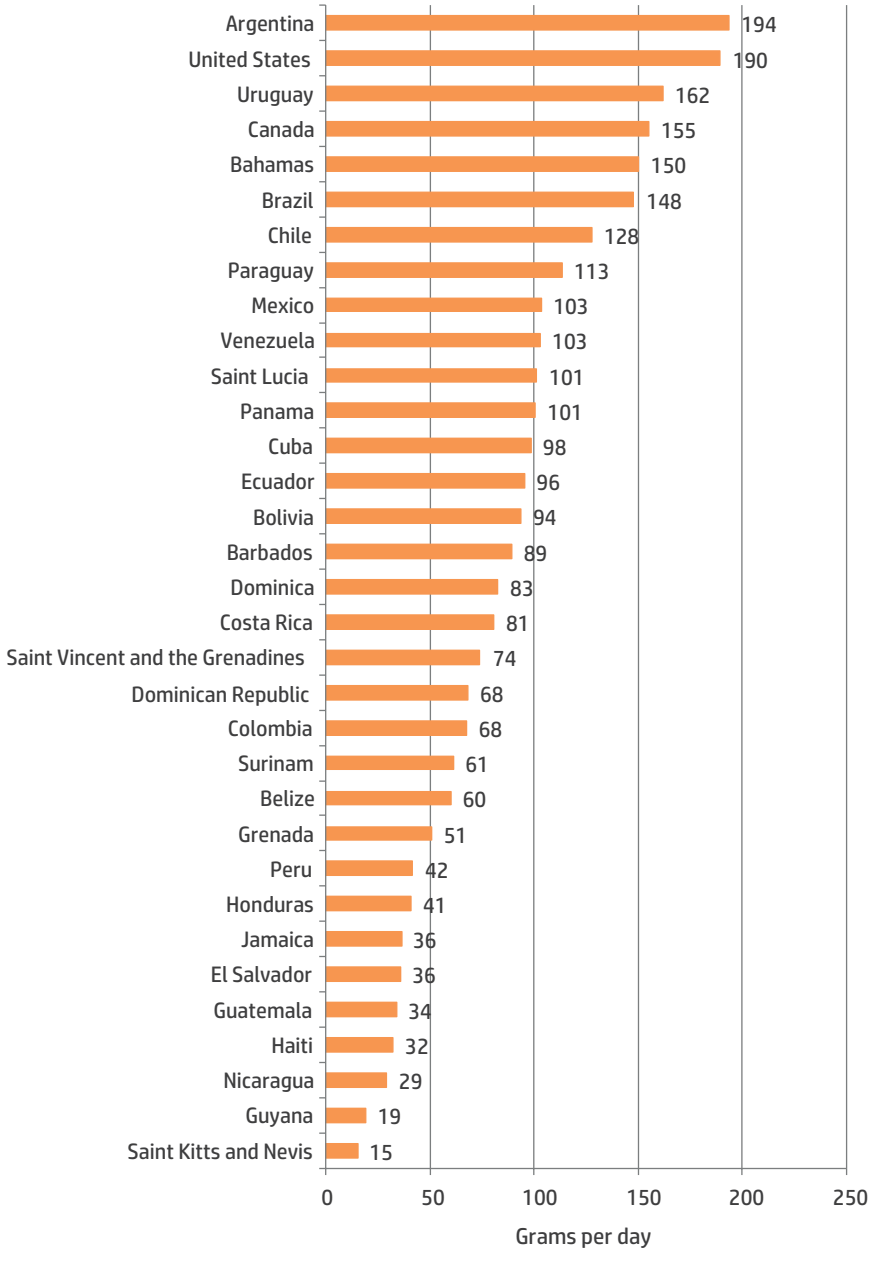

Figure 1. Daily availability of red meat per capita, according to each country. America, 2010.

Source: Own elaboration based on data from Food and Agriculture Organization.[10]

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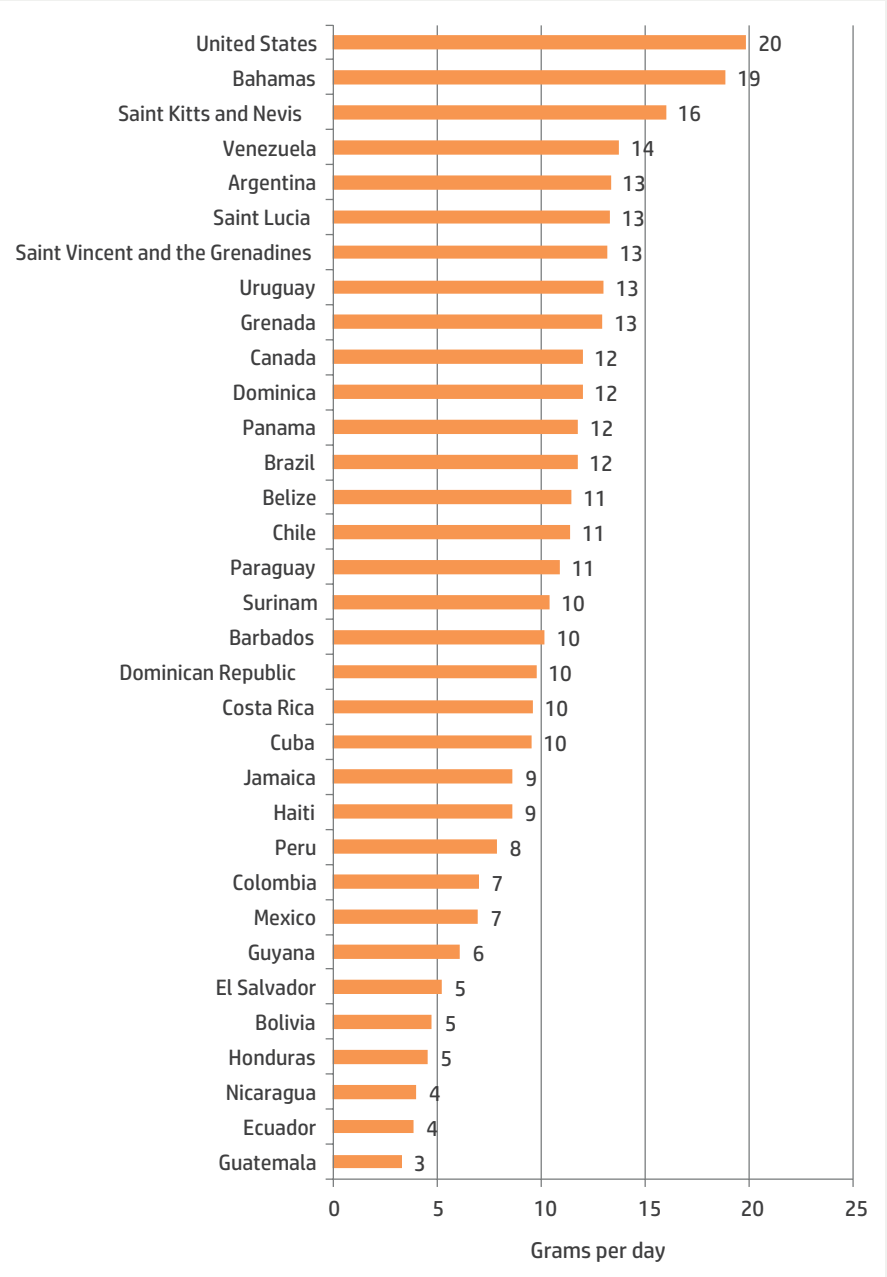

Figure 2. Daily availability of alcoholic beverages (grams of ethanol) per capita, according to each country. America, 2010.

Source: Own elaboration based on data from Food and Agriculture Organization.[10]

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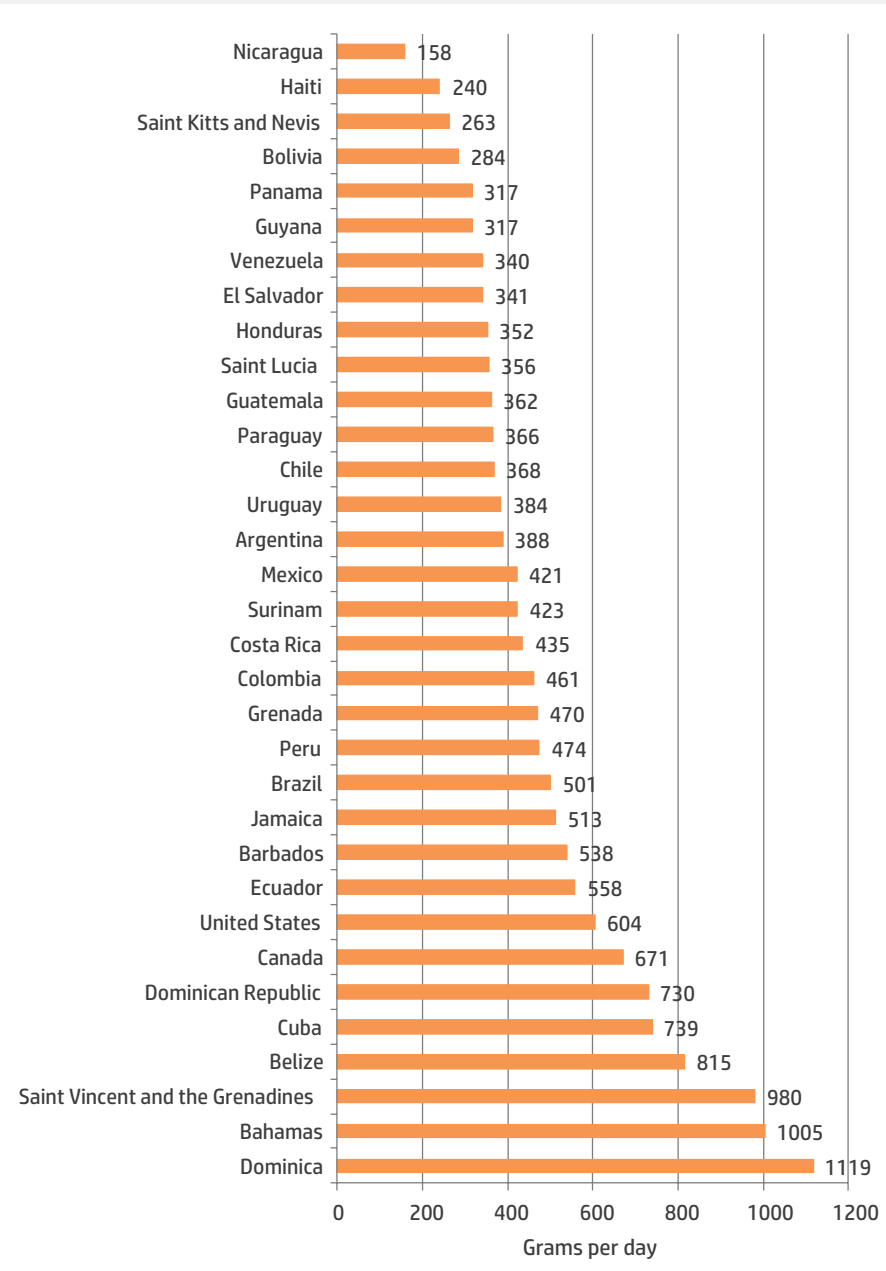

Figure 3. Daily availability of fruits and non-starchy vegetables per capita, according to each country. America, 2010.

Source: Own elaboration based on data from Food and Agriculture Organization.[10]

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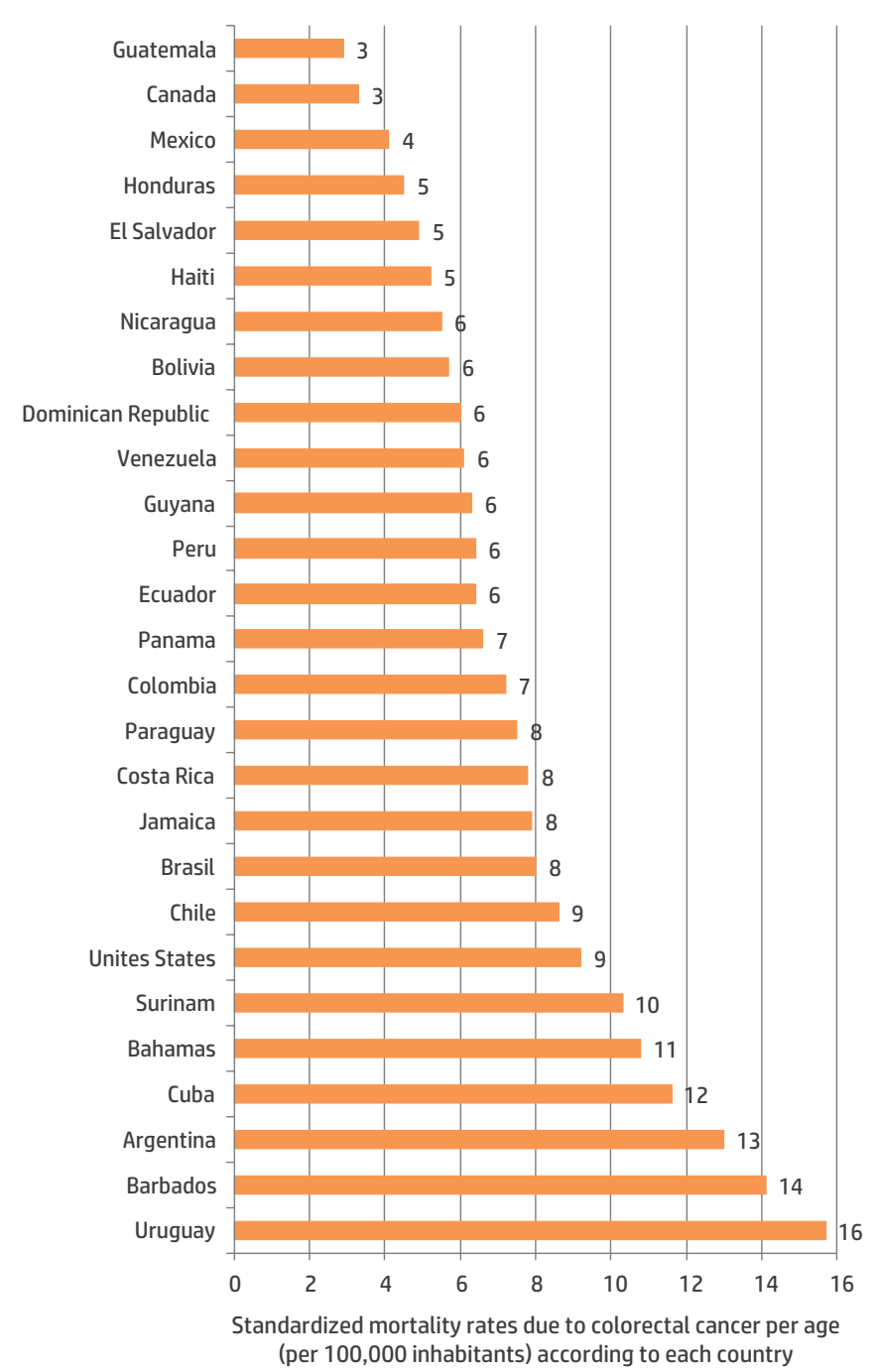

Figure 4. Standardized mortality rates due to colorectal cancer per age (per 100,000 inhabitants), according to each country. Argentina, 2010.

Source: Own elaboration based on data from the International Agency for Research on Cancer.[11]

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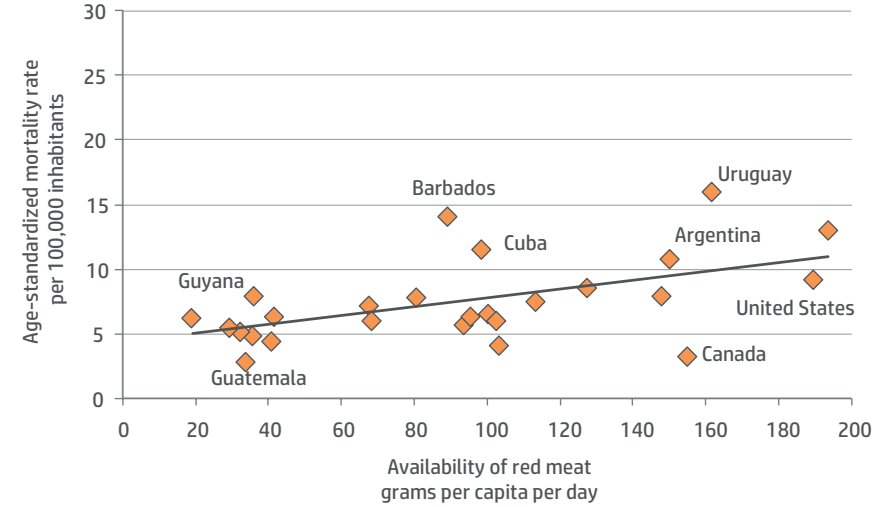

Figure 5. Association between availability of red meat and age-standardized mortality rates due to colorectal cancer (per 100,000 inhabitants), according to each country. America, 2010.

Source: Own elaboration based on data from the Food and Agriculture Organization[10] and the International Agency for Research on Cancer.[11]

The association between the availability of fruits and non-starchy vegetables and the mortality rate due to colorectal cancer showed a weak positive correlation, which contradicts the recommendations conferring a protective role to this food group.

The association between calorie availability and age-standardized mortality rates due to colorectal cancer was moderate positive with a Spearman's correlation coefficient of 0.56 and a coefficient of determination of 0.16.

The association between the availability of total fats and mortality rates due to colorectal cancer was weak positive (rho factor: 0.47). The countries with the highest availability of fat, that is to say, the US and Canada, showed intermediate and low colorectal cancer mortality rates, respectively, whereas countries such as Uruguay, Barbados, and Argentina showed intermediate and high rates of fat availability.

Finally, a slightly stronger association was found between the availability of animal fat and the colorectal cancer mortality rate, with a Spearman's correlation coefficient of 0.6 (moderate positive association).

DISCUSSION AND ANALYSIS

Food availability

The results found with regard to food availability showed great variability among countries. The differences were greater in food availability than in caloric intake. A certain profile could be observed in each country. The countries with higher calorie availability also had greater availability of total fats, animal fats, alcohol, and red meat. The availability of fruits and vegetables showed lower variability among countries than the other foods studied.

At first sight, the most developed countries and the major food producers seem to have the greatest availability, whereas the countries with the lowest income economies have the lowest availability. Even countries with lower availability reached levels of sufficiency for kilocalories, which is consistent with the FAO guidelines and the increase in obesity.[14]

The countries with the highest amounts of total available fats had a high percentage

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of calories provided by fats (between 31% and 40% of the total caloric value) and a high calorie availability, with the exception of Ecuador and Grenada that showed high fat availability and low calorie availability. The countries with the lowest total fat availability were Haiti, Peru, Bolivia, and Guyana, all of them with less than 55 grams of fat per person per day and with approximately 20% of the total caloric value supplied by fats.

The US, Argentina, Canada, and Saint Lucia are among the countries with the highest availability of animal fat, with higher availability of animal fat than the availability of total fats in the countries in the lowest limit. Five countries (Peru, Haiti, Bolivia, Guyana, Guatemala, and El Salvador) showed animal fat availability lower than 25 g per capita per day.

The abovementioned data support the literature with regard to the coexistence of hunger and obesity, and the considerable number of individuals who suffer from hunger, although the global prevalence of malnutrition has decreased.[14]

If the red meat availability mentioned above is compared with the intake recommendation to prevent colorectal cancer (a maximum of 70 grams of red meat per day), it can be observed that the availability of most of the countries in the Americas is much higher (Figure 1). Sixteen countries amply exceed the full availability of red meat. Among these, Argentina and the US stand out with an availability close to 190 g per capita per day and, followed by Uruguay, Canada, the Bahamas, and Brazil, with an availability close to 150 g per capita per day.

> Particularly in Argentina, the traditional dietary profile is characterized by a high consumption of proteins and animal fats obtained mainly from red meat, and a low intake of fish, fruits and vegetables. Furthermore, roasted grilled meat is common in the region.[4]

Only nine countries showed red meat availability lower than 50 g per capita per day (Saint Kitts and Nevis, Guyana, Nicaragua, Haiti, Guatemala, El Salvador, Jamaica, Honduras, and Peru). These countries also showed low calorie availability (with the exception of Jamaica), which could indicate that the low availability of red meat would be a consequence of low overall food availability.

The availability of alcoholic beverages showed a variability of 43%. The proportions of ethanol in beverages are highly variable and this conversion may not be accurate. The limits of alcohol intake suggested to prevent diseases vary by sex and are aimed at adults. The availability of alcoholic beverages is shown in the balance sheets per capita, without age or gender differentiation. Alcohol consumption occurs mainly in adults and adolescents and discriminates by gender, being, in general, higher in men than in women.[15] In the light of the abovementioned, of all the components of food availability, alcohol is the most difficult to compare with the recommendations; nonetheless, the comparison between countries is relevant as the limitations are the same in all countries.

The availability of fruits and non-starchy vegetables was generally low with an average of 421 g per capita per day, well below the IARC recommendations of 600 g per day.

This makes us reflect on the difficulty of individuals, in the rest of the countries, to comply with such recommendation, particularly, the less favored groups, in which the access to food is usually compromised. It would be interesting to analyze the temporary trends of availability of fruits and vegetables to elucidate whether it is a disproportionate recommendation to the historical capacity of countries to provide food or if it responds to the current situation. In this case, the following questions should be asked: What is happening that so many countries fail to reach a good availability of fruits and vegetables? Are crops decreasing? Are crops used for non-food purposes?

As regards the non-food purposes of crops, it has been argued that biofuels can also be a threat to food security, by assigning land suitable for crops to the production of cereals and seeds for energy purposes.[16]

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Analysis of colorectal cancer mortality rate

A great variability in mortality rates due to colorectal cancer was observed, both in the age-standardized rate and in the five-year-old rates from 55 to 74 years with a coefficient of variation greater than 40% in all the groups studied. Uruguay led all the mortality groups. Other countries with high mortality rates include Barbados, Argentina, Cuba, the US, and Bahamas.

It should be mentioned that among the countries with the highest rates are countries such as the US and the Bahamas with stable economies and gross domestic product of 53,000 and 31,500 dollars per capita, respectively, and the presence of Argentina, Uruguay, and Barbados with a gross domestic product (GDP) of 15,000 dollars per capita, approximately, and Cuba with a GDP of 6000 dollars per capita.

The countries with the lowest mortality rates due to colorectal cancer include: Guatemala, Canada, Mexico, Haiti, and Honduras. The presence of Canada stands out as a country with a GDP of 52,000 per capita, with a high incidence of colorectal cancer but low mortality, where early diagnosis and timely treatment would be mortality reduction factors. The other countries with low rates were countries with a GDP lower than 4,000 dollars per capita, with the exception of Mexico, a developing country with a GDP of 10,000 dollars per capita.

Analysis of the associations between food availability and colorectal cancer mortality rates

Moderate positive associations were found between the colorectal cancer mortality rate and the calorie availability of animal fat, red meat, and alcohol. The World Health Organization (WHO) panel of experts reported an unconvincing association between the consumption of animal fat and colorectal cancer.[17] In this study, the association was weak positive.

Neither does the WCRF report of 2011 on colorectal cancer and diet make any recommendations about dietary fats.[5] In this study, a weak positive association was found between the mortality rate due to colorectal cancer and the availability of total fats, which is consistent with the literature.

With respect to red meat, a traditional and pioneering ecological study conducted by Armstrong and Doll in 1975 found a correlation of 0.85 for men and 0.89 for women[7] as opposed to the correlation of 0.59 for both sexes found here.

Analysis of the strengths and limitations of this study

The traditional studies of diet and cancer have been basically ecological correlation studies in which the mortality and diet rates in central countries were compared. The data source to quantify the diet has been food availability.

In this sense, this study replicates this technique by comparing the data in the countries of the Americas covering countries located north and south of the Equator.

The role of ecological studies in nutritional epidemiology is controversial. On the one hand, they have promoted much of the cancer and diet research and emphasized the difference in mortality rates between countries. On the other hand, they have also been considered a poor source to determine causality due to their multiple confusion effects and the difficulties in measuring diet directly.[18]

As in any ecological study, special care must be taken not to commit ecological fallacy, where inferences at the individual level are deduced from the group level. The results and recommendations should be made at the same level in which the data were taken, that is at the population level.

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RECOMMENDATIONS

There are more accurate approaches to colorectal cancer and diet that were not used in this work because of the absence of good quality data in most of the countries studied.

As regards colorectal cancer, incidence is a much more accurate measure than mortality. Mortality is affected by early diagnosis and timely treatment, which differs among countries and does not depend on diet. In this sense, diagnosis and treatment can be considered as confounding factors in this study as countries with high incidence and good diagnosis and treatment will have low mortality, for instance, Canada. Unfortunately, there is also great difference in the quality of incidence data between developed and developing countries.

There is a lack of high-quality records in Latin America and the Caribbean. According to *Cancer incidence in five continents 2007*, Volume IX, published by the IARC, only 6% of the population is covered by population-based cancer registrations, in contrast to 83% in North America and 32% in Europe.[19]

Food availability as a way to characterize diet has been widely used; however, it has some important limitations: it is not categorized differentiated by sex, age, or special conditions, and does not show the availability of food items. Fifty years ago, this was not relevant, but currently a large part of the diet is based on ultra-processed foods. Therefore, processed meats have not been included in this study due to the lack of data.

According to the panel of experts of the WHO on diet and chronic diseases, in order to better understand the association between the characteristics of food consumption, diets, and the onset of noncommunicable diseases, it is crucial to obtain more reliable information on the actual patterns and trends of food consumption based on representative studies of consumption.[20] It is essential to use a direct way of measuring diet, which not only discriminates by type of basic food, but also differentiates processed foods. Therefore, to overcome this, European studies on diet and cancer have used other methodologies and, based on the data from these studies, the WCRF recommendations used in this study were formulated.[5,6,7,8,9,12,13,14,17]

The *European Prospective Investigation into Cancer and Nutrition* (EPIC) is one of the largest cohort studies in the world with 521 million participants recruited from 10 countries and followed up for 15 years. It uses a combination of methods to measure the diet of the population. By using a combination of methods, the limitations of each method are reduced separately.

If the incidence of cancer registration was improved and a way of measuring diet in the countries of the Americas was systematized, it would be possible to gain access to reliable information that would allow to relate diet and colorectal cancer in the region more accurately. Moreover, the registration of the incidence of cancer and diet in a direct form would allow associations to be made with other variables of interest, such as the socioeconomic status, sex, obesity, physical activity, among others, which could be operating in this phenomenon of disease and health.

CONCLUSIONS

There is great variability of food availability in the countries of the Americas and in mortality rates from colorectal cancer. There is full availability of calories, total fats, animal fat, and red meat in most countries which do not reach sufficient availability of fruits and vegetables to comply with IARC guidelines. This deserves further analysis as this group of foods is considered fundamental in a healthy diet.

Middle and high-income countries were among the countries with the highest mortality rates from colorectal cancer. Moderate positive associations were found between the mortality rate from colorectal cancer and the calorie availability of animal fat, alcoholic beverages, and red meat. This fact is consistent with previous literature findings, but

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with different strength. The association found with animal fat was stronger in this study than that reported in the literature; and for the other variables, the association was weaker than previously reported. A weak positive association was found among the mortality rate from colorectal cancer, the availability of fat, and the availability of non-starchy fruits and vegetables, as opposed to the guidelines that would suggest a protective effect.

It would be advisable to improve the tumor incidence records to be included in future studies instead of mortality records. It would be equally important to systematize direct ways of measuring diet for a more accurate approach to population diets. If the records of obesity and physical activity at country level could be generalized, it would be very useful to include them in future studies along with the socioeconomic status of the countries.

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