ELSEVIER

Urologic Oncology: Seminars and Original Investigations 24 (2006) 184–194

UROLOGIC ONCOLOGY

Original article

International comparisons of prostate cancer mortality rates with dietary practices and sunlight levels

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Received 14 March 2005; received in revised form 19 May 2005; accepted 20 May 2005

Abstract

Prostate cancer mortality rates vary widely across the world. The purpose of this study is to identify environmental factors associated with prostate cancer mortality risk. Prostate cancer mortality rates in 71 countries were compared to per capita food intake rates using age-adjusted cancer rates (year 2000) from the International Agency for Research on Cancer, and food consumption data (1990–1992) provided by the Food and Agricultural Organization of the United Nations. Simple regression models were applied to prostate cancer mortality rates and consumption rates for 38 foods (or food categories), and sunlight levels (latitude from the equator and ultraviolet indexes). The analysis found a correlation between increased prostate cancer mortality rates and the consumption of total animal calories, total animal fat calories, meat, animal fat, milk, sugar, alcoholic beverages, and stimulants. The consumption of cereal grains and rice, in particular, correlated strongly with decreasing prostate cancer mortality. The analysis found that increased sunlight levels and consumption of oilseeds, soybeans, and onions also correlate with decreased prostate cancer mortality risk. Stepwise multiple regression analysis was used to build a regression model with minimum colinearity between the variables. Cereals, total animal fat calories, sugar, and onions are the foods that resulted in a model with the best fit. Cereals, ultraviolet index, sugar, and onions were the variables found to provide the best fit in a model when ambient sunlight exposure was included as a factor.

Keywords: Prostate cancer; Epidemiology; Cancer prevention; Diet; Sunlight; International

1. Introduction

In some countries such as China and Vietnam, average annual prostate cancer mortality rates are approximately 1 death per 100,000 people, while in other countries such as Norway and Sweden, the rate is approximately 27 deaths per 100,000 [1]. Prostate cancer risk appears to be associated with environmental factors because prostate mortality rates change when people migrate to other countries and change lifestyles. Some researchers believe that dietary practices may contribute to a large part of prostate cancer risks. Also, there is increasing evidence that exposure to sunlight may reduce the risk from prostate cancer. In this study, we have focused on the effect of 2 factors on prostate cancer mortality: the consumption of various foods and ambient sunlight exposure.

The World Health Organization has compiled cancer incidence and mortality rates from a large number of countries. Consumption rates for various foods and food categories are available from the Food and Agricultural Organization (FAO) of the United Nations for a large number of countries. The approach is to compare prostate cancer mortality rates to consumption rates for foods consumed in various countries and ambient sunlight levels in those countries to determine if there are correlations that suggest associations. We will then search the literature to determine whether studies by other researchers corroborate these associations.

2. Methods

Age-standardized prostate cancer mortality rates for 71 countries were obtained from the GLOBOCAN 2000 database [1]. The GLOBOCAN 2000 database, which has been developed by the International Agency for Research on Cancer (IARC), has compiled data on cancer incidence,

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1078-1439/06/$ – see front matter
doi:10.1016/j.urolonc.2005.05.023

mortality, and prevalence on most of the countries of the world. The disease rates are not necessarily for the year 2000 but for the most recent data available, generally 3–5 years earlier. Incidence and mortality rates by age group (0–14, 15–44, 45–54, 55–64, 65+ years old) were gathered by IARC for as many countries as possible. Mortality data by cause are available from many countries because of registration of vital events, although the quality of the data varies considerably. Depending on the quality of the data, one of the following methods was used by IARC for determining national cancer mortality rates: (1) national mortality data was used, (2) local mortality data was used to establish national mortality data, (3) mortality was estimated from incidence because mortality data were not available or known to be of poor quality, and (4) mortality rates were calculated from the average of neighboring countries in the same region because no other data were available. For this study, we selected countries in which the prostate cancer mortality rates exceeded 100 deaths per year and excluded countries with IRAC data based on the fourth method previously discussed.

The following countries with prostate cancer mortality data derived from aforementioned methods 1 and 2 were selected for inclusion in the study: Canada, Costa Rica, Cuba, Dominican Republic, Jamaica, Mexico, Panama, United States, Argentina, Brazil, Chile, Columbia, Ecuador, Uruguay, Venezuela, China, Israel, Japan, Jordan, Korean Republic, Azerbaijan, Uzbekistan, Austria, Belarus, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Ukraine, Spain, Sweden, Switzerland, the United Kingdom, Australia, and New Zealand. The following countries with prostate cancer mortality data through method 3 were selected for inclusion in the study: Nicaragua, Bolivia, Paraguay, Peru, Algeria, Tunisia, Myanmar, Cambodia, Cyprus, India, Indonesia, Laos, Malaysia, Pakistan, Philippines, Syria, Thailand, Turkey, and Vietnam. The GLOBOCAN 2000 database contained age-standardized prostate cancer mortality rates calculated from crude rates that were used in this study.

Per capita food consumption rates for each country were obtained from the FAOSTAT database [2] compiled by the FAO of the United Nations. Country level data are collected for the FAOSTAT database by questionnaires sent annually to member countries. When data from member countries are missing, as may be the case for developing countries, FAO statisticians compile secondary derived statistics. Information on domestic production, imports, exports, and losses were used by FAO statisticians for estimating per capita consumption levels for foods in the FAOSTAT database. For this study, we selected per capita consumption rates for the following foods or food categories: total caloric intake (total calories); total calories from animal sources (total animal); total animal fat; cereals; wheat; rice; maize; rye; barley; potatoes; sugar; pulses; beans; peas; tree nuts; oil seeds; soybeans; vegetable oils; soybean oil; sunflower oil; groundnut oil; rape/mustard oil; olive oil; vegetables; tomatoes; onions; other vegetables; fruits; bananas; stimulants; coffee; cocoa; alcoholic beverages; beer; beverages alcoholic other than beer and wine; meat; offal; animal fat; milk; eggs; fish; freshwater fish; demersal fish; and pelagic fish. In all cases, the units of the food consumption rates are calories per day. Food consumption data for the year 1990 were used when they were available. Where food consumption data were unavailable for 1990 (as was the case for Azerbaijan, Uzbekistan, Belarus, Russian Federation, Slovakia, Slovenia, and Ukraine), food consumption data for 1992 were used.

Latitudes from the equator were obtained by estimating values at the geographic center of each country from a standard world atlas [3]. The ultraviolet indexes were read from maps obtained from that that were developed by the Tropospheric Emission Monitoring Internet Service (TEMIS) [4]. TEMIS is part of the Data User Program of the European Space Agency. The ultraviolet index is the effective irradiance (1 U equals 25 mW/m2) reaching the earth's surface under clear sky conditions for the local solar noon. The algorithm that is used by TEMIS applies a functional relation between the ultraviolet index, the local solar noon ozone field, and the solar zenith angle at the local solar noon.

2.1. Statistical analysis

Initially, the data for all foods or food categories were examined for normalcy and to identify outlier values. Mean, maximum, minimum, and percentile values (25th and 75th) were determined for each variable (Table 1). Simple regression coefficients (B), Pearson correlation coefficients (R), and probability values (P) to test the null hypothesis that the parameter is actually zero were calculated to examine the association between prostate cancer mortality rates and consumption of each independent variable that showed normal or near normal characteristics. All P values presented are 2-sided. The 95% confidence interval (CI) for the regression coefficient was also calculated. In those cases in which the independent variable did not possess a normal or near normal distribution, Spearman correlation coefficients (R) and the associated probability values were calculated.

Foods or food categories that showed a strong correlation ($P < 0.05$) with prostate cancer mortality were subject to stepwise multiple regression analysis. Stepwise regression procedures are semiautomated processes of building a regression model by successively adding or removing variables based solely on the P values of the estimated coefficients. The objective of the variable selection process is to obtain a balance between model simplicity and goodness of fit. Also, stepwise regression procedures were used to identify colinearity (linear or nearly linear relationships) between the independent vari-

Table 1
Summary statistics for prostate cancer mortality rate/100,000, per capita average daily food intake (calories) latitude from the equator and ultraviolet index

Variable	Number of countries	Mean	Minimum	Maximum	Percentile values	
					25th	75th
Mortality rate	71	13.2	1.0	27.3	6.8	18.5
Total calories	71	2928	1830	3711	2533	3312
Total animal	71	687	95	1337	335	1039
Total animal fat	71	446	54	1014	210	687
Meat	71	258.1	20	536	128	392
Offals	71	11.0	2	59	5	15
Animal fat	71	134.5	9	525	35	197
Milk	71	139.9	2	402	88	209
Eggs	71	35.0	2	87	18	49.0
Fish	71	32.0	1	199	11	39.0
Freshwater	71	3.9	0	17	2.0	5.0
Demersal	57	10.7	0	80	2.0	11.0
Pelagic	64	14.8	0	90	4.3	20.0
Cereals	71	1106	542	2109	803	1412
Wheat	70	658	4.0	1645	330	990
Rice	71	297	9.0	2044	38	416
Maize	67	103	0	1091	18	141
Barley	65	15.8	0	141	0	13.0
Rye	51	43.7	0	512	0	56.0
Potatoes	70	88.6	1	310	23	130
Sugar	71	321	8.0	577	253	412
Pulses	71	42.3	0	171	17	50
Beans	68	21.6	0	171	6.0	27.5
Peas	58	9.2	1	42	2.0	13
Tree nuts	69	13.9	0	60	3.0	22
Oil seeds	71	31.3	0	206	8	39
Soybeans	60	7.5	0	122	0	2.8
Vegetable oils	71	294	25	638	196	396
Soybean	66	89.3	0	431	23	127
Sunflower	62	66.9	0	31	5.8	105
Groundnut	59	8.4	0	78	0	7.0
Rape/mustard	43	56.8	0	246	6.0	109
Olive	57	29.1	0	424	1.0	10.0
Vegetables	71	54.4	6	151	28.0	74.0
Tomatoes	67	11.3	1	58	4.0	13.0
Onions	67	7.0	0	25	4	9.0
Other vegetables	71	38.1	3	141	19.0	50.0
Fruits	71	102.0	18	320	59.0	133
Bananas	65	19.9	0	87	7.0	25.0
Stimulants	71	12.3	0	67	3.0	16.0
Coffee	69	3.8	0	16	1.0	5.0
Cocoa	65	8.3	0	56	1.0	10.0
Alcoholic beverages	71	111.6	0	298	50.0	171.0
Beer	70	53.5	0	195	9.0	88.0
Hard liquor	70	33.3	0	108	11.8	57.0
Latitude	71	34.2	0	64	22.0	47.0
Ultraviolet index	71	7.5	2	14	5.0	10.0

ables. Colinearity between the independent variables causes problems for regression analysis and makes it difficult to make any conclusions from the results. The approach in this study is to identify independent variables that show colinearity and select a single variable from the pool having a high regression coefficient and low *P* value. All data in this study were analyzed using the SPSS Base for Windows software program (version 12.0, SPSS, Inc., Chicago, IL).

3. Results

In Table 2, linear regression coefficients (B) for daily food intakes (calories) and age-standardized prostate mortality rates are presented with 95% CIs, Pearson correlation coefficients (R), and probability values (*P*). The strongest correlation between increased prostate cancer mortality and foods are: sugar (R = 0.71), total animal calories (R = 0.70), total animal fat calories (R = 0.67), meat (R = 0.65),

Table 2
Regression coefficients (B) for per capita food intake (calories/d) and sunlight levels compared to age-standardized prostate cancer mortality rates with 95% confidence intervals, correlation coefficients (R), and probability values (*P*)

Variable	Number of countries	B	95% CI		R	*P*
			Lower	Upper		
Total calories	71	0.005	0.002	0.009	0.38	0.004
Total animal	71	0.014	0.010	0.017	0.70	0.0001
Total animal fat	71	0.017	0.013	0.022	0.67	0.0001
Meat	71	0.029	0.021	0.038	0.65	0.0001
Offal	71	0.328	0.144	0.512	0.39	0.001
Animal fat	71	0.031	0.019	0.043	0.55	0.0001
Milk	71	0.047	0.030	0.064	0.57	0.0001
Eggs	71	0.099	0.014	0.185	0.27	0.023
Fish	71	0.027	0.026	0.081	0.12	0.31
Freshwater	70	−0.363	−0.821	0.094	−0.19	0.12
Pelagic	64	−0.021	−0.130	0.088	−0.05	0.70
Cereals	71	−0.016	−0.019	−0.013	−0.82	0.0001
Wheat	70	−0.003	−0.007	0.001	−0.18	0.15
Rice	71	−0.008	−0.011	−0.006	−0.60	0.0001
Maize	67	0.004	−0.007	0.015	0.09	0.48
Potatoes	70	0.027	0.005	0.050	0.28	0.018
Sugar	71	0.037	0.028	0.046	0.71	0.0001
Pulses	71	−0.003	−0.050	0.044	−0.02	0.90
Beans	68	0.009	−0.046	0.064	0.04	0.75
Peas	58	0.100	−0.090	0.291	0.14	0.30
Tree nuts	69	0.082	−0.037	0.200	0.17	0.17
Oil seeds	71	−0.054	−0.100	−0.008	−0.27	0.021
Vegetable oils	71	0.016	0.004	0.028	0.31	0.008
Soybean	66	0.026	0.007	0.046	0.32	0.010
Sunflower	62	−0.002	−0.026	0.021	−0.03	0.84
Rape/mustard	43	0.029	−0.010	0.068	0.23	0.15
Vegetables	71	−0.017	−0.070	0.037	−0.08	0.53
Tomatoes	67	−0.068	−0.225	0.088	−0.11	0.39
Onions	67	−0.351	−0.701	−0.002	−0.26	0.049
Other vegetables	71	−0.023	−0.098	0.052	−0.07	0.55
Fruits	71	0.056	0.027	0.086	0.42	0.0001
Bananas	65	0.093	0.007	0.180	0.26	0.035
Stimulants	71	0.242	0.136	0.349	0.48	0.0001
Coffee	69	1.095	0.776	1.414	0.65	0.0001
Cocoa	65	0.179	0.045	0.314	0.32	0.010
Alcoholic beverages	71	0.050	0.034	0.067	0.60	0.0001
Beer	71	0.074	0.049	0.100	0.59	0.0001
Hard liquor	70	−0.003	−0.069	0.064	−0.01	0.93
Latitude	71	0.14	0.044	0.240	0.33	0.003
Ultraviolet index	71	−0.81	−1.292	−0.322	−0.38	0.001

Abbreviations: B = coefficient from regressing prostate cancer mortality on the independent variable; *P* = probability value used to test the null hypothesis H_o: B = 0; R = Pearson correlation coefficient.

coffee (R=0.65), alcoholic beverages (R = 0.60), milk (R = 0.57), animal fat (R = 0.55), stimulants (R = 0.48), offal (R = 0.39), and total calories (R = 0.38). The correlation between increased prostate cancer mortality and sugar consumption can be seen in Fig. 1.

In those cases in which the independent variable did not show a normal or near normal distribution, Spearman correlation coefficients (R) and the associated probabilities were calculated. These are: barley (R = −0.018, *P* = 0.89); rye (R = 0.23, *P* = 0.10); soybeans (R = −0.40, *P* = 0.002); groundnut oil (R = 0.044, *P* = 0.74); olive oil (R = 0.08, *P* = 0.55); and demersal fish (R = 0.40, *P* = 0.002).

The strongest correlation between decreased prostate cancer mortality and foods are cereals (R = −0.82), rice (R = −0.60), soybeans (R = −0.40), oil seeds (R = −0.27), and onions (R = −0.26). The correlation between decreased prostate cancer mortality and cereal consumption can be seen in Fig. 2.

In Table 3, regression coefficients (B) for sunlight levels (latitude from the equator and ultraviolet index) and age-standardized mortality rates with 95% CIs and probability values are presented. There is a positive association between prostate cancer mortality and increased latitude (B = 0.14), and a negative association between prostate cancer and increased ultraviolet index (B = −0.81), which are consistent. The correlation coefficient for the ultraviolet index

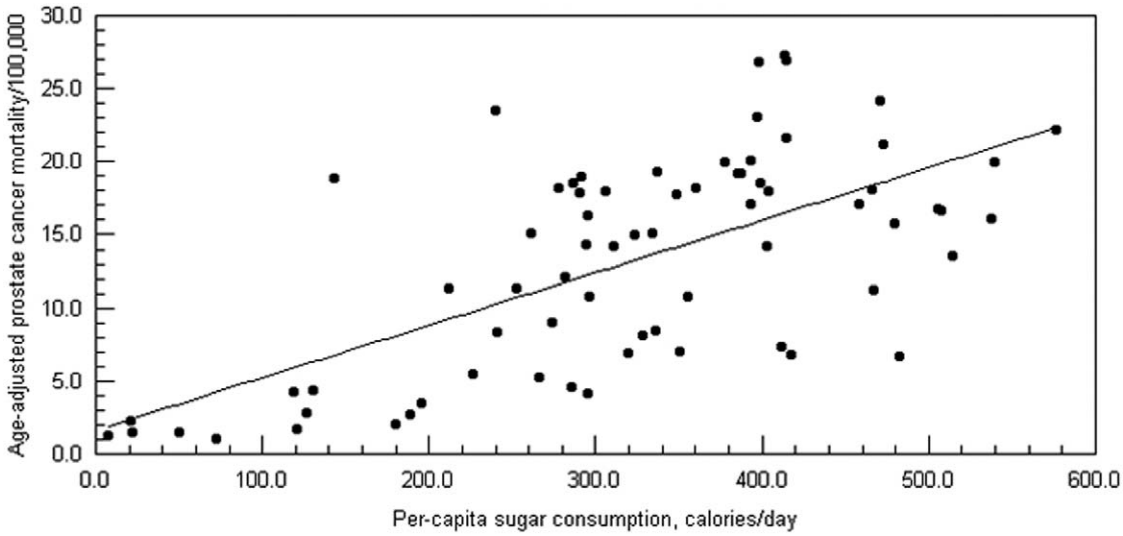

Fig. 1. Prostate cancer mortality versus sugar consumption in 71 countries.

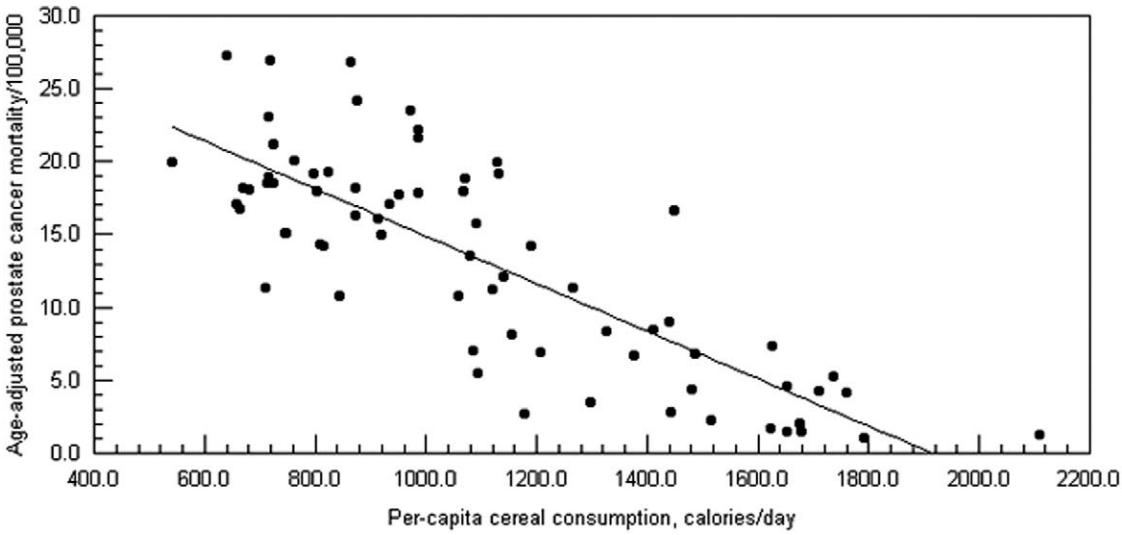

Fig. 2. Prostate cancer mortality versus cereal consumption in 71 countries.

Table 3
Regression coefficients (B) latitude from the equator and age-standardized prostate cancer mortality rates with 95% CIs, correlation coefficients, and *P* values

	Variable	
	Latitude	Ultraviolet index
Number of countries	71	71
B	0.14	−0.81
95% CI		
Lower	0.044	−1.292
Upper	0.240	−0.322
R	0.33	−0.38
P Value	0.003	0.001

Abbreviations: B = coefficient from regressing prostate cancer mortality on the independent variable; *P* = probability value used to test the null hypothesis H_o:B = 0; R = Pearson correlation coefficient.

(R = −0.38) is higher than that for latitude (R = 0.33), and the *P* value is lower for ultraviolet index (*P* = 0.001) than for latitude (*P* = 0.003). These data suggest that sunlight exposure is the cause of the correlation with prostate cancer mortality because ultraviolet index is a better indicator of sunlight exposure than latitude.

Stepwise multiple regression analysis between prostate cancer mortality and independent variables with the strongest correlations were conducted to develop the best multivariable regression model from the data generated in this study. Evaluation of the correlation matrix generated as part of the analysis indicated that total animal calories, total animal fat, meat, animal fat, alcoholic beverages, latitude, and ultraviolet index showed colinearity because the correlation coefficients were high, ranging from 0.922 to 0.782.

Table 4
Stepwise multiple regression analysis on independent variables with age-standardized prostate cancer mortality rates: regression coefficients (B), probability values (*P*), and effect of the variable across the interquartile

	Variable			
	Total animal fat	Sugar	Cereal	Onions
B	0.005	0.015	−0.011	−0.356
95% CI				
Lower	0.000	0.007	−0.014	−0.554
Upper	0.009	0.023	−0.008	−0.158
P Value	0.03	0.001	0.0001	0.001
BX_{75}–BX_{25}	2.4	2.4	−6.7	−1.8

Abbreviations: B = coefficient from regressing prostate cancer mortality on the independent variable; BX_{75}–BX_{25} = estimated effect of the variable across the interquartile (deaths/100,000 population); *P* = probability value used to test the null hypothesis H_o:B = 0.

"Total animal fat" was selected as the independent variable from this group to be used in the final model. By successfully adding or removing variables based solely on the *P* values of the estimated coefficients, a regression model was built using the following foods or food categories: total animal fat, sugar, cereal, onions, milk, oil seeds, soybeans, stimulants, coffee, and total calories. This process resulted in a model containing total animal fat, sugar, cereals, and onions as the independent variables with the lowest *P* values. Regression coefficients for each of the variables with 95% CIs, *P* values, and the estimated effect of the independent variable across the interquartile are provided in Table 4.

A model using ultraviolet index in place of total animal calories was developed because of the strong colinearity detected between these 2 variables to disallow their use together. This process resulted in a model containing ultraviolet index, sugar, cereals, and onions as the independent variables. Regression coefficients for each of the variables with 95% CIs, *P* values, and the estimated effect of the independent variable across the interquartile are provided in Table 5. Data on prostate cancer mortality and the independent variables for the 71 countries used in the final models developed from the stepwise multiple regression analysis are provided in Table 6.

4. Discussion

Studies from the 1970s showed a strong positive association between prostate cancer mortality and fat consumption [5–7]. Many case-control studies have examined the association between fat and prostate cancer, [8-21] and only 3 studies failed to show a positive association with total fat intake [13,16,19]. The association between fat intake and prostate cancer has been investigated in at least 6 cohort studies [22-27]. A positive association was reported in 4 of the studies [22-25], while 2 other studies [26,27] did not detect an association. Dietary fat intake has been more consistently linked to prostate cancer than any other food category.

A strong association between sugar consumption and prostate cancer mortality was found in this study, and sugar consumption was not found to show colinearity with any other independent variable such as total animal calories, total animal fat, meat, or animal fat consumption. An earlier cross-international study [28] comparing prostate cancer mortality and food consumption rates also presented data indicating that sugar consumption correlated strongly with increased prostate cancer mortality. The association between diabetes and prostate cancer risk has been widely studied in the past. As reported by Gapstur et al. [29], the findings from 14 past epidemiologic studies have been in-

Table 5
Stepwise multiple regression analysis on independent variables with age-standardized prostate cancer mortality rates: regression coefficients (B), probability values (*P*), and effect of the variable across the interquartile

	Variable			
	Ultraviolet index	Sugar	Cereal	Onions
B	−0.270	0.016	−0.012	−0.284
95% CI				
Lower	−0.583	0.007	−0.015	−0.490
Upper	0.043	0.024	−0.009	−0.077
P Value	0.09	0.001	0.0001	0.008
BX_{75}–BX_{25}	1.6	2.5	−7.3	−1.4

Abbreviations: B = coefficient from regressing prostate cancer mortality on the independent variable; BX_{75}–BX_{25} = estimated effect of the variable across the interquartile (deaths/100,000 population); *P* = probability value used to test the null hypothesis H_o:B = 0.

Table 6
Prostate cancer mortality and independent variables used in models from stepwise multiple regression analysis

Country	Prostate cancer mortality*	Total fat[a]	Sugar	Cereals	Onions	Ultraviolet index[b]
Algeria	4.57	40.2	286	1654	8	9
Argentina	17.68	156	349	952	13	7
Australia	18.01	158	466	683	6	8
Austria	18.95	167	292	718	6	5
Azerbaijan	4.31	37.9	131	1482	7	7
Belarus	8.13	71.5	329	1157	4	5
Bel-Lux	19.99	176	394	764	7	4
Brazil	17.02	150	458	934	6	11
Bulgaria	8.95	78.8	274	1441	7	5
Cambodia	2.21	19.5	21	1518	–	11
Canada	17.07	150	394	659	6	5
Chile	19.94	175	378	1129	15	7
China	1.03	9.1	73	1792	4	8
Columbia	15.08	133	334	745	12	14
Costa Rica	16.03	141	538	914	5	11
Cuba	22.11	195	577	988	2	10
Cyprus	10.7	94.2	356	846	13	7
Czech Republic	15.74	139	480	1092	10	5
Denmark	23.07	203	397	717	7	3
Dominican Republic	18.11	159	278	669	2	10
Ecuador	14.95	132	324	920	–	14
Finland	19.11	168	388	798	4	3
France	19.23	169	337	824	5	4
Germany	18.45	162	287	726	6	4
Greece	10.7	94.2	297	1061	12	6
Hungary	17.93	158	404	1068	11	5
Iceland	16.69	147	506	666	3	2
India	2.76	24.3	127	1445	3	12
Indonesia	4.21	37	119	1711	3	14
Ireland	21.58	190	415	987	7	3
Israel	14.21	125	403	1192	14	7
Italy	12.09	106	282	1142	7	6
Jamaica	24.1	212	471	876	2	10
Japan	5.47	48.1	227	1094	11	7
Jordan	6.77	59.6	418	1489	8	7
Korea Republic	2	17.6	180	1678	9	7
Laos	1.47	12.9	22	1680	–	11
Malaysia	7	61.6	351	1087	7	14
Malta	13.49	119	515	1080	8	8
Mexico	16.59	146	508	1449	1	9
Myanmar	1.2	10.6	8	2109	4	11
Netherlands	19.96	176	540	542	3	3
New Zealand	21.19	186	473	725	–	6
Nicaragua	19.11	168	386	1134	2	11
Norway	26.76	235	398	866	0	3
Pakistan	3.42	30.1	196	1298	6	9
Panama	16.28	143	296	874	3	11
Paraguay	11.28	99.2	212	710	7	8
Peru	14.22	125	311	817	6	14
Philippines	11.3	99.4	253	1268	1	14
Poland	11.22	98.7	467	1121	13	4
Portugal	17.86	157	291	987	7	6
Romania	8.27	72.8	241	1329	10	5
Russia	6.84	60.2	320	1208	10	4
Slovakia	14.3	126	295	810	7	4
Slovenia	18.81	166	143	1072	6	4
Spain	15.04	133	262	750	20	6
Sweden	27.26	240	414	641	5	3
Switzerland	26.89	237	415	720	0	5

Table 6
(continued)

Country	Prostate cancer mortality*	Total fat[a]	Sugar	Cereals	Onions	Ultraviolet index[b]
Syria	8.45	74.4	336	1412	5	7
Thailand	2.65	23.3	189	1180	3	11
Tunisia	5.17	45.5	267	1737	5	8
Turkey	4.14	36.4	296	1762	25	7
United Kingdom	18.5	163	399	715	9	3
Ukraine	6.64	58.4	483	1377	10	5
Uruguay	23.52	207	240	974	5	9
United States	17.9	158	306	803	8	7
Uzbekistan	1.64	14.4	121	1625	9	7
Venezuela	18.17	160	361	873	3	12
Vietnam	1.4	12.3	50	1654	2	11
Yugoslavia	7.29	64.1	412	1628	13	6

"–" indicates missing data.
* Deaths per 100,000 population.
[a] Food consumption per capita in calories per day.
[b] The effective irradiance reaching the earth's surface under clear sky conditions at noon.

consistent, although 3 of the studies found prostate cancer risk increased during the early stages of diabetes but declined later. Increased levels of insulin have been suggested to explain the increased risk of prostate cancer by most investigators. The increased prostate cancer risk during the early stages of diabetes mellitus with a decline in the later stages of the disease could be explained by a 2-step process for the development of type II diabetes that has been proposed [30]. In the first step of the disease, insulin secretion increases in response to insulin resistance, although there is a transition from normal to impaired glucose tolerances. In the second stage of type II diabetes mellitus, there is a decline of insulin secretion.

Several investigators compared the association between serum glucose and insulin levels to prostate cancer risk. Some studies [29,31,32], although not all [33,34], found a positive association. Although past epidemiologic studies linking insulin resistance and prostate cancer risk have been inconsistent, an association between high plasma insulin levels and prostate cancer is suggested by theoretical considerations. Insulin has had a dose-related growth promoting effect on prostate cancer cells in vitro [35]. Also, high concentrations of insulin may increase the bioavailability of insulin-like growth factor-1 (IGF-1) [29]. In vitro, IGF-1 has increased prostate cell proliferation [36]. Four studies have shown a strong association between prostate cancer risk and IGF-1 plasma concentrations [33,37-39].

The range of sugar consumption rates between inhabitants of countries in this study is very high (from 8 to 577 calories per day). The increased prostate cancer risk found may result from insulin levels and circulating IGF-1 plasma concentrations, which remain increased for extensive periods because of dietary practices, not abnormal glucose metabolism. This result may explain why the association between sugar consumption and increased prostate cancer mortality rates was seen in this study and the other international study [28], which compared prostate cancer mortality rates to a wide range of sugar consumption rates.

In this study, we found that alcohol consumption does not have an independent association with prostate cancer mortality but is interrelated to total animal calories, total animal fat, meat, and animal fat consumption. Virtually all past studies in the literature have indicated the absence of an overall relationship between prostate cancer risk and the consumption of alcoholic beverages [10,23,26,40-50]. Coffee consumption had an association with prostate cancer incidence in a retrospective cohort study [51], and in another study [52] comparing prostate cancer risk and world dietary practices. However, a large number of studies in the literature found no association between prostate cancer risk and the consumption of coffee [26,46,53-55].

Consumption of cereal grains strongly correlated with reduced prostate cancer mortality risk in this study and several past international studies [28,56]. The cereal grains that are consumed to the largest extent in the world are wheat, rice, and maize. Our analysis found that rice is the grain that has the strongest correlation with decreasing prostate cancer mortality, while wheat and barley have a weaker association. We found no association between maize or rye consumption and prostate cancer mortality.

A prospective study of men of Japanese ancestry found a decreased risk of prostate cancer was associated with the consumption of rice [57], which supports findings from this study. Cereals contain phytoestrogens such as lignan, plant stanols and sterols, as well as antioxidants, all of which are believed to be protective. However, a study of antioxidants in grains found that corn had the highest antioxidant activity, followed by wheat, oats, and, finally, rice [58]. These results contradict the order of protection afforded by cereals found in this study, suggesting antioxidants are not the component in grains responsible for protection from prostate cancer. It has been suggested that the consumption of

whole grain cereals mediates insulin and glucose response, thereby decreasing the observed risk of colon and breast cancer [59]. This hypothesis is consistent with results of this study implicating sugar consumption with prostate cancer mortality.

The regression analysis conducted in our study indicates that vegetables as a group are weakly associated with prostate cancer mortality protection. We also compared prostate cancer mortality risk to 3 subcategories of vegetables: tomatoes, onions and other vegetables. In our study, consumption of tomatoes was very weakly associated with a reduction in prostate cancer risk ($R = -0.11$, $P = 0.2$). Other researchers have found a correlation between consumption of tomatoes and reduced prostate cancer risk [22,60].

We found that consumption of onions showed a moderately strong correlation with prostate cancer mortality ($R = -0.26$, $P = 0.02$), with a high negative regression coefficient ($B = -0.35$), suggesting that the protective effects, if present, are high. There is increasing evidence that *Allium* vegetables, including garlic, scallions, onions, chives, and leeks, have tumor inhibiting properties in laboratory studies [61-67]. Another study [68] found that *Allium* vegetables inhibit the proliferation of the human prostate cell cancer lines. In several population-based case-control studies [69,70], the consumption of *Allium* vegetables reduced prostate cancer risk.

In this study, we found that prostate cancer mortality risk increases with latitude from the equator ($B = 0.14$, $P = 0.003$) and ultraviolet index ($B = -0.81$, $P = 0.001$). This is consistent with results found by other researchers. It has long been hypothesized that vitamin D deficiencies may be a risk factor for prostate cancer [71,72]. Since the major source of vitamin D results from exposure to ultraviolet light, several studies have been conducted to determine whether there is a correlation with prostate cancer risk and exposure to sunlight. In a study [73] of prostate cancer mortality in 3,073 counties in the United States with differing ultraviolet radiation, prostate cancer mortality was found to decrease with increasing ultraviolet radiation ($P < 0.0001$). More recently, a death certificate case-control study [74] in the United States found that prostate cancer mortality correlated with residential exposure to sunlight but not occupational exposure to sunlight. Another study [75] of 210 cases of prostate cancer and 155 controls found that the development of prostate cancer correlated with low ultraviolet radiation exposure in the past. The correlation between prostate cancer mortality and sunlight levels found in this study is consistent with results observed by others, although the strength of the association ($P = 0.003$ for latitude and $P = 0.001$ for ultraviolet index) may have been weaker because of the wide variation in lifestyles and diets of the inhabitants of the countries in this study.

The results of this study have a degree of uncertainty. Therefore, the results should not be used for dietary recommendations but may provide additional insights into risk factors for prostate cancer that need to be corroborated or disproved by further research. The data from this study are aggregated, and what may apply on a population basis may not necessarily be observed on an individual basis. Aggregating data by country does not allow consideration or relationships within a country, and limits control of confounders and effects modifiers. Also, differences in the lifestyles among men of different countries may influence prostate cancer risk, and these factors have not been considered. For example, although there is some evidence that physical activity and body weight affect prostate cancer risk, we were not able to consider these confounding factors because of the lack of data.

Although the GLOBOCAN 2000 database has been built using a large amount of data available to IARC, there is uncertainty in the data from some countries. There are errors in converting crude rate prostate cancer mortality rates to age-standardized rates, although excluding countries with poor prostate cancer mortality data has tended to exclude countries having populations with low life spans, where the errors are highest. The data on food consumption obtained from the FAO database may have a high degree of uncertainty. Per capita food intake levels are obtained from food that is produced and imported, reduced by food that is exported and wasted. It does not consider variations that can occur throughout each country as a result of affluence or ethnicity.

5. Conclusions

Linear regression models gathered in this study suggest that animal fats, sugar, cereals, onions, and sunlight levels are the variables associated with prostate cancer prostate mortality. There is a strong body of past research linking prostate cancer risk to the consumption of animal fats, so that the results from this study regarding fats supplement existing evidence. The results of this study regarding protection from prostate cancer risk afforded by sunlight are also consistent with several studies in the literature. This study, and several earlier international studies, found a strong correlation between the consumption of cereals and reduced prostate cancer risk. We identified rice and, to a lesser extent, wheat and barley as the cereals most strongly associated with affording protection.

The reduction in prostate cancer mortality resulting from estimating the effect of cereals across the interquartile in this study is more than the combined increases from meat and sugar consumption (Table 4). In as much cereal consumption is projected to have such a large positive effect on prostate cancer mortality and the correlations from 3 other international studies [28,52,57] also suggest a strong association, more research to investigate the effect of cereal consumption on prostate cancer risk may be warranted. There is a growing body of evidence that *Allium* vegetables, including onions, provide protection from a variety of can-

cers, including prostate cancer, which is supported by the data from this study. There is strong correlation between the consumption of sugar and prostate cancer mortality found in this study and in an earlier international study [28] conducted on a similar basis.

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