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Investigating the dietary links to pancreatic cancer: A case–control study on dairy, meat, and egg consumption

Sabika Allehdan[1], Mohammed O. Ibrahim[2], Narmeen Al-Awwad[3], Aya Hamdan[4], Tareq Al-Jaberi[5], Ahmad F. Hushki[6], Yaser Rayyan[7], and Reema F. Tayyem[4]*

[1]Department of Biology, College of Science, University of Bahrain, Zallaq, Sakhir, Bahrain

[2]Department of Nutrition and Food Technology, Faculty of Agriculture, Mu'tah University, Mu'tah, Karak, Jordan

[3]Department of Clinical Nutrition and Dietetics, Faculty of Applied Medical Sciences, Hashemite University, Zarqa, Jordan

[4]Department of Human Nutrition, College of Health Sciences, Qatar University, Doha, Qatar

[5]Department of General and Pediatric Surgery, Faculty of Medicine, Jordan University of Science and Technology, Al Ramtha, Irbid, Jordan

[6]Gastroenterology Division, King Hussein Cancer Center, Amman, Jordan

[7]Department of Gastroenterology and Hepatology, Faculty of Medicine, The University of Jordan, Amman, Jordan

***Corresponding author:**
Reema F. Tayyem
(reema.tayyem@qu.edu.qa)

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Abstract

Research has demonstrated that the intake of specific foods and nutrients is linked to the risk of pancreatic cancer, but the role of meat and dairy consumption in pancreatic carcinogenesis remains controversial. The main objective of this study is to investigate the association between the intake of dairy products and meats and the risk of pancreatic cancer. A case–control study was conducted between March 2015 and August 2018 at four main hospitals in Jordan; one of the hospitals was an oncology center. Participants in the study included 101 histologically confirmed pancreatic cancer patients, which were frequency-matched with 314 controls. The required information for this study was gathered through questionnaires based on face-to-face interviews. An Arabic food-frequency questionnaire that has been validated was used to collect data on the intake of different food items from dairy and meat groups. Multinomial logistic regression was employed to determine odds ratios (ORs) and their corresponding 95% confidence intervals (CIs), considering potential confounders. The consumption of different levels and frequencies of yogurt, white cheese, processed cheese, red meats, and chicken was observed to increase the risk of pancreatic cancer. The adjusted OR indicated that the risk of pancreatic cancer was positively related to a daily intake of yogurt (OR: 2.88 [95%CI: 1.40 – 5.91; $p = 0.001$]), cooked lamb meat (OR: 2.50 [95%CI: 1.30 – 4.84; $p = 0.002$]), and cooked veal meat (OR: 1.72 [95%CI: 1.11 – 3.77; $p = 0.011$]). Furthermore, daily and weekly consumption of white cheese, processed cheese, and cooked chicken may be associated with an increased risk of pancreatic cancer. According to the study's findings, the consumption of yogurt, white cheese, processed cheese, red meat, and chicken was linked to a higher risk of developing pancreatic cancer.

Keywords: Case–control study; Pancreatic cancer; Dairy products; Meats; Eggs

1. Introduction

Pancreatic cancer is one of the most rapidly lethal cancers worldwide with low survival rates and a high mortality rate.[1,2] This cancer is often diagnosed at a progressed stage and is poorly responsive to therapeutic interventions.[1,3] The occurrence of pancreatic cancer has been increasing over the years and is projected to increase by about 70% in 2040, posing a significant public health burden.[4,5] In fact, incidence rates in most Middle East and North Africa countries surpass the global average.[5,6] Pancreatic cancer is currently the seventh leading cause of cancer death among both men and women, with a 5-year survival rate of only 8%.[7,8] It is estimated that it will emerge as the second leading cause of cancer-related deaths by 2030.[2] Therefore, identifying modifiable risk factors and understanding their association with pancreatic cancer is crucial for reducing the burden of this deadly disease.[3]

Pancreatic cancer is a complex disease influenced by a combination of genetic and environmental factors that play a role in its development.[1,3,4,9,10] Previous literature indicates that the incidence of pancreatic cancer in 90% of cases is attributed to environmental conditions and unhealthy lifestyle, including diet.[2,3] Since diet could be a primary contributor to pancreatic cancer,[2] many studies have investigated the link between specific foods and nutrients and pancreatic cancer risk, specifically focusing on the intake of dairy products, meats, and eggs. However, the findings from these studies were inconsistent.[4,9,11-20]

Dairy products include nutrients that have been hypothesized to encourage or inhibit carcinogenesis. It may incorporate hormones and growth factors that raise tumor growth.[17] A positive relationship between a high intake of dairy products and pancreatic cancer risk has been reported.[17] In contrast, recent studies found no links between pancreatic cancer risk and the intake of milk, cheese, and yogurt.[15,16] The impact of meat consumption on the development of pancreatic cancer remains a topic of interest, with some studies indicating an increased risk associated with red and processed meat consumption, particularly in men.[2-4,11-13] The risk of pancreatic cancer increases by 11% for every 100 g daily consumption of red meat.[11] Consumption of processed meat cooked at high temperatures either barbequed or fried has also been related to pancreatic cancer, as well as cold meat, which includes N-nitroso compounds (NOCs) and nitrite preservatives.[2] The World Cancer Research Fund and the American Institute for Cancer Research reported some evidence of the above relationship.[10] However, further investigation is warranted to better understand the specific types of meat, meat choices, and cooking methods that may contribute to this association.[13,14] Eggs have received limited attention regarding their correlation with pancreatic cancer risk. High dietary intake of eggs was associated with pancreatic risk, as well as all-cause and cancer mortality.[18,19] A Western diet, which typically includes a greater consumption of eggs, red and processed meats, high-fat dairy products, potato chips, sugary drinks, sweets, and refined grains, was associated with a 2.4-fold higher risk of pancreatic cancer.[20]

Given the anticipated high prevalence of pancreatic cancer worldwide, this study aimed to investigate the correlation between the intake of dairy products, meats, and eggs, and pancreatic cancer. By understanding their potential impact on pancreatic cancer risk, we can gain valuable insights into the relationship between diet and pancreatic cancer incidence.

2. Methods

2.1. Study design and participants

The study current case–control study was conducted at the King Hussein Cancer Center, King Abdullah University Hospital, Jordan University Hospital, and Al-Bashir Hospital in Jordan from March 2015 to August 2018. The study protocol was approved by the Institutional Review Board Ethics Committee of the King Hussein Cancer Center (IRB No. 15 KHCC 03, Amman, Jordan), King Abdullah University Hospital, Jordan University Hospital, and Al-Bashir Hospital, in accordance with the ethical standards outlined in the 1975 Declaration of Helsinki.

The study participants were Jordanian individuals aged 18 or older, verbally competent, and free from chronic illnesses related to food. These participants included individuals with confirmed pancreatic cancer, while controls were those without the disease. The study involved a total of 415 participants, comprising 101 pancreatic cancer patients and 314 community-selected controls. The controls were matched to the pancreatic cancer patients based on factors such as age, gender, employment, and marital status, resulting in a 1:3 ratio of pancreatic cancer patients to controls. Informed consent was obtained from all participants before their enrollment in the study.

2.2. Data collection

Sociodemographic and health-related information, along with details on physical activity and dietary habits, were collected using structured questionnaires. Trained interviewers completed these questionnaires for both participants with pancreatic cancer and controls. The dietitians were instructed to collect anthropometric measures. Participants were asked to wear only the bare minimum of clothing and shoes, and weight was measured using a SECA scale (Seca GmbH & Co. KG, Germany), adjusted to the closest 0.1 kg. Participants were asked to

stand upright and without shoes while having their height measured with a SECA stadiometer (Seca GmbH & Co. KG, Germany), adjusted to the closest 0.1 cm. The body mass index (BMI) was then determined by dividing the weight (in kg) by the square of height (in m).[21]

2.3. Physical activity questionnaire

Data on participants' physical activity levels was gathered using a validated 7-day physical activity recall (PAR).[22,23] Each participant was requested to complete this form to assess their activity levels. The 7-day PAR is a structured questionnaire that asks participants to recollect how much time they spend exercising each day for a week, as well as the quantity, degree, and duration of physical exercise. The total amount of physical activity was then computed by taking the number of hours spent at different levels of physical activity intensity and converting it into metabolic equivalents (METs) per minute per week.

2.4. Dietary intake assessment

A validated Arabic quantitative food frequency questionnaire (FFQ) was employed to assess the intake of food over the past 12 months.[24] The FFQ includes 110 food items categorized according to food types: 21 vegetable items; 16 meat items, including red meat (lamb and beef), chicken, eggs, fish, and processed meats; 21 fruit and juice items; eight milk and dairy products; eight cereal items; four types of beans; four soups and sauces; five beverages; nine snacks and sweets; and 14 herbs and spices.[24] Participants were requested to recall how often, on average, they consumed one standard serving of each food item from 10 frequency categories (ranging from 1 to 6 times per year to two or more times per day). Portion sizes for each food item were classified into three categories (small, medium, or large) based on commonly used sizes. To accurately estimate the portion sizes of dairy products, meats, fish, and eggs, food models and standard measuring tools, such as cups, tablespoons, teaspoons, and glasses, were utilized.

2.5. Statistical analysis

The Statistical Package for the Social Sciences version 29 (IBM Corporation, United States of America [USA]) was employed for statistical analysis, and a $p < 0.05$ was regarded as statistically significant. To identify variations among participants based on their consumption frequencies, descriptive analyses were performed. Mean and standard error of the mean were used to represent normally distributed continuous data, while frequency and percentage were used to report normally distributed categorical variables. To compare variations in the means of continuous variables, a one-way analysis of variance was used. The Pearson Chi-square test was used to determine whether categorical variables differed. Two techniques were employed to calculate how much dairy and meat were consumed: (i) depending on how frequently they are consumed, dairy products and meats were divided into four categories: daily, weekly, monthly, and infrequently; (ii) grouping them based on number of servings consumed per week: ≤1 serving per week, 2 – 3 servings per week, 4 – 6 servings per week, and ≥1 serving per day.

The median (25^{th} – 75^{th} percentile) was calculated to represent the weekly consumption of dairy products and meats. The Mann–Whitney U test was performed to identify variations in the consumption of particular dairy and meat products between pancreatic cancer patients and controls.

The odds ratios (ORs) and corresponding 95% confidence intervals (CIs) for various categories of dairy and meat intake over a week were calculated using a multinomial logistic regression. The category with the lowest intake of consumption (<1 serving per week) served as the reference group. Based on the previously indicated risk variables for pancreatic cancer, prospective confounders, such as age, gender, marital status, education level, BMI, smoking, smoking duration, family history of pancreatic cancer, and physical activity (MET-min/week), were chosen.[25] The *p*-value for the trend was calculated using linear logistic regression.

3. Results

Table 1 presents the distribution of sociodemographic and health characteristics of the study participants based on their frequency of dairy and meat consumption. There were no significant differences noted in age, gender, body weight status, marital status, education level, occupational status, smoking habits, personal history of chronic diseases, or family history when pancreatic cancer patients were categorized by the number of servings of dairy products and meats consumed. Most pancreatic cancer patients (89 out of 101) consumed dairy products daily, and half of them consumed meat weekly. Previous BMI was significantly lower among weekly consumers of dairy products than daily (26.5 ± 1.5 kg/m^2 vs. 30.7 ± 0.80 kg/m^2; $p = 0.045$). The caloric intake was significantly higher among pancreatic cancer patients who consumed meat daily compared to a weekly basis (3371.3 ± 141.0 kcal/day vs. 2938.0 ± 108.5 kcal/day; $p = 0.045$).

There were no significant differences in sociodemographic and health characteristics of controls by frequency of dairy products, except daily total caloric intake, physical activity, and gender. Significant differences were found in age, total caloric intake, marital status, and

Table 1. Sociodemographic and health characteristics of study participants with pancreatic cancer by frequency of dairy product and meat consumption

Variable	Dairy products (n=101)					Meats (n=101)				
	Rarely (*n*=0)	Monthly (*n*=0)	Weekly (*n*=12)	Daily (*n*=89)	*p**	Rarely (*n*=0)	Monthly (*n*=2)	Weekly (*n*=52)	Daily (*n*=47)	*p*[a]
Age (years)	-	-	54.4±4.1	57.3±1.2	0.434	-	58.0±6.0	56.5±1.6	57.5±1.8	0.908
Weight (kg)										
Previous	-	-	75.4±5.3	84.5±2.1	0.144	-	101.0±19.0	79.4±2.0	87.1±3.6	0.071
Current	-	-	65.3±3.6	69.9±1.5	0.303	-	80.5±20.5	68.5±1.8	69.8±16.12.2	0.494
Height (cm)	-	-	168.6±2.3	164.0±2.1	0.427	-	170.5±10.5	166.2±1.3	162.5±3.7	0.574
BMI (kg/m^2)										
Previous	-	-	26.2±1.5	30.7±0.8	0.045	-	34.3±2.3	28.8±27.3	31.5±1.2	0.104
Current	-	-	22.8±0.8	25.4±0.6	0.090	-	27.1±3.7	24.9±0.7	25.3±0.5	0.789
Total caloric intake (kcal/day)	-	-	2991.1±258.8	3154.7±94.3	0.550	-	2824.4±126.0	2938.0±108.5	3371.3±141.0	0.045
Physical activity (MET-min/week)[b]	-	-	2375.0±705.4	1979.0±216.2	0.556	-	1050.0±630.0	1965.0±263.4	1851.0±362.8	0.758
Gender (%)										
Male (*n*=59)	-	-	7 (58.3)	52 (58.4)	0.995	-	2 (100.0)	25 (48.1)	32 (68.1)	0.063
Female (*n*=42)	-	-	5 (41.7)	37 (41.6)		-	0 (0.0)	27 (51.9)	15 (31.9)	
Marital status (%)										
Married (*n*=87)	-	-	12 (100)	75 (84.3)	0.534	-	2 (100.0)	45 (86.5)	40 (85.1)	0.989
Single (*n*=5)	-	-	0 (0.0)	5 (5.6)		-	0	2 (3.8)	3 (6.4)	
Divorced (*n*=3)	-	-	0 (0.0)	3 (3.4)		-	0	2 (3.8)	1 (2.1)	
Widowed (*n*=6)	-	-	0 (0.0)	6 (6.7)		-	0	3 (5.8)	3 (6.4)	
Educational level (%)										
Less than high school diploma (*n*=45)	-	-	3 (25.0)	42 (47.2)	0.057	-	0 (0.0)	21 (40.4)	24 (51.0)	0.736
High school diploma and above (*n*=56)	-	-	9 (75.0)	47 (52.8)		-	2 (100.0)	31 (59.5)	23 (48.9)	
Working (*n*=45) (%)	-	-	7 (58.3)	38 (43.2)	0.322	-	1 (50.0)	18 (34.6)	20 (42.6)	0.392
History of chronic diseases (*n*=55) (%)	-	-	6 (50.0)	49 (55.1)	0.741	-	1 (50.0)	25 (48.1)	29 (61.7)	0.394
Smoking (*n*=38) (%)	-	-	4 (33.3)	34 (38.2)	0.632	-	0 (0)	18 (34.6)	20 (42.6)	0.692
Family history of pancreatic cancer (*n*=2) (%)	-	-	0 (0.0)	2 (2.2)	0.600	-	0 (0.0)	1 (1.9)	1 (2.1)	0.977

Note: Data are presented either as mean±mean square error or *n* (%); [a]*p*-value is calculated using a sample *t*-test for continuous variables and Pearson's Chi-square test for categorical variables; $p<0.05$ is considered statistically significant. [b]MET indicates metabolic equivalent.
Abbreviation: BMI: Body mass index.

history of chronic diseases, categorized based on number of meat servings consumed by the controls (Table 2).

Median weekly intakes (and the 25th and 75th percentiles) for a variety of dairy and meat products are given in Table 3. Yogurt, white cheese, processed cheese, cooked red meat, and cooked poultry were substantially more frequently consumed by pancreatic cancer patients than by controls ($p < 0.05$). On the other hand, cooked fish was consumed significantly higher in controls compared to pancreatic cancer patients (1.8 [1.0 – 3.4] vs. 1.6 [0.56 – 2.8]; $p = 0.024$). Between pancreatic cancer patients and controls, there was no statistically significant difference in the intake of cooked yogurt, buttermilk, drained yogurt (Labneh), ice cream, grilled beef, cooked liver, tuna, and processed meats.

Table 4 displays the risk of pancreatic cancer according to the consumption of dairy products and meats. The

Table 2. Sociodemographic and health characteristics of the study control participants by frequency of dairy product and meat consumption

Variable	Dairy products (*n*=314)					Meats (n=314)				
	Rarely (*n*=1)	Monthly (*n*=2)	Weekly (*n*=125)	Daily (*n*=186)	*p**	Rarely (*n*=0)	Monthly (n=22)	Weekly (n=241)	Daily (n=51)	*p*[a]
Age (years)	55.0	43.0±2.0	55.6±1.1	53.0±0.92	0.182	-	57.6±2.5	54.8±0.8	48.4±2.0	0.001
Weight (kg)										
Previous	79.0	74.5±17.5	80.6±1.6	81.0±1.3	0.957	-	81.1±5.1	81.6 ±1.1	76.2 ±1.9	0.149
Current	79.0	76.0±16.0	80.6±1.6	81.2±1.2	0.966	-	82.0±5.2	81.4 ±1.1	77.9 ±1.8	0.374
Height (cm)	168.0	170.0±10.0	168.4±0.70	167.6±0.68	0.871	-	168.7±1.9	167.7±0.56	168.7±1.2	0.691
BMI (kg/m^2)										
Previous	28.0	25.3±3.1	28.5±0.56	28.3±0.54	0.801	-	28.6±1.9	29.1±0.37	26.9±0.66	0.072
Current	28.0	25.9±2.5	28.5±0.56	29.0±0.40	0.824	-	29.0±2.0	29.0±0.36	27.7±0.61	0.196
Total caloric intake (kcal/day)	2622.3	2117.1±146.3	2085.6±53.2	2951.2±248.6	0.046	-	2000.6±149.6	2332.1±46.3	3235.5±127.6	< 0.001
Physical activity (MET-min/week)[b]	1297.5	5069.5±2114.5	1940.2±81.2	2168.9±98.9	0.002	-	2026.6±206.7	2104.1±76.3	2093.6±69.2	0.952
Gender (%)										
Male (*n*=191)	1 (100.0)	1 (50.0)	92 (73.6)	97 (52.2)	0.002	-	17 (77.3)	144 (59.8)	30 (58.8)	0.259
Female (*n*=123)	0 (0.0)	1 (50.0)	33 (26.4)	89 (47.8)		-	5 (22.7)	97 (40.2)	21 (41.2)	
Marital status (%)										
Married (*n*=273)	1 (100.0)	2 (100.0)	114 (91.2)	156 (83.9)	0.908	-	19 (86.4)	216 (89.6)	38 (74.5)	0.007
Single (*n*=20)	0	0	5 (4.0)	15 (8.1)		-	3 (13.6)	8 (15.7)	8 (15.7)	
Divorced (*n*=7)	0	0	2 (1.6)	5 (2.7)		-	0 (0.0)	4 (1.7)	3 (5.9)	
Widowed (*n*=14)	0	0	4 (3.2)	10 (5.4)		-	0 (0.0)	12 (5.0)	2 (3.9)	
Educational level (%)										
Less than high school diploma (*n*=98)	0 (0.0)	2 (100.0)	43 (34.4)	53 (28.5)	0.573	-	11 (54.5)	114 (58.1)	28 (36.0)	0.016
High school diploma and above (*n*=216)	1 (100.0)	0 (0.0)	82 (65.6)	133 (71.5)		-	10 (45.4)	101 (41.9)	32 (64.0)	
Working (*n*=153) (%)	0 (0)	0 (0.0)	7 (58.3)	38 (43.2)	0.560	-	11 (50.0)	114 (47.3)	28 (56.0)	0.825
History of chronic diseases (*n*=163) (%)	1 (100.0)	2 (100.0)	54 (43.5)	100 (53.8)	0.510	-	11 (50.0)	124 (51.5)	22 (44.0)	0.024
Smoking (*n*=99) (%)	1 (100.0)	1 (50.0)	44 (35.2)	53 (28.5)	0.756	-	8 (36.4)	74 (30.7)	17 (33.3)	0.808
Family history of pancreatic cancer (*n*=3) (%)	0	0	2 (1.7)	1 (0.5)	0.811	-	1 (4.5)	2 (0.9)	0 (0.0)	0.178

Note: Data are presented either as mean±mean square error or n (%); *p*[a]-value is calculated using a sample t-test for continuous variables and Pearson's Chi-square test for categorical variables; $p<0.05$ is considered statistically significant. [b]MET indicates metabolic equivalent.
Abbreviation: BMI: Body mass index.

intake of white and processed cheeses and cooked chicken on a weekly and daily basis had positive significant associations with the risk of pancreatic cancer. However, the consumption of yogurt daily may enhance the risk of pancreatic cancer by approximately threefold (OR: 3.21; 95%CI: 1.67 – 6.19; $p = 0.001$). Likewise, the daily consumption of cooked veal meat (OR: 2.04; 95%CI: 1.01 – 4.012; $p = 0.042$) and cooked lamb meat (OR: 3.03; 95%CI:

Table 3. Median weekly intake of dairy and meat products for pancreatic cancer and control subjects

Food item (serving size)	Median serving per week (25th–75th percentile)		p^a
	Pancreatic cancer (n=101)	Control (n=314)	
Milk (cup)	1.9 (0.0 – 4.8)	0.73 (0.2 – 4.4)	0.669
Yogurt (cup)	3.5 (2.0 – 7.0)	2.7 (1.4 – 4.4)	< 0.001
Cooked yogurt (Jameed) (cup)	0.44 (0.20 – 0.74)	0.44 (0.17 – 0.74)	0.219
Buttermilk (cup)	0.74 (0.15 – 2.6)	0.44 (0.17 – 0.98)	0.243
Drained yogurt (Labneh) (1/4 cup)	5.5 (3.5 – 7.0)	5.1 (2.5 – 7.0)	0.719
White cheese (oz)	3.3 (0.98 – 3.5)	1.5 (0.5 – 3.5)	< 0.001
Processed cheese (oz)	2.0 (0.23 – 5.3)	0.58 (0.07 – 2.0)	< 0.001
Ice cream (1/2 cup)	0.41 (0.14 – 1.9)	0.41 (0.14 – 1.9)	0.531
Cooked red meat (veal) (oz)	3.4 (0.81 – 7.1)	2.0 (0.71 – 3.4)	0.005
Grilled meat (oz)	0.61 (0.25 – 1.2)	0.81 (0.25 – 1.2)	0.530
Cooked red meat (lamb) (oz)	3.4 (0.81 – 7.1)	2.0 (0.71 – 3.4)	0.002
Cooked chicken (oz)	8.1 (5.0 – 14.0)	7.0 (2.3 – 12.2)	< 0.001
Cooked liver (oz)	0.64 (0.46 – 1.7)	0.55 (0.27 – 1.4)	0.757
Cooked fish (oz)	1.6 (0.56 – 2.8)	1.8 (1.0 – 3.4)	0.024
Tuna (oz)	0.69 (0.44 – 2.7)	0.64 (0.46 – 1.7)	0.176
Cooked egg (egg)	3.0 (2.0 – 4.0)	2.0 (3.0 – 4.0)	0.233
Processed meats (oz)	0.0 (0.0 – 0.42)	0.16 (0.0 – 0.53)	0.348

Note: [a]p-values were calculated using the Mann-Whitney U test; p<0.05 is considered statistically significant.

1.68 – 5.45; $p < 0.001$) may increase the risk of pancreatic cancer. Moreover, the daily intake of processed cheese (OR: 4.95; 95%CI: 2.51 – 9.76; $P < 0.001$) and cooked chicken (OR: 5.25; 95%CI: 2.02 – 13.62; $p < 0.001$) may also increase the risk of pancreatic cancer by around five folds.

The adjusted ORs and 95%CIs for dairy products and meats are provided in Table 5. The daily consumption of yogurt (OR: 2.88; 95%CI: 1.97 – 8.86; $p = 0.002$), white cheese (OR: 2.38; 95%CI: 1.18 – 4.79; $p < 0.001$), processed cheese (OR: 5.62; 95%CI: 2.53 – 12.48; $p < 0.001$), cooked red meat (veal; OR: 1.72; 95%CI: 1.11 – 3.77; $p = 0.011$), cooked red meat (lamb; OR: 2.5; 95%CI: 1.30 – 4.84; $p = 0.002$), and cooked poultry (OR: 6.63; 95%CI: 2.22 – 19.77; $p < 0.001$) was positively associated with the incidence of pancreatic cancer. Significant associations were observed for weekly consumption of white cheese (OR: 2.00; 95%CI: 1.07 – 3.94; $p = 0.01$; per 4 – 6 servings/week), processed cheese (OR: 2.35; 95%CI: 1.11 – 4.98; $p < 0.001$; per 4 – 6 servings/week), and cooked chicken (OR: 3.76; 95%CI: 1.12 – 12.60; $p < 0.001$; per 4 – 6 servings/week). On the other hand, the weekly consumption of fish may reduce the risk of pancreatic cancer (OR: 0.45; 95%CI: 0.21 – 0.97; $p = 0.032$; per 4 – 6 servings/week).

4. Discussion

Studying the associations between dietary food items and the incidence or prevalence of pancreatic cancer is crucial, as it can aid in the development and implementation of effective recommendations and guidelines for the prevention or treatment of the disease. Our results revealed that the extensive consumption of three dairy products (including yogurt, white cheese, and processed cheese) and three meat products (including cooked red meats [veal and lamb] and cooked chicken) may be significantly associated with an increased risk of pancreatic cancer. Meanwhile, our study results indicated that the intake of cooked fish may have a protective effect against the risk of pancreatic cancer.

Regarding yogurt, the findings of our study contradicted the results of a recent study (i.e., Japan Collaborative Cohort Study [JACC Study]) conducted by Arafa *et al.*[15]. In their study, it was reported that the consumption of yogurt is not associated with the risk of pancreatic cancer. Likewise, a pooled analysis by Genkinger *et al.*[26] suggested that yogurt consumption does not have a relationship with the risk of pancreatic cancer. A more recent study found no associations between the consumption of total dairy products and pancreatic cancer.[27] Another study found that intake of fermented dairy products may be significantly

Table 4. Crude odds ratios (ORs) and corresponding 95% confidence intervals (CIs) based on the number of consumed servings of dairy products and meats among 101 pancreatic cancer and 314 control subjects

Food item (serving size)	OR (95%CI)				*p*
	≤1 serving per week[a]	2 – 3 servings per week	4 – 6 servings per week	≥1 serving per day	
Milk	1	1.58 (0.85 – 2.95)	2.50 (1.21 – 5.16)	1.19 (0.65 – 2.19)	0.203
No. of pancreatic cancer/control	48/184	19/46	15/23	19/61	
Yogurt	1	0.95 (0.47 – 1.93)	1.22 (0.62 – 2.40)	3.21 (1.67 – 6.19)	<0.001
No. of pancreatic cancer/control	18/80	19/89	25/91	39/54	
Cooked yogurt (Jameed)	1	1.60 (0.66 – 3.85)	-	-	0.552
No. of pancreatic cancer/control	93/297	8/16	0/1	0/0	
Drained Yogurt (Labneh)	1	1.02 (0.42 – 2.51)	1.52 (0.74 – 3.19)	1.75 (0.91 – 3.40)	0.051
No. of pancreatic cancer/control	14/63	10/44	24/71	53/136	
Buttermilk	1	2.02 (1.15 – 3.57)	1.94 (0.89 – 4.23)	0.46 (0.06 – 3.77)	0.103
No. of pancreatic cancer/control	65/241	24/44	11/21	1/8	
White cheese	1	2.04 (1.07 – 3.87)	2.40 (1.30 – 4.44)	3.06 (1.65 – 5.66)	<0.001
No. of pancreatic cancer/control	31/164	20/52	24/53	26/45	
Processed cheese	1	1.54 (0.779 – 3.03)	2.41 (1.20 – 4.85)	4.95 (2.51 – 9.76)	<0.001
No. of pancreatic cancer/control	50/225	14/41	15/28	22/20	
Ice cream	1	0.55 (0.29 – 1.07)	0.92 (0.45 – 1.86)	0.19 (0.05 – 0.83)	0.023
No. of pancreatic cancer/control	74/192	13/61	12/34	2/27	
Cooked red meat (veal)	1	1.19 (0.58 – 2.44)	1.26 (0.62 – 2.53)	2.04 (1.01 – 4.12)	0.042
No. of pancreatic cancer/control	15/63	25/88	29/97	32/66	
Cooked red meat (lamb)	1	0.99 (0.58 – 1.70)	1.59 (0.30 – 8.53)	3.03 (1.68 – 5.45)	<0.001
No. of pancreatic cancer/control	36/143	31/124	2/5	32/42	
Grilled red meat	1	0.55 (0.26 – 1.16)	0.48 (0.11 – 2.17)	1.27 (0.38 – 4.23)	0.408
No. of pancreatic cancer/control	86/246	9/47	2/12	4/9	
Cooked chicken	1	1.20 (0.30 – 4.76)	3.46 (1.20 – 10.02)	5.25 (2.02 – 13.62)	<0.001
No. of pancreatic cancer/control	5/57	4/38	17/56	75/163	
Cooked liver	1	1.07 (0.55 – 2.06)	1.10 (0.42 – 2.90)	0.94 (0.25 – 3.50)	0.904
No. of pancreatic cancer/control	78/244	14/41	6/17	3/10	
Cooked fish	1	0.53 (0.32 – 0.89)	0.55 (0.28 – 1.07)	0.83 (0.31 – 2.25)	0.093
No. of pancreatic cancer/control	50/111	31/130	14/57	6/16	
Tuna	1	1.59 (0.93 – 2.71)	1.50 (0.66 – 3.42)	2.09 (0.59 – 7.37)	0.061
No. of pancreatic cancer/control	61/223	27/62	9/22	4/7	
Cooked egg	1	1.32 (0.71 – 2.48)	1.33 (0.70 – 2.50)	1.43 (0.75 – 2.74)	0.293
No. of pancreatic cancer/control	24/93	27/79	26/76	24/65	
Processed meats	1	0.97 (0.44 – 2.12)	1.56 (0.28 – 8.63)	-	0.977
No. of pancreatic cancer/control	90/280	9/29	2/4	0/1	

Note: [a]Reference group.

associated with decreased overall cancer risk (OR: 0.87; 95%CI: 0.80 – 0.95).[28]

White cheese is considered the primary cheese type produced in Jordan.[29] To the best of our knowledge, our study is the first to provide a novel finding regarding a positive association between dietary intake of white cheese and the risk of pancreatic cancer. This association may be attributed to the chemical composition and ingredients added during the processing and preparation of white cheese. In Jordan, two varieties of boiled or pasteurized white cheese are produced seasonally using milk from ewes or goats, or a combination of both, with a chemical

Table 5. Adjusted odds ratios (ORs) and corresponding 95% confidence intervals (CIs) based on the number of consumed servings of dairy products and meats among 101 pancreatic cancer patients and 314 controls

Food item (serving size)	OR (95%CI)[a]				*p*
	≤1 serving per week[b]	2 – 3 servings per week	4 – 6 servings per week	≥1 serving per day	
Milk	1	1.54 (0.76 – 3.10)	2.22 (1.01 – 4.89)	1.17 (0.60 – 2.30)	0.306
No. of pancreatic cancer/control	48/184	19/46	15/23	19/61	
Yogurt	1	1.59 (0.58 – 4.34)	1.10 (0.52 – 2.31)	2.88 (1.40 – 5.91)	0.002
No. of pancreatic cancer/control	18/80	19/89	25/91	39/54	
Cooked yogurt (Jameed)	1	1.12 (0.57 – 2.22)	-	-	0.326
No. of pancreatic cancer/control	93/297	8/16	0/1	0/0	
Drained yogurt (Labneh)	1	1.25 (0.47 – 3.37)	1.43 (0.62 – 3.29)	1.77 (0.83 – 3.76)	0.102
No. of pancreatic cancer/control	14/63	10/44	24/71	53/136	
Buttermilk	1	2.35 (1.24 – 4.43)	2.63 (1.09 – 6.32)	0.56 (0.06 – 5.15)	0.044
No. of pancreatic cancer/control	65/241	24/44	11/21	1/8	
White cheese	1	1.88 (0.93 – 3.83)	2.00 (1.01 – 3.94)	2.38 (1.18 – 4.79)	0.010
No. of pancreatic cancer/control	31/164	20/52	24/53	26/45	
Processed cheese	1	2.07 (0.95 – 4.52)	2.35 (1.11 – 4.98)	5.62 (2.53 – 12.48)	<0.001
No. of pancreatic cancer/control	50/225	14/41	15/28	22/20	
Ice cream	1	0.61 (0.30 – 1.25)	1.12 (0.50 – 2.54)	0.24 (0.05 – 1.08)	0.095
No. of pancreatic cancer/control	74/192	13/61	12/34	2/27	
Cooked red meat (veal)	1	1.10 (0.50 – 2.46)	1.12 (0.52 – 2.42)	1.72 (1.11 – 3.77)	0.011
No. of pancreatic cancer/control	15/63	25/88	29/97	32/66	
Cooked red meat (lamb)	1	1.03 (0.57 – 1.85)	0.84 (0.08 – 8.33)	2.50 (1.30 – 4.84)	0.002
No. of pancreatic cancer/control	36/143	31/124	2/5	32/42	
Grilled red meat	1	0.46 (0.20 – 1.04)	0.73 (0.13 – 4.01)	1.10 (0.29 – 4.24)	0.474
No. of pancreatic cancer/control	86/246	9/47	2/12	4/9	
Cooked chicken	1	1.39 (0.29 – 6.80)	3.76 (1.12 – 12.60)	6.63 (2.22 – 19.77)	< 0.001
No. of pancreatic cancer/control	5/57	4/38	17/56	75/163	
Cooked liver	1	1.08 (0.50 – 2.30)	1.62 (0.56 – 4.71)	1.06 (0.26 – 4.41)	0.601
No. of pancreatic cancer/control	78/244	14/41	6/17	3/10	
Cooked fish	1	0.40 (0.22 – 0.72)	0.45 (0.21 – 0.97)	0.60 (0.18 – 1.99)	0.032
No. of pancreatic cancer/control	50/111	31/130	14/57	6/16	
Tuna	1	1.59 (0.85 – 2.96)	1.38 (0.53 – 3.63)	2.62 (0.62 – 11.14)	0.109
No. of pancreatic cancer/control	61/223	27/62	9/22	4/7	
Cooked eggs	1	1.13 (0.57 – 2.26)	1.23 (0.61 – 2.46)	1.39 (0.68 – 2.86)	0.499
No. of pancreatic cancer/control	24/93	27/79	26/76	24/65	
Processed meats	1	0.98 (0.43 – 2.23)	3.40 (0.45 – 25.75)	-	0.072
No. of pancreatic cancer/control	90/280	9/29	2/4	0/1	

Note: [a]Adjusted for caloric intake, age, gender, marital status, education level, body weight status, smoking, period of smoking, family history of pancreatic cancer, and physical activity level; the control group was considered the reference group for analysis. [b]Reference group.

composition of approximately 46% moisture, 16.3% protein, 23.7% fat, 5.6% carbohydrates, and 8.4% ash.[30]

The third dairy product that has demonstrated a positive association with the risk of pancreatic cancer in our study is processed cheese. Processed cheese is a homogeneous product produced by blending different natural cheeses with emulsifying salts and other dairy and non-dairy ingredients.[31] Our study result regarding processed cheese is in agreement with the results of the study conducted by Thiébaut *et al.*[32] The study indicated that the saturated fat intake from cheese and other dairy products was positively

associated with the risk of pancreatic cancer (hazard ratio [HR]: 1.19; 95%CI: 1.01 – 1.42; $p = 0.005$).[32] Similarly, Zhang *et al.*[28] reported that cheese intake may be significantly associated with an increased risk of pancreatic cancer (OR: 1.16; 95%CI: 087 – 1.53). Meanwhile, the results of the study conducted by Azeem *et al.*[33] were not in accordance with our results. They documented the protective role of cheese in relation to the risk of pancreatic cancer, but the association was not significant. Conversely, Genkinger *et al.*[26] reported that no associations were noticed between cheese intake and the risk of pancreatic cancer.

As aforementioned, three meat products may be significantly associated with the risk of pancreatic cancer. Two of these products are cooked red meat from both veal and lamb origins. Grilled meat did not exhibit any significant differences between pancreatic cancer patients and controls in our study, indicating that meat cooking methods and doneness play a key role in pancreatic health. Our study results were consistent with the results of the study conducted by Taunk *et al.*,[34] which documented that the risk of pancreatic cancer may be significantly increased with intake of high-temperature-cooked red meat (HR: 1.21; 95%CI: 1.00 – 1.45) and intake of well/very well-done red meat (HR: 1.32; 95%CI: 1.10 – 1.58).[34] In the same context, an Italian case–control study illustrated that frequent intake of cooked red meat (by both methods of preparation either boiling/stewing or broiling/roasting) may be significantly associated with an increased risk of pancreatic cancer (95%CI: 1.18 – 3.36).[35] Moreover, in a follow-up study by Petrick *et al.*[36] on African American women aged ≥50 years, it was reported that by comparing the highest (quartile 4) and lowest (quartile 1) intake of total red meat, the total consumption of red meat may be associated with a 65% increased risk of pancreatic cancer risk (HR: 1.65; 95%CI: 0.98 – 2.78). Several potential mechanisms could explain the association between red meat intake and the risk of pancreatic cancer. A recent meta-analysis of prospective studies documented some of the mechanisms. These mechanisms include: (i) production of heterocyclic aromatic amines and polycyclic aromatic hydrocarbons due to cooking red meat at high temperatures; (ii) enhanced cytotoxicity, proliferation of epithelial cells, inducing lipid peroxidation, and formation of free radicals, DNA adducts, and NOCs due to heme iron in red meat; and (iii) increasing the risk of insulin resistance (which play a crucial role in the etiology of pancreatic cancer) due to animal-derived proteins rich in branched-chain amino acid and aromatic amino acids in red meat.[3] Conversely, a meta-analysis included seven cohort studies and one case–control study, encompassing a total of 7,158 pancreatic cancer patients and 805,177 controls, and suggested that there is no relationship between the consumption of red and processed meat and the risk of pancreatic cancer.[37] Another meta-analysis involving 20 prospective cohort studies with 3,934,909 participants identified 11,315 cases of pancreatic cancer and also found no significant association between the consumption of red and processed meat and the risk of pancreatic cancer, that is, when comparing the highest and lowest intake levels.[38]

Regardless of the red meat preparation method, Huang *et al.*[39] noticed that red meat consumption, in general, was associated with a higher risk of pancreatic cancer in the Multiethnic Cohort study (relative risk [RR]: 1.18; 95%CI: 1.02 – 1.37). Furthermore, a meta-analysis (composed of 11 case-control studies) conducted by Paluszkiewicz *et al.*[40] concluded that the ingestion of red meat may be associated with increased pancreatic cancer risk, by approximately 48% (95%CI: 1.25 – 1.76). In addition, in a meta-analysis of 11 cohort studies conducted by Larsson and Wolk,[41] an increase in the intake of red meat by 120 g/day may be significantly associated with the risk of pancreatic cancer (RR: 1.13; 95%CI: 0.93 – 1.39). Moreover, a systematic review and meta-analysis found that a daily intake of 100 g of red meat consumption may be significantly linked to a higher risk of pancreatic cancer.[11]

The third meat product in our study related to pancreatic cancer is cooked chicken (poultry). Our study results agreed with the results of a recent systematic review and meta-analysis of 25 cohort studies; the pooled RR of pancreatic cancer for the highest versus lowest category of poultry consumption was 1.14 (95%CI: 1.02 – 1.26), suggesting that a large intake of poultry may increase the risk of pancreatic cancer.[14] Similarly, results of a study conducted by Rohrmann *et al.*[42] indicated that intake of poultry may be associated with an increased risk of pancreatic cancer (RR per 50 g intake/day: 1.72; 95%CI: 1.04 – 2.84). In contrast, the results of a follow-up study conducted by Larsson *et al.*[43] were not in agreement with our result. The study indicated that long-term intake of poultry may be negatively associated with the risk of pancreatic cancer ($p = 0.04$) and that substituting poultry for red meat might reduce pancreatic cancer risk.[43]

Our study results indicated that the consumption of cooked fish may help protect against pancreatic cancer, observed from the median between pancreatic cancer patients and controls, as well as the adjusted ORs for the number of consumed servings of cooked fish among study participants. Our results were not in agreement with the results of the meta-analysis study conducted by Jiang *et al.*,[44] which was composed of 13 prospective studies. They found that consumption of fish is not significantly associated with pancreatic cancer risk (RR per 50 g intake/day: 1.03; 95%CI: 0.95 – 1.12).[43] Likewise, Rohrmann *et al.*[42] reported

that intake of fish was not associated with an increased risk of pancreatic cancer (RR per 50 g intake/day: 1.22; 95%CI: 0.92 – 1.62). Similarly, Gao *et al.*[14] reported that there was no association between fish intake and the risk of pancreatic cancer risk (RR: 1.00; 95%CI: 0.93 – 1.07). The differences between our findings and those of previous studies regarding fish intake may be attributed to variations in cooking methods and preparation techniques, as well as the chemical composition of the fish consumed.

The current case–control study offers several advantages, including the ability to adjust statistical analyses for a large number of significant confounders, which is thought to strengthen our conclusions by mitigating their impact on pancreatic cancer risk. This study employed a culturally relevant FFQ that incorporates various food items to accurately reflect the typical dietary habits of the study population. The inclusion of pancreatic cancer patients and controls drawn from significant public hospitals and the community also guarantees an accurate representation of the various diets that coexist in Jordan. The questionnaire was well-received overall, with a notable response rate of >95%. Despite the study's strengths, it is important to note some of its limitations. One of the limitations of the current study is memory bias, a common issue in case–control studies, especially when participants are asked to recall their dietary intake over the past 12 months. In addition, reporting bias can occur, as participants may selectively report information that aligns with their disease status.[45] Moreover, the participants' diagnoses (i.e., pancreatic cancer vs. controls) were not concealed from the interviewers. However, all interviewers received extensive training to ensure they treated every participant equally and professionally, minimizing any unintentional influence on participants' responses stemming from their knowledge of the participants' diagnoses, regardless of their status.

5. Conclusion

Pancreatic cancer patients had significantly higher consumption rates of yogurt, white and processed cheeses, as well as cooked red meats and chicken, compared to the controls. The high intake of white cheese, processed cheese, cooked red meats, and chicken may be associated with an elevated risk of pancreatic cancer.

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Conflict of interest

The authors state that there are no conflicts of interest.

Author contributions

Conceptualization: Tareq Al-Jaberi, Reema F. Tayyem
Data curation: Sabika Allehdan, Tareq Al-Jaberi, Aya Hamdan, Yaser Rayyan
Formal analysis: Sabika Allehdan, Mohammed O. Ibrahim, Reema F. Tayyem
Investigation: Sabika Allehdan, Reema F. Tayyem
Methodology: Tareq Al-Jaberi, Reema F. Tayyem
Writing – original draft: Sabika Allehdan, Aya Hamdan, Mohammed O. Ibrahim, Narmeen Al-Awwad, Reema F. Tayyem
Writing – review & editing: All authors

Ethics approval and consent to participate

The research was carried out following the principles outlined in the Declaration of Helsinki and received approval from the Institutional Review Board (IRB) of King Hussein Cancer Center (IRB No. 15 KHCC 03, Amman, Jordan), as well as from King Abdullah University Hospital, Jordan University Hospital, and Al-Bashir Hospital. Each participant provided written consent.

Consent for publication

Informed consent from the patients obtained for releasing their data.

Availability of data

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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