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# Fish and Shellfish Intake and Diabetes in a Costal Population of the Adriatic

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## A B S T R A C T

*The objective of the study was to examine the association between fish and shellfish intake and diabetes in an island population, and the design of the study was Cross-sectional. Two independent population-based field surveys were conducted in Hvar Island of the eastern Adriatic coast of Croatia in May 2007 and May 2008, with a total of 1,379 adult participants. In multivariable logistic regression models, total fish intake was positively associated with diabetes prevalence in the total population ($OR_{Q4\ vs.\ Q1}$ = 1.64; 95% CI = 1.01–2.66; p-trend = 0.09). Oily fish intake also exhibited a positive association with diabetes prevalence in the total population ($OR_{Q4\ vs.\ Q1}$ = 2.22; 95% CI = 1.35–3.64; p-trend = 0.01) and in analyses stratified by body mass index, males and those with a high waist circumference. The study suggests an association between oily fish intake and diabetes in the population of the Hvar Island in Croatia. Longitudinal studies incorporating measures of persistent organic pollutants and local cooking practices are warranted to identify factors in fatty fish that may influence the development or persistence of diabetes.*

***Key words:** diabetes, fish, Mediterranean diet, organic pollutants, Adriatic*

## Introduction

The consumption of fish and n-3 fatty acids has been shown to reduce the risk of cardiovascular disorders[1–3]. However, the relationship between fish and seafood intake and diabetes is not well explored and the available data inconsistent. In several prospective cohorts inverse associations between fish consumption and diabetes have been reported[4–6]; although, others have found increased diabetes risk with higher fish intake[7–9]. These inconsistencies have been shown to differ according to geographical region, suggesting contamination of fish by organic pollutants, or differences in the methods used for cooking fish could, in part, be contributing the discrepant findings[10].

Traditionally Croatians engaged in fishing and farming for their livelihood[11] and adhered to a Mediterranean diet rich in fish, fruits, and vegetables[12]. More recent analysis of the diet of Croatian Adriatic islanders, however, suggests a transition from a traditional Mediterranean diet to a more diverse food intake incorporating high intakes of fruits and vegetables and fish (~70 grams per day) together with increased red meat and vegetable oil consumption[13]. Croatians in general were consuming around 17.3 pounds (7.84 kg) of seafood per year[14] an intake greater than the 14.4 pounds (6.5 kg) of fish and shellfish consumed in the U.S.[15]. Our study population therefore, provides a unique opportunity to investigate higher fish intake in relation to the development and presentence of diabetes.

Diabetes is one of the components of the metabolic syndrome and our previous research has shown a dietary pattern high in meat, alcohol, and fish to be positively associated with the metabolic syndrome among the Croatians[16]. However, the relationship between specific types of fish and shellfish consumption and diabetes in this population remains unknown. Therefore, the purpose of this study was to examine the association of fish and shellfish with the prevalence of diabetes in this population.

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## Material and Methods

### *Study population*

The study was conducted on the island of Hvar on the eastern Adriatic cost of Croatia. The study details have been described elsewhere[17]. In brief, two separate population-based, cross-sectional field surveys were conducted in eight different villages on Hvar Island. Participants were recruited by general advertisements, public notices and announcements at community meetings. Adults (N = 1405) between the ages of 20 to 94 years were eligible to participate (excluding those ≤20 years of age (N = 37) in an attempt to restrict participants to only those with type 2 diabetes). Participants reporting implausible total energy intakes of ≥7500 kcal/d (N = 21) or missing data on intake of fish and shellfish (N=3) or blood glucose (N=4) were further excluded from this analysis. A total of 1,377 participants were finally analyzed. The study was approved by the Ethics Committee of the Institute for Anthropological Research in Zagreb, Croatia and the Institutional Review Board of the University of Cincinnati.

### *Dietary assessment*

Dietary intake of 74 food items and beverages that are commonly consumed in the region were assessed by an interviewer-administered quantitative food frequency questionnaire (FFQ)[16]. Five items on the FFQ queried fish and shellfish consumption (white-fish, oily-fish, dry-fish,

**TABLE 1**
CHARACTERISTICS OF THE STUDY POPULATION ACCORDING TO PREVALENT TYPE 2 DIABETES STATUS

| | Diabetics | Non-diabetics | p* |
|---|---|---|---|
| | (N=182) | (N=1195) | |
| Age, years | | | |
| $\overline{X}$ (SD) | 66.0 (10.6) | 53.8 (15.8) | <0.001 |
| Gender,% | | | |
| Males | 52.75 | 40.67 | 0.002 |
| Education attained, % | | | |
| Elementary | 48.62 | 27.73 | <0.001 |
| High school | 43.09 | 53.68 | |
| College | 8.29 | 18.6 | |
| Socio-economic index, % | | | |
| Low scores (≤10) | 44.75 | 31.89 | <0.001 |
| Medium scores (11–12) | 30.94 | 31.64 | |
| High scores (≥13) | 24.31 | 36.47 | |
| Smoking status, % | | | |
| Current smoker | 12.09 | 24.9 | <0.001 |
| Former smoker | 19.78 | 18.44 | |
| Never smoker | 68.13 | 56.66 | |
| Physical activity, MET hrs/wk | | | |
| $\overline{X}$ (SD) | 1.5 (0.1) | 1.5 (0.1) | 0.11 |
| Anthropometric measures, $\overline{X}$ (SD) | | | |
| Body mass index, kg/m$^2$ | 29.0 (4.6) | 27.0 (4.0) | <0.001 |
| Waist circumference, cms | 101.7 (11.5) | 93.3 (12.0) | <0.001 |
| Biochemical measure, $\overline{X}$ (SD) | | | |
| Fasting plasma glucose, mmol/L | 8.6 (2.0) | 5.6 (0.6) | <0.001 |
| Dietary intake, $\overline{X}$ (SD) | | | |
| White fish, g/1000kcal/wk | 24.5 (21.3) | 22.7 (20.2) | 0.23 |
| Oily fish, g/1000kcal/wk | 23.6 (21.4) | 18.9 (19.1) | 0.002 |
| Dried fish, g/1000kcal/wk | 3.1 (6.0) | 4.2 (8.0) | 0.07 |
| Squid-octopus, g/1000kcal/wk | 6.3 (14.1) | 5.5 (6.7) | 0.20 |
| Shell-crustaceans, g/1000kcal/wk | 2.0 (4.1) | 3.1 (6.0) | 0.01 |

SD, standard deviation; MET, metabolic equivalent task
*p calculated using generalized linear models for continuous, and $\chi^2$-tests for categorical variables

squid-octopus, and shell-crustaceans). Photographs of each food item (small, medium, and large portion) were used to assist in estimating the quantity of food items usually consumed[18]. The frequency of food intake was determined based on the weekly consumption reported as 5–7 times, 3–4 times, and 1–2 times per week, or never. The questionnaire was a modified version of the FFQ used in several nutritional surveys in other Croatian island populations[19,20] and has been tested for reproducibility and relative validity[21]. Food intakes were converted to grams per day and total energy intake was derived using the USDA Nutrient Database for Standard Reference, Release 24, 2011.

### *Defining diabetes*

Biospecimen collection for this study has been described previously in detail[17]. Briefly, blood samples were drawn during field surveys by venipuncture after 12 hours of fasting. After separating the serum, samples were kept frozen until shipped for biochemical analysis in Labor Centar, in Zagreb. The enzymatic hexokinase assay CHOD-PAP method was used to analyze FPG. Diabetes was defined as taking anti-diabetic medications and/or having a FPG ≥7.00 mmol/L.

### *Covariates*

Anthropometric measurements of height, weight and waist circumference (WC) were obtained using standard techniques[17] and BMI was calculated as weight in kilograms divided by height in meters square. The highest level of education attained determined the educational status of the participants and was categorized into elementary, high-school, and college. The socioeconomic index calculated by the presence or absence of material lifestyle variables formed the low, medium and high socioeconomic status groups. Smoking status was categorized into current, former, and non-smokers. Physical activity performed in the past week was collected as hours of sitting, light, moderate, and heavy activity based on the International Physical Activity Questionnaire that had been validated for the Croatian population[22]. The activity factors pertinent to each physical activity in Harris Benedict equation[23] were used to calculate total physical activity.

### *Statistical analysis*

Participant characteristics were described by means and standard deviations for continuous variables and by percentages for categorical variables. Differences in participant characteristics according to diabetes status were tested by ANOVA and $\chi^2$-tests for continuous and categorical variables, respectively. Dietary intakes of fish and shellfish were examined per 1,000 kcal. Total fish intake was calculated as sum of white-fish, oily-fish, and dried-fish. Total shellfish included intakes of squid-octopus and shell-crustaceans. Dietary intakes were categorized into quantiles based on the exposure distribution of all subjects and the lowest level of intake considered as the reference group in all models. Since, many participants reported zero consumption for dried fish and total shellfish, the intake of these two food items were categorized into three groups and zero consumption used as the reference. Multiple logistic regression models were used and odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for the presence of diabetes. Liner trends were tested by examining median values of quantiles as continuous variables. The following covariates were included in all models as continuous variables; age (years), BMI (kg/m$^2$), physical activity (MET hrs/wk), total energy intake (kcal/wk), meat intake (g/wk), and alcohol intake (g/wk). Gender (males versus females), smoking status (current, former, and never), socio-economic status (low, medium, and high), and education (elementary, high-school, and college) were entered as categorical variables. To examine the effect of BMI on the relationship between fish, shellfish and diabetes, participants were categorized into low (≤27.3) and high (>27.3) BMI groups using the mean population BMI as the cutoff. To examine more precise estimate of the association in high WC participants, analyses restricted to those with a gender specific WC for Europeans, above the IDF cutoff[(24)]. Low WC participants could not be examined separately because of the small number of diabetics (N=21). Two-sided p-values <0.05 were considered to be statistically significant. All analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC).

## Results

The characteristics of study participants by diabetes status are provided in Table 1. Those with diabetes were older, more often male, had lower educational attainment, belonged to a lower socio-economic status group, and had never smoked. Diabetics had a higher BMI, WC, and oily fish intake, but low intake of shellfish-crustaceans. The consumption of white fish, dried fish, and squid-octopus did not differ between the two study groups.

Table 2 provides the odds ratios and 95% confidence intervals for prevalent diabetes according to intakes of fish, types of fish, and shellfish. In the total study population, odds ratios for diabetes were positively associated with total and oily fish intake. For total fish, the odds ratio for diabetes was 1.6 times higher between the highest and lowest quartiles ($OR_{Q4\ vs.\ Q1}$ = 1.64; 95% CI = 1.01–2.66; p-trend = 0.09). Similarly, for oily fish intake the odds ratio for diabetes was 2.2 times higher when comparing extreme quartiles and the test for a linear trend was statistical significant ($OR_{Q4\ vs.\ Q1}$ = 2.22; 95% CI = 1.35–3.64; p-trend = 0.01). In gender-specific models associating oily fish intake with diabetes, point estimates were similar for males ($OR_{Q4\ vs.\ Q1}$ = 2.28; 95% CI = 1.16–4.49; p-trend = 0.06) and females ($OR_{Q4\ vs.\ Q1}$ = 2.05; 95% CI = 0.97–4.32; p-trend = 0.07); however, the odds ratio failed to depart from unity for females. Other categories of fish or shellfish were not associated with prevalent diabetes in the total population or in gender-specific analyses.

**TABLE 2**

ODDS RATIOS AND 95% CONFIDENCE INTERVALS FOR PREVALENT TYPE 2 DIABETES ACCORDING TO QUANTILES OF FISH AND SHELLFISH CONSUMPTION

| | All participants (N=1377) | | | Males (N=582) | | | Females (N=795) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Diabetes / participants | OR (95% CI) | p-trend* | Diabetes / participants | OR (95% CI) | p-trend* | Diabetes / participants | OR (95% CI) | p-trend* |
| Total fish and shellfish, g/1000kcal/wk | | | | | | | | | |
| ≤29.7 | 44/344 | 1.00 | 0.22 | 20/144 | 1.00 | 0.16 | 24/200 | 1.00 | 0.82 |
| >29.7 – ≤45.4 | 43/344 | 1.01 (0.62-1.64) | | 26/144 | 1.30 (0.66-2.57) | | 17/200 | 0.77 (0.38-1.57) | |
| >45.4 – ≤68.8 | 35/344 | 0.72 (0.43-1.20) | | 16/142 | 0.75 (0.35-1.62) | | 19/202 | 0.69 (0.34-1.38) | |
| >68.8 | 60/345 | 1.45 (0.91-2.29) | | 34/152 | 1.80 (0.94-3.47) | | 26/193 | 1.13 (0.58-2.20) | |
| Total fish, g/1000kcal/wk | | | | | | | | | |
| ≤ 22.8 | 36/344 | 1.00 | 0.09 | 17/146 | 1.00 | 0.11 | 19/198 | 1.00 | 0.51 |
| >22.8 – ≤36.2 | 45/344 | 1.33 (0.80-2.19) | | 26/153 | 1.53 (0.76-3.08) | | 19/191 | 1.10 (0.53-2.31) | |
| >36.2 – ≤58.3 | 42/344 | 1.09 (0.65-1.81) | | 21/136 | 1.20 (0.57-2.53) | | 21/208 | 0.97 (0.47-1.98) | |
| >58.3 | 59/345 | 1.64 (1.01-2.66) | | 32/147 | 1.94 (0.98-3.85) | | 27/198 | 1.32 (0.66-2.65) | |
| Total shellfish, g/1000kcal/wk | | | | | | | | | |
| 0 | 66/421 | 1.00 | 0.48 | 29/161 | 1.00 | 0.11 | 37/260 | 1.00 | 0.61 |
| >0 – ≤9.6 | 56/478 | 0.87 (0.56-1.34) | | 32/216 | 1.12 (0.60-2.07) | | 24/262 | 0.68 (0.36-1.28) | |
| >9.6 | 60/478 | 1.16 (0.76-1.79 | | 35/205 | 1.66 (0.88-3.12) | | 25/273 | 0.86 (0.47-1.59) | |
| White fish, g/1000kcal/wk | | | | | | | | | |
| ≤10.1 | 38/344 | 1.00 | 0.85 | 15/151 | 1.00 | 0.47 | 23/193 | 1.00 | 0.52 |
| >10.1 – ≤17.0 | 49/344 | 1.23 (0.75-2.01) | | 32/147 | 2.19 (1.09-4.42) | | 17/197 | 0.67 (0.32-1.40) | |
| >17.0 – ≤30.5 | 40/344 | 0.78 (0.47-1.31) | | 19/138 | 0.94 (0.43-2.05) | | 21/206 | 0.64 (0.32-1.28) | |
| >30.5 | 55/345 | 1.20 (0.74-1.94) | | 30/146 | 1.79 (0.87-3.66) | | 25/199 | 0.79 (0.40-1.55) | |
| Oily fish, g/1000kcal/wk | | | | | | | | | |
| ≤8.4 | 32/344 | 1.00 | 0.01 | 18/151 | 1.00 | 0.06 | 14/193 | 1.00 | 0.07 |
| >8.4 – ≤13.9 | 45/344 | 1.74 (1.04-2.91) | | 25/144 | 1.80 (0.89-3.64) | | 20/200 | 1.60 (0.74-3.48) | |
| >13.9 – ≤25.1 | 43/344 | 1.40 (0.83-2.35) | | 19/143 | 1.10 (0.52-2.30) | | 24/201 | 1.69 (0.80-3.58) | |
| >25.1 | 62/345 | 2.22 (1.35-3.64) | | 34/144 | 2.28 (1.16-4.49) | | 28/201 | 2.05 (0.97-4.32) | |
| Dried fish, g/1000kcal/wk | | | | | | | | | |
| 0 | 124/785 | 1.00 | 0.18 | 63/325 | 1.00 | 0.79 | 61/460 | 1.00 | 0.10 |
| >0 – ≤6.5 | 25/296 | 0.65 (0.40-1.05) | | 15/139 | 0.78 (0.41-1.51) | | 10/139 | 0.54 (0.25-1.14) | |
| >6.5 | 33/296 | 0.80 (0.52-1.24) | | 18/118 | 0.97 (0.52-1.79) | | 15/118 | 0.64 (0.34-1.20) | |

Unmatched logistic regression analyses were performed and odds ratios (OR) and confidence intervals (CI) presented. All models adjusted for age (y), sex, BMI (kg/m2), total physical activity/wk, smoking status (current, former, and never), socio-economic status (low, medium and high), education (elementary, high-school, and college), total energy intake/wk, meat intake (g/1000kcal/wk), and alcohol intake (g/1000kcal/wk). * p for trend tested across quantiles of each fish type intake considering median values of quantiles as continuous variable.

**TABLE 3**
ODDS RATIOS AND 95% CONFIDENCE INTERVALS FOR PREVALENT DIABETES ACCORDING TO QUANTILES OF FISH AND SHELLFISH CONSUMPTION STRATIFIED BY BODY MASS INDEX

| | BMI ≤27.3‡ | | | BMI >27.3‡ | | |
|---|---|---|---|---|---|---|
| | Diabetes / participants | OR (95% CI) | p-trend* | Diabetes / participants | OR (95% CI) | p-trend* |
| Total fish and shellfish, g/1000kcal/wk | | | | | | |
| ≤29.7 | 14/187 | 1.00 | 0.08 | 30/157 | 1.00 | 0.93 |
| >29.7 – ≤45.4 | 16/186 | 1.22 (0.54-2.78) | | 27/158 | 0.91 (0.49-1.66) | |
| >45.4 – ≤68.8 | 15/182 | 0.97 (0.41-2.26) | | 20/162 | 0.61 (0.32-1.16) | |
| >68.8 | 25/171 | 2.13 (0.98-4.62) | | 35/174 | 1.13 (0.63-2.03) | |
| Total fish, g/1000kcal/wk | | | | | | |
| ≤22.8 | 11/192 | 1.00 | 0.21 | 25/152 | 1.00 | 0.32 |
| >22.8 – ≤36.2 | 19/182 | 1.76 (0.76-4.05) | | 26/162 | 1.09 (0.58-2.04) | |
| >36.2 – ≤58.3 | 19/188 | 1.36 (0.59-3.16) | | 23/156 | 0.88 (0.46-1.69) | |
| >58.3 | 21/164 | 1.93 (0.85-4.40) | | 38/181 | 1.43 (0.78-2.61) | |
| Total shellfish, g/1000kcal/wk | | | | | | |
| 0 | 21/213 | 1.00 | 0.03 | 45/208 | 1.00 | 0.28 |
| >0 – ≤9.6 | 18/249 | 0.95 (0.45-1.99) | | 38/229 | 0.73 (0.43-1.26) | |
| >9.6 | 31/264 | 2.13 (1.06-4.29) | | 29/214 | 0.73 (0.41-1.29) | |
| White fish, g/1000kcal/wk | | | | | | |
| ≤10.1 | 7/190 | 1.00 | 0.27 | 31/154 | 1.00 | 0.56 |
| >10.1 – ≤17.0 | 25/193 | 2.60 (1.03-6.59) | | 24/151 | 0.82 (0.44-1.53) | |
| >17.0 – ≤30.5 | 17/176 | 1.70 (0.64-4.51) | | 23/168 | 0.57 (0.30-1.08) | |
| >30.5 | 21/167 | 2.38 (0.92-6.15) | | 34/178 | 0.90 (0.51-1.61) | |
| Oily fish, g/1000kcal/wk | | | | | | |
| ≤8.4 | 10/191 | 1.00 | 0.08 | 22/153 | 1.00 | 0.07 |
| >8.4 – ≤13.9 | 17/177 | 1.83 (0.75-4.45) | | 28/167 | 1.64 (0.87-3.12) | |
| >13.9 – ≤25.1 | 19/184 | 1.65 (0.70-3.92) | | 24/160 | 1.21 (0.63-2.33) | |
| >25.1 | 24/174 | 2.32 (1.00-5.38) | | 38/171 | 2.04 (1.09-3.81) | |
| Dried fish, g/1000kcal/wk | | | | | | |
| 0 | 52/401 | 1.00 | 0.01 | 72/384 | 1.00 | 0.99 |
| >0 – ≤6.5 | 11/172 | 0.62 (0.29-1.33) | | 14/124 | 0.60 (0.31-1.16) | |
| >6.5 | 7/153 | 0.35 (0.14-0.82) | | 26/143 | 1.09 (0.65-1.85) | |

‡ Mean values of body mass index (BMI) were used to create groups. Unmatched logistic regression analyses were performed and odds ratios (OR) and confidence intervals (CI) were presented All models adjusted for age (y), sex, total physical activity/wk, smoking status (current, former, and never), socio-economic status (low, medium, and high), education (elementary, high-school, and college), total energy intake/wk, meat intake (g/1000kcal/wk), and alcohol intake (g/1000kcal/wk). * p for trend tested across quantiles of each fish intake considering median values of quantiles as continuous variable

**TABLE 4**
ODDS RATIOS AND 95% CONFIDENCE INTERVALS FOR PREVALENT DIABETES ACCORDING TO QUANTILES OF FISH AND SHELLFISH CONSUMPTION IN PARTICIPANTS WITH HIGH WAIST CIRCUMFERENCE (WC)

| | Diabetes / participants | OR (95% CI) | p-trend* |
|---|---|---|---|
| Total fish/shellfish, g/1000kcal/wk | | | |
| ≤29.7 | 41/254 | 1.00 | 0.61 |
| >29.7 – ≤45.4 | 38/255 | 0.93 (0.56–1.54) | |
| >45.4 – ≤68.8 | 36/266 | 0.74 (0.44–1.25) | |
| >68.8 | 49/268 | 1.21 (0.74–1.96) | |
| Total fish, g/1000kcal/wk | | | |
| ≤22.8 | 34/251 | 1.00 | 0.26 |
| >22.8 – ≤36.2 | 39/257 | 1.21 (0.72–2.03) | |
| >36.2 – ≤58.3 | 39/266 | 1.06 (0.63–1.79) | |
| >58.3 | 49/269 | 1.41 (0.85–2.34) | |
| Total shellfish, g/1000kcal/wk | | | |
| 0 | 61/321 | 1.00 | 0.86 |
| >0 – ≤9.6 | 48/360 | 0.74 (0.47–1.17) | |
| >9.6 | 52/362 | 1.03 (0.66–1.62) | |
| White fish, g/1000kcal/wk | | | |
| ≤10.1 | 37/251 | 1.00 | 0.79 |
| >10.1 – ≤17.0 | 42/249 | 1.12 (0.67–1.86) | |
| >17.0 – ≤30.5 | 37/270 | 0.81 (0.48–1.37) | |
| >30.5 | 45/273 | 1.03 (0.62–1.70) | |
| Oily fish, g/1000kcal/wk | | | |
| ≤8.4 | 28/252 | 1.00 | 0.01 |
| >8.4 – ≤13.9 | 39/251 | 1.81 (1.05–3.12) | |
| >13.9 – ≤25.1 | 42/278 | 1.58 (0.92–2.69) | |
| >25.1 | 52/262 | 2.12 (1.25–3.59) | |
| Dried fish, g/1000kcal/wk | | | |
| 0 | 109/604 | 1.00 | 0.18 |
| >0 – ≤6.5 | 21/213 | 0.55 (0.32–0.93) | |
| >6.5 | 31/226 | 0.81 (0.52–1.28) | |

‡ High WC defined as ≥94 cms for males, and ≥80 cms for females. Unmatched logistic regression analyses were performed in the low and high WC groups, but because of very low frequency of prevalent diabetes in the low WC group, odds ratios (OR) and confidence intervals (CI) were presented only for those with high WC. All models adjusted for age (y), sex, total physical activity/wk, smoking status (current, former, and never), socio-economic status (low, medium, and high), education (elementary, high-school, and college), total energy intake/wk, meat intake (g/1000kcal/wk), and alcohol intake (g/1000kcal/wk). * p for trend were tested across quantiles of each fish intake by considering median values of quantiles as continuous variable

The associations between fish, shellfish and diabetes stratified by BMI are presented in Table 3. Comparing results for the two BMI groups, odds ratios for diabetes associated with fish or shellfish intake were generally higher among those in the low BMI group; the exception being the inverse association observed for dried fish. In the low BMI group, total shellfish was associated with a two fold increase in prevalent diabetes ($OR_{T3\ vs.\ T1}$ 2.13; 95% CI = 1.06–4.29; p-trend = 0.03). In addition, the odds ratio for diabetes with oily fish intake was 2.3 times higher between the highest and lowest quartiles ($OR_{Q4\ vs.\ Q1}$ = 2.32; 95% CI = 1.00–5.38; p-trend = 0.08). In the high BMI group, only oily fish intake was associated with diabetes ($OR_{Q4\ vs.\ Q1}$ = 2.04; 95% CI = 1.09–3.81; p-trend = 0.07). Examining the relationship of various categories of fish and shellfish intakes with diabetes in the high WC group (Table 4), only oily fish intake was associated with prevalent diabetes ($OR_{Q4\ vs.\ Q1}$ = 2.12; 95% CI = 1.25–3.59; p-trend = 0.01).

## Discussion

In this population-based, cross-sectional study conducted among residents of the costal population of Hvar Island, Croatia, high intake of total fish and oily fish was associated with an increased odds ratio for prevalent diabetes. Associations were restricted for other categories of fish intake including total fish and shellfish, shellfish, and white fish. Between the various types of fish and diabetes, associations were more pronounced in males and in those with a lower BMI. To the best of our knowledge, this is the first Croatian study investigating associations between fish and shellfish intake and diabetes.

Few studies have examined associations between fish intake and diabetes. The association observed in our study between total fish and diabetes is in line with findings from third National Family Health Survey (NFHS-3), showing higher odds ratio for prevalent diabetes with daily and weekly fish intake[25]. Mixed results have been reported by prospective studies investigating diabetes risk with fish intake. Several studies have shown increased risk for type 2 diabetes with higher intakes of fish[7–9] while others have found either inverse association[4–6] or no association[26,27]. Meta-analysis of randomized controlled trials (RCT) have reported no effect of omega-3 fatty acids on insulin sensitivity[28]. Similarly, daily supplementation of marine n-3 fatty acids in RCTs have not found protective effect against cardiovascular events in presence of dysglycemia[29,30]. Heterogeneity between the studies could reflect difference in the level, duration, and types of fish intake influenced by the population studied.

Currently there is a debate as to whether presence of persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and dioxins may mediate the association between diabetes and seafood consumption[31,32]. Organic pollutants are slow degrading chemicals which accumulate in marine food[33] and have been suggested as risk factor for diabetes[34,35] by altering insulin signaling pathways[36,37] and disrupting glucose transport[38]. These environmental pollutants are more likely to be accumulated in fatty fish because of its lipophilic nature. In certain species such as farmed salmon, sardines, and tuna higher PCB levels have been detected[1]. Several studies have reported elevated levels of POPs in different marine species in the Adriatic Sea[39–41]. Among various species of fish from the Adriatic, highest amount PCB was detected in the fatty fish[39]. Examining levels of POPs in several types of fish over time from the Croatian sea coast a trend for increase in PCB levels have been shown[42]. Elevated levels of POPs have been found in cod liver oils as opposed to other fish oils or fish oils mixed with vegetable oils[43]. We observed a generalized trend for having higher odds ratios for diabetes with oily fish intake in the total study population and all subgroups examined including those with a high waist circumference. Low and high chlorinated PCBs associate differently with respect to abdominal obesity[44] and differences in POPs concentrations in marine mammals between the geographical regions have been demonstrated[45]. Given the small number of participants in our sample with a recommended waist circumference we were unable to assess potential differences in associations of fatty fish intake and diabetes by this proxy of abdominal adiposity. Thus, the possibility of exposure to different types of POPs through fish intake and its relationship with diabetes and measures of adiposity in this population warrants further exploration.

The methods used for cooking fish have been suggested to alter the beneficial effect of fish on health outcomes[46,47] and this can contribute to the positive association between fish intake and diabetes. Traditionally Croatians consumed boiled, smeared, grilled or deep fried fish[12]. These traditions still seem to be preserved by the islanders in general; large fish are usually grilled and small fish are deep fried[48]. In our population the specific method for cooking fish could not be captured; however, the majority reported stewing vegetables as a preferred cooking method.

Strength of our study includes the relatively large cohort of men and women with similar genetic make-up due to population migration and settlement patterns in these isolated islands and sharing similar environmental exposures[11]. The data on various types of fish and shellfish, detailed covariate data, high fish and shellfish consumption, and fasting plasma glucose measurements were also strengths. The absence of data on methods used for cooking fish is a limitation. In addition, the cross-sectional design precludes causal inferences. Croatians in general are aware of health benefits of eating fish[49] and this may have resulted in differential reporting. The possibility of residual confounding also cannot be ruled out.

## Conclusion

An association was found between oily fish intake and diabetes in a population residing on the Hvar Island in Croatia. Our findings are in support of other epidemiological studies suggesting a link between fish intake and diabetes. Longitudinal studies incorporating measures of persistent organic pollutants and local cooking practices are warranted to identify factors in fatty fish that may influence the development or persistence of diabetes.

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## UNOS RIBE, RAKOVA I ŠKOLJKI I DIJABETES U OBALNOM STANOVNIŠTVU JADRANA


### S A Ž E T A K

Cilj istraživanja bio je ispitati povezanost između unosa ribe i školjkaša i dijabetesa u otočnom stanovništvu, a studija je bila transverzalna. Provedena su dva neovisna terenska istraživanja stanovništva na otoku Hvaru, na istočnoj obali Jadrana u Hrvatskoj u svibnju 2007. i svibnju 2008. godine, s ukupno 1.379 odraslih ispitanika. U modelima multivarijatne logističke regresije, ukupan unos ribe pozitivno je povezan s učestalosti dijabetesa u ukupnom stanovništvu ($OR_{Q4\ vs.\ Q1}$ = 1,64; 95% CI = 1,01–2,66; p-trend = 0,09). Unos masne ribe pokazao je pozitivnu povezanost s učestalosti dijabetesa u ukupnom stanovništvu ($OR_{Q4\ vs.\ Q1}$ = 2,22; 95% CI = 1,35–3,64; p-trend = 0,01) i, u analizi prema indeksu tjelesne mase, kod muškaraca i kod onih s širokim opsegom struka. Studija ukazuje na povezanost unosa masne ribe i dijabetesa u populaciji otoka Hvara u Hrvatskoj. Potrebna je longitudinalna studija, koja uključuje mjere postojanih organskih onečišćujućih tvari i lokalnu praksu kuhanja, za identifikaciju čimbenika koji kod unosa masne ribe mogu utjecati na razvoj ili postojanost dijabetesa.