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Exploring the Link between Seafood and Traditional Fish Sauces, and Blood Pressure: A Bandar Kong Cohort Study

Afshin Samiei; PhD[1, 5], Shide Rafati; PhD [2], Mohammad Mohammadi; PhD[3], Azim Nejatizadeh; PhD[4] & Narges Khaghanzadeh; PhD*[4, 5]

[1] Tobacco and Health Research Center, Hormozgan University of Medical Sciences, Bandar Abbas, Iran; [2] Social Determinants in Health Promotion Research Center, Hormozgan Health Institute, Hormozgan University of Medical Sciences, Bandar Abbas, Iran; [3] Food Health Research Center, Hormozgan University of Medical Sciences, Bandar Abbas, Iran; [4] Molecular Medicine Research Center, Hormozgan Health Institute, Hormozgan University of Medical Sciences, Bandar Abbas, Iran; [5] Department of Immunology, Faculty of Medicine, Hormozgan University of Medical Sciences, Bandar Abbas, Iran.

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***Corresponding author:**
n.khaghanzadeh@gmail.com
Molecular Medicine Research Center, Hormozgan Health Institute, Hormozgan University of Medical Sciences, Bandar Abbas, Iran.

Postal code: 7919693116
Tel: +98 763 3710373

ABSTRACT

Background: High blood pressure (BP) is a risk factor for various health conditions, and dietary factors have been linked to the development of high blood pressure. Scientific studies have shown that consuming marine food, particularly oily fish, can be beneficial in reducing blood pressure levels. This study aims to investigate the relationship between traditional fish sauces and seafood consumption, and blood pressure levels in Bandar Kong Cohort study. **Methods:** Cross-sectional analyses were performed using data from 2823 volunteers, collected through questionnaires and BP measurements following a standardized protocol. Age-adjusted and multivariate associations between BP and seafood consumption were estimated using multiple linear regressions. Three models of analysis were used: model 1, daily energy intake; model 2, daily energy intake along with age; and model 3, daily energy intake, age, education, body mass index (BMI), residence, occupation, marital status, using hookah, socio-economic status, physical activity, and family history of hypertension. **Results:** Among 2823 participants (age; 46.88±8.94 yrs.), 1138(40.3%) men and 1685(59.7%) women, 693 (24.5%) individuals had hypertension, (n=288) accounting for 25.3% men and (n=405) 24.0% women. After adjusting for covariates, the study found significant negative relationships between the consumption of salted fish-water, Mahyaveh and Suragh (traditional Iranian fish sauces), and BP. **Conclusions:** This study suggests that consuming traditional Iranian fish sauces, Mahyaveh and Suragh, is associated with lower BP levels. This study sheds light on potential benefits of traditional dietary choices for regulating blood pressure.

Keywords: *Mahyaveh; Suragh; Seafood; Fish products; Fish sauces; Blood pressure; Hypertension; Diet; Fermented foods*

Introduction

High blood pressure (BP), also known as hypertension, is among the risk factors for various health conditions, including heart disease, brain disorders, kidney problems (Hashemian *et al.*, 2020, Oparil *et al.*, 2018), eye conditions, and sexual dysfunction. Furthermore, hypertension can increase the risk of several cancers, oral health disorders, and osteoporosis (Kokubo and

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Iwashima, 2015, World Health Organization, 2013). Several epidemiological studies have indicated that dietary factors play a role in the development of high BP. It appears that an individual's diet and BP levels are closely linked (Farshidi *et al.*, 2020, Schwingshackl *et al.*, 2017). Public education is recommended to control salt intake as a modifiable risk factor for cardiovascular diseases. Scientific studies have demonstrated that consuming marine food, especially oily fish, can lower BP levels (Del Brutto *et al.*, 2016, Ramel *et al.*, 2010, Xun *et al.*, 2012, Zheng *et al.*, 2011). However, there is inconsistency in this effect (Soleha and Qomaruddin, 2020, Yang *et al.*, 2016), particularly when traditional fish or fish constituents are consumed, mainly due to inadequate research.

Many fermented fish products are prepared and consumed in different parts of the world, such as "kecap ikan" in Indonesia, "nam pla" in Thailand, "patis" in the Philippines, "shottsuru" in Japan, and so on (Irianto, 2017, Marti-Quijal *et al.*, 2020, Se-Kwon and Fidel, 2017). Fish sauce is a salt-soluble protein in the form of amino acids and peptides, produced during the fermentation of whole, headed or gutted fish (Irianto, 2017). Mahyaveh is a traditional fermented fish sauce in Iran, widely consumed in Larestan and Hormozgan. Mahyaveh is typically composed of headed sardines (*Sardinella sp*.) or anchovies (*Stelophorus sp*.), salt, mustard (Brassica juncea), various spices such as cumin (*Cuminum cyminum*), coriander (*Coriandrum sativum*), fennel seeds (*Foeniculum vulgare*), black pepper (*Piper nigrum*), thyme (*Thymus capitatus*), and water. Mahyaveh sauce is produced through a fermentation process for one-two months until the desirable taste and aroma is completed (Zarei *et al.*, 2012). Suragh, another traditional sauce from this region, is made using Sardines (Sardinella sp.) or Anchovies (Stelophorus sp.), salt, orange peel, and the unique red soil found on Hormuz Island. The red soil on Hormuz Island is primarily composed of hematite and iron hydroxides, giving it a distinct color (Mosallaei *et al.*, 2023).

Mahyaveh, Suragh, and salted fish-water are traditional fish products commonly consumed in southern Iran, including Bandar Kong. These sauces are a regular part of the local diet, but no prior study has investigated their relationship with BP. These sauces contain high levels of salt (7-19%), which is added during preparation (Moghadam *et al.*, 2019, Zarei *et al.*, 2012). Several studies have examined the risk of hypertension and its associated risk factors in the southern region of Iran (Dabaghmanesh *et al.*, 2007, Farshidi *et al.*, 2006, Safari Moradabadi *et al.*, 2007). A cross-sectional study conducted in Bandar Abbas identified salt consumption as a significant factor affecting uncontrolled hypertension in adults (Fallahi *et al.*, 2023). Therefore, the study aims to explore the association between consumption of seafood and traditional fish products, and blood pressure in participants of the Bandar Kong Cohort study with a focus on the odds of hypertension.

Materials and Methods

Study design

The Bandar Kong Cohort study was conducted as a branch of a prospective epidemiological research study in Iran, Hormozgan Province. The study protocol, design, and methods have already been detailed (Nejatizadeh *et al.*, 2022). Briefly, the present study included 4063 participants aged 35–70 who were recruited on Oct 2016 and re-evaluated every 5 years along with annual follow-ups. The required data including demographic and socio-economic status, anthropometric measurements, physical activity levels, and medical history were obtained by trained interviewers. Detailed information on dietary intake of participants was also collected using the food frequency questionnaire (FFQ). The validity and reliability of this FFQ have been established in a prior study (Eghtesad *et al.*, 2023). The current study utilized baseline data from the ongoing Bandar Kong Cohort study.

Study population

A total of 4063 volunteers underwent a clinical consultation between October 2016 and April 2021. Considering the exclusion criteria, The

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authors identified 2823 eligible participants for the analysis phase. Pregnant women and participants who self-reported to have a history of cardiovascular disease, diabetes, and cancer as well as participants with low (<800 kcal/day) or high (>4200 kcal/day) calorie intake were excluded (Banna *et al.*, 2017).

Data collection

Seafood (g/day) intake assessment: In this study, trained interviewers used a 132-item semi-quantitative open-ended FFQ to assess the usual dietary intake of participants in Bandar Kong Cohort study. Participants responded to a multiple-choice questionnaire consisting of two questions about each food item: (1) the frequency of consumption on daily, weekly, or monthly of food items during the preceding 12 months, and (2) the typical portion size consumption for each food item listed on FFQ. The obtained data on the consumption of seafood, Mahyaveh, Suragh, and salted fish-water (juice) were converted to grams per day measurement using household measures (Swindale and Ohri-Vachaspati, 2005). To estimate daily energy and nutrient intakes of each participant, the United States Department of Agriculture (USDA) food composition database was used (Haytowitz *et al.*, 2019, Lelong *et al.*, 2015).

Anthropometrics, demographic, health, and lifestyle data collection: Demographic, health, and lifestyle data collection, annual follow-ups, and re-surveys have been detailed elsewhere (Nejatizadeh *et al.*, 2022, Poustchi *et al.*, 2017). Briefly, self-administrated questionnaires provided data on three key fields; general, medical, and nutritional components controlled by four well-educated interviewers.

Blood pressure measurement: BP was measured using a standard mercury sphygmomanometer after the participant had rested for at least 5 minutes. The cuff size used was appropriate for the participant's upper-arm circumference, while they were seated with their feet on the floor, and their arm was supported at heart level. Two measurements were taken at least 5 minutes apart, and the average of these two readings was used for analysis. Hypertension was defined as a sustained BP of 140/90 mmHg or higher, or treatment with anti-hypertensive medications. If the values were elevated (≥140/90 mmHg), they were confirmed on a separate day (Nikparvar *et al.*, 2021).

Ethical considerations

The study was approved by Ethics Committee with the code IR.HUMS.REC.1399.409 as part of the Persian cohort study, supported by Hormozgan University of Medical Sciences, with rigorous ethical considerations, including plagiarism and informed consent, diligently managed by the authors.

Data analysis

Quantitative variables were reported as mean±standard deviation (SD) or standard error mean (SE), and categorical variables were reported by frequency and percentage. Independent samples t-test and $\chi 2$ test were used to compare variables in men and women.

Daily seafood consumption (gram per day) was categorized in 3 groups based on the first and third quartile (Low<Q_1, Q_1≤Moderate<Q_3, and High≥Q_3).

Physical activity was evaluated by calculating the metabolic equivalent of task (MET) score for 24 hours, using a continuous score system. This score was determined by assigning MET values to various activities such as sleeping, resting, watching TV, reading, working while seated, eating, driving, cooking, washing dishes, house cleaning, walking, cycling, heavy labor, and professional sports. Participants were then categorized into three groups based on their MET score quartile (Low<Q1, Q1≤Moderate<Q3, High≥Q3): low, moderate, and high physical activity.

The study utilized binary logistic regression analysis to calculate crude odds ratio (OR) and a 95% confidence interval (CI) with the purpose of examining the associations between variables and the likelihood of hypertension in both women and men. Additionally, multivariable binary logistic regression analysis was used to compute the

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adjusted odds ratio (OR) and a 95% CI to determine the correlation between seafood consumption and the risk of hypertension. Model 1 was adjusted for daily energy intake; Model 2 was controlled for daily energy intake as well as age; and Model 3 was adjusted for daily energy intake, age, education, body mass index (BMI) (all continuous variables), residence (urban/rural), occupation (employed/ unemployed), marital status (single, married, widowed or divorced), hookah use (yes/no), socio-economic status (low/medium/high), family history of hypertension (yes/no) and physical activity (low/medium/high), and. In addition, multivariable linear regression was used to find the average difference in systolic and diastolic BP between different groups (supplementary). All tests were performed using SPSS (version 19). P-value < 0.05 was considered statistically significant.

Results

Socioeconomic, anthropometric parameters, and nutritional status assessment

Table 1 reports the study population characteristics**.** Out of 2823 participants, 59.7% were women with a mean age of 46.62±8.78 and the mean age for men was 47.27±9.15 years. The median age for women was 45 with an interquartile range of 14 years, while for men it was 45 with an interquartile range of 15 years. Out of the total number of women, 51.8% (872) were aged 45 or older, while 53.8% (612) of men fell within this age range.

Table 2 displays a comparison of seafood consumption (grams per day) among both genders with and without hypertension. Totally, 693 individuals (24.5%); 288 men (25.3%) and 405 women (24.0%) had hypertension.

Table 1. Characteristics of the study population.

Variables	Total (n=2823)	Men (n=1138; 40.3%)	Women (n=1685; 59.7%)	P-value
Age (year)	46.88±8.94	47.27±9.15	46.62±8.78	0.062
Total energy intake (kcal/day)	2741.2±665.0	3024.0±613.9	2550.3±629.4	<0.001
Residence				
Urban	2397(84.9)	971(85.3)	1426(84.6)	0.630
Rural	426(15.1)	167(14.7)	259(15.4)	
Education (year)				
<6	1628(57.7)	481(42.3)	1147(68.1)	<0.001
6-12	929(32.9)	500(43.9)	429(25.5)	
>12	266(9.4)	157(13.8)	109(6.5)	
Occupation				
Unemployed	1557(55.3)	160(14.1)	1397(83.1)	<0.001
Employed	1261(44.7)	977(85.9)	284(16.9)	
Physical activity				
Low	706(25.0)	300(26.4)	406(24.1)	<0.001
Medium	1413(50.1)	503(44.2)	910(54.0)	
High	704(24.9)	335(29.4)	369(21.9)	
Body mass index (kg/m^2)				
≤24.9	1101(39.1)	551(48.6)	550(32.7)	<0.001
25-29.9	1055(37.5)	416(36.7)	639(38.0)	
≥30	658(23.4)	167(14.7)	491(29.2)	
Marital status				
Single	83(2.9)	18(1.6)	65(3.9)	<0.001
Married	2517(89.2)	1106(97.2)	1411(83.7)	
Widowed/Divorced	223(7.9)	14(1.2)	209(12.4)	
Cigarette smoking (yes)	363(12.9)	358(31.6)	5(0.3)	<0.001
Alcohol drinker (yes)	135(4.8)	131(11.6)	4(0.2)	<0.001
Hookah use (yes)	451(16.1)	243(21.5)	208(12.4)	<0.001
Drug use (yes)	115(4.1)	107(9.5)	8(0.5)	<0.001

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Socio-economic status				
Low	1070(38.0)	355(31.3)	715(42.6)	
Medium	586(20.8)	242(21.3)	344(20.5)	<0.001
High	1158(41.2)	538(47.4)	620(36.9)	
Family history of hypertension (yes)	1551(54.9)	536(47.1)	1015(60.2)	<0.001
Canned fish				
Low	734(26.0)	242(21.3)	492(29.2)	<0.001
Medium	1384(49.0)	538(47.2)	846(50.2)	
High	705(25.0)	358(31.5)	347(20.6)	
Salted fish				
Low	1556(55.1)	580(51.0)	976(57.9)	<0.001
Medium	486(17.2)	188(16.5)	298(17.7)	
High	781 (27.7)	370(32.5)	411(24.4)	
Shrimp/ crab				
Low	740(26.2)	249(21.9)	491(29.1)	<0.001
Medium	1355(48.0)	546(48.0)	809(48.0)	
High	728(25.8)	343(30.1)	385(22.8)	
Mahyaveh/ suragh				
Low	705(25.0)	299(26.3)	406(24.1)	0.379
Medium	1381(48.9)	542(47.6)	839(49.8)	
High	737(26.1)	297(26.1)	440(26.1)	
Fish Bandar Kong				
Low	576(20.4)	179(15.7)	397(23.6)	<0.001
Medium	1642(58.2)	630(55.4)	1012(60.1)	
High	605(21.4)	329(28.9)	276(16.4)	
Salted fish-water				
Low	2134(75.6)	853(75.0)	1281(76.0)	0.532
High	689(24.4)	285(25.0)	404(24.0)	

Data are in mean ± standard deviation for quantitative variables and frequency (percent) for categorical variables.
[a]: Independent samples t-test applied for quantitative and $\chi 2$ test for categorical variables.

Table 2. The comparison of seafood consumption (g/day) in both genders with and without hypertension.

Variable	Men (n=1138)			Women (n=1685)		
	Without (n=850)	With (n=288)	P-value	Without(n=1280)	With(n=405)	P-value[a]
Canned fish	3.21±0.16	2.75±0.21	0.138	2.19±0.08	2.17±0.15	0.888
Salted fish	1.59±0.08	1.17±0.10	0.001	1.08±0.05	0.95±0.07	0.135
Shrimp/crab	6.11±0.39	6.19±0.89	0.932	4.72±0.29	3.22±0.25	<0.001
Mahyaveh/suragh	8.55±0.51	7.65±0.75	0.359	7.72±0.28	8.56±0.86	0.355
Fish Bandar Kong	33.02±0.88	32.91±1.31	0.948	24.75±0.55	24.58±0.97	0.883
Salted fish-water	1.79±0.16	1.46±0.23	0.287	1.80±0.13	1.81±0.24	0.981
Canned fish						
Low	169(19.8)	73(25.3)	0.068	375(29.2)	117(28.9)	0.593
Medium	401(47.2)	137(47.6)		635(49.7)	211(52.1)	
High	280(33.0)	78(27.1)		270(21.1)	77(19.0)	
Salted fish						
Low	425(48.1)	155(53.8)	0.059	742(58.0)	234(57.7)	0.196
Medium	133(15.6)	55(19.1)		216(16.9)	82(20.2)	
High	292(34.3)	78(27.1)		322(25.1)	89(22.1)	
Shrimp/crab						
Low	182(21.4)	67(23.3)	0.342	357(27.9)	134(33.1)	0.053
Medium	402(47.3)	144(50.0)		616(48.1)	193(47.6)	
High	266(31.3)	77(26.7)		307(24.0)	78(19.3)	
Mahyaveh/suragh						
Low	210(24.7)	89(30.9)	0.118	287(22.4)	119(29.4)	0.014
Medium	413(48.6)	129(44.8)		656(51.3)	183(45.2)	
High	227(26.7)	70(24.3)		337(26.3)	103(25.4)	

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Fish Bandar Kong						
Low	143(16.8)	36(12.5)		311(24.3)	86(21.2)	
Medium	460(54.2)	170(59.0)	0.172	754(58.9)	258(63.7)	0.227
High	247(29.0)	82(28.5)		215(16.8)	61(15.1)	
Salted fish-water						
Low	624(73.4)	229(79.5)	0.041	969(75.7)	312(77.0)	0.022
High	226(26.6)	59(20.5)		311(24.3)	93(236.0)	

Data are presented in mean ± standard error for quantitative variables and frequency (percent) for categorical variables. [a]: Independent samples t-test applied for quantitative and χ2 test for categorical variables.

The associations between high blood pressure and different variables in both men and women

Based on the findings of univariable binary logistic regression and values of crude odds ratios in **Table 3**, the associations between the risk of hypertension and age, energy intake, occupation, BMI, socio-economic status, and family history of hypertension were strong in both sexes. The relationship between risk of hypertension and physical activity, hookah use, and consumption of canned fish, salted fish, and salted fish-water (juice) were significant for men while for women the associations between hypertension and other factors such as marital status, education, and consumption of shrimp or crab were strong items.

Table 3. The associations between high BP and different variables in both men and women.

Variable	**Men (n=1138; 40.3%)**			**Women (n=1685; 59.7%)**		
	Crude OR	**95% CI**	**P-value**	**Crude OR**	**95% CI**	**P-value**
Age (year)	1.08	1.07-1.10	<0.001	1.10	1.08-1.11	<0.001
Total energy intake (kcal/day)	0.91	0.86-0.96	<0.001	0.93	0.89-0.97	<0.001
Residence						
Urban	Reference					
Rural	1.19	0.82-1.71	0.362	1.92	1.44-2.55	<0.001
Education (years)						
<6	2.56	1.61-4.06	<0.001	7.51	3.26-17.26	<0.001
6-12	1.26	0.78-2.02	0.340	2.26	0.94-5.43	0.067
>12	Reference					
Occupation						
Unemployed	3.81	2.69-5.39	<0.001	2.29	1.60-3.30	<0.001
Employed	Reference					
Physical activity						
Low	1.83	1.27-2.63	0.001	1.25	0.89-1.74	0.194
Medium	1.41	1.01-1.97	0.047	1.19	0.89-1.59	0.238
High	Reference					
Body mass index (kg/m^2)						
≤24.9	Reference					
25-29.9	1.23	0.92-1.66	0.168	1.63	1.22-2.12	0.001
≥30	1.87	1.28-2.73	0.001	2.77	2.06-3.72	<0.001
Marital Status						
Single	Reference					
Married	2.71	0.62-11.87	0.185	1.48	0.76-2.86	0.244
Widow/Divorce	6.00	0.98-36.71	0.053	2.32	1.14-4.71	0.020
Hookah use						
No	Reference					
Yes	1.66	1.22-2.26	0.001	0.99	0.71-1.40	0.985
Socio -economic status						
Low	1.03	0.76-1.40	0.856	1.38	1.07-1.77	0.013
Medium	1.03	0.73-1.46	0.876	1.08	0.79-1.49	0.618
High	Reference					
Family history of hypertension						
No	Reference					
Yes	1.49	1.14-1.95	0.004	1.64	1.29-2.08	<0.001

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Canned fish						
Low	1.55	1.07-2.25	0.021	1.09	0.79-1.52	0.591
Medium	1.23	0.89-1.68	0.207	1.16	0.87-1.57	0.314
High	Reference					
Salted fish						
Low	1.36	1.01-14.86	0.049	1.14	0.86-1.50	0.351
Medium	1.55	1.04-2.31	0.033	1.37	0.97-1.94	0.072
High	Reference					
Shrimp/ crab						
Low	1.27	0.87-1.86	0.212	1.48	1.07-2.03	0.016
Medium	1.24	0.90-1.70	0.188	1.23	0.92-1.66	0.166
High	Reference					
Mahyaveh/suragh						
Low	1.37	0.95-1.98	0.088	1.36	0.99-1.84	0.052
Medium	1.013	0.73-1.41	0.940	0.91	0.69-1.20	0.515
High	Reference					
Fish Bandar Kong						
Low	0.76	0.49-1.18	0.221	0.97	0.67-1.41	0.892
Medium	1.11	0.82-1.51	0.491	1.21	0.88-1.66	0.248
High	Reference					
Salted fish-water						
Low	1.41	1.02-1.94	0.039	1.08	0.83-1.40	0.584
High	Reference					

OR: Odds ratio; **CI**: confidence interval.

Furthermore, as in **Table 3**, the risk of hypertension increases in men and women up to 0.08 and 0.10, respectively by age per year. Moreover, for one unit of increase in total energy intake, the risk of hypertension in men and women are reduced by 0.09 and 0.07, respectively. The risk of hypertension was 0.92 higher for rural women than those who lived in cities. The risk of hypertension in men and women with primary and lower educational backgrounds was 2.56 and 7.51 times higher than their college-educated counterparts, respectively. The odds of hypertension were 3.81 and 2.29 times higher for unemployed males and females compared with their employed counterparts, respectively. The risk in men with low and moderate physical activity was 0.83 and 0.41 higher than men with high physical activity, respectively. The odds of hypertension was 0.87 higher for men with BMI≥30 kg/m^2 than those with BMI<25 kg/m^2, the risk was 1.63 and 2.77 time higher for women with 25≤BMI<30, and BMI≥30 kg/m^2, respectively, compared with those with a BMI<25 kg/m^2.

The risk of hypertension in widowed and divorced women was 2.32 times higher than single females. The risk in males who smoked hookah was 0.66 higher than their counterparts. The risk was 0.38 higher for women with low socio-economic status than those who had a high level of socio-economic status. The risk in men and women with a family history of hypertension was 0.49 and 0.64, higher than their counterparts, respectively.

Seafood consumption and the risk of hypertension

Salted fish: According to **Table 2**, there was a significant difference in the mean consumption of salted fish (*P*=0.001) between men with and without hypertension. Furthermore, the risk of hypertension in males with low and moderate consumption of salted fish was respectively 0.36 and 0.55 higher, than males who consumed a high amount of salted fish (**Table 3**). After adjusting daily energy intake and age in model 2 (**Table 4**), the risk of hypertension in males with low and moderate consumption of salted fish was 0.45 and 0.58 higher compared with males who consumed a high amount of salted fish. According to the results of multivariable linear regression (presented in supplementary, **Table 1**), after adjusting for covariates of daily energy intake, age, education, BMI, residence, job,

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marital status, hookah use, socio-economic status, physical activity, and family history of hypertension, the mean of diastolic BP in males who consumed low amounts of salted fish was 1.77 mmHg higher than those who consumed high amounts of this food.

Table 4. Multivariable logistic regression analysis of the relationship between seafood consumption and the risk of hypertension in women and men.

Variable	Model 1		Model 2		Model 3	
	Adjusted OR (95%CI[a])	P-value	Adjusted OR (95%CI[a])	P-value	Adjusted OR (95%CI[a])	P-value
Men						
Canned fish						
Low	1.42(0.97-2.07)	0.070	1.15(0.77-1.71)	0.495	1.06(0.70-1.62)	0.779
Medium	1.15(0.83-1.59)	0.390	1.01(0.72-1.41)	0.976	0.97(0.69-1.38)	0.884
High	Reference					
Salted fish						
Low	1.25(0.91-1.71)	0.173	1.45(1.04-2.02)	0.030	1.49(1.04-2.13)	0.029
Medium	1.45(0.97-2.18)	0.069	1.58(1.03-2.43)	0.035	1.50(0.96-2.36)	0.076
High	Reference					
Shrimp/ crab						
Low	1.13(0.77-1.66)	0.543	0.98(0.65-1.48)	0.939	0.96(0.62-1.51)	0.965
Medium	1.15(0.84-1.59)	0.381	1.05(0.75-1.47)	0.781	1.07(0.75-1.52)	0.722
High	Reference					
Mahyaveh/suragh						
Low	1.33(0.92-1.92)	0.131	1.62(1.09-2.39)	0.016	1.63(1.07-2.48)	0.022
Medium	0.98(0.70-1.38)	0.926	1.18(0.83-1.68)	0.364	1.18(0.81-1.72)	0.388
High	Reference					
Fish Bandar Kong						
Low	0.71(0.45-1.11)	0.130	0.96(0.60-1.53)	0.852	1.12(0.68-1.84)	0.647
Medium	1.05(0.77-1.42)	0.774	1.15(0.83-1.59)	0.411	1.27(0.90-1.80)	0.168
High	Reference					
Salted fish-water						
Low	1.34(0.96-1.85)	0.082	1.54(1.09-2.18)	0.014	1.57(1.07-2.29)	0.020
High	Reference					
Women						
Canned fish						
Low	1.00(0.72-1.39)	0.999	0.93(0.65-1.32)	0.671	1.01(0.69-1.47)	0.976
Medium	1.11(0.83-1.51)	0.469	1.21(0.88-1.66)	0.242	1.26(0.90-1.77)	0.175
High	Reference					
Salted fish						
Low	1.06(0.80-1.40)	0.694	1.17(0.87-1.58)	0.298	1.37(0.99-1.90)	0.058
Medium	1.32(0.93-1.87)	0.116	1.42(0.98-2.06)	0.061	1.45(0.98-2.14)	0.063
High	Reference					
Shrimp/crab						
Low	1.34(0.97-0.86)	0.075	1.16(0.82-1.64)	0.402	1.03(0.71-1.50)	0.874
Medium	1.18(0.87-1.59)	0.288	1.09(0.80-1.51)	0.560	1.01(0.72-1.41)	0.980
High	Reference					
Mahyaveh/suragh						
Low	1.24(0.91-1.70)	0.178	1.40(1.01-1.96)	0.049	1.65(1.15-2.36)	0.007
Medium	0.85(0.64-1.12)	0.250	0.99(0.73-1.33)	0.925	1.03(0.75-1.41)	0.867
High	Reference					
Fish Bandar Kong						
Low	0.87(0.59-1.27)	0.467	1.02(0.68-1.53)	0.919	1.24(0.81-1.90)	0.315
Medium	1.12(0.81-1.55)	0.483	1.13(0.81-1.60)	0.467	1.19(0.83-1.70)	0.340
High	Reference					

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Salted fish-water						
Low	1.02(0.78-1.33)	0.899	1.09(0.83-1.46)	0.515	1.40(1.02-1.92)	0.035
High	Reference					

Model 1: Adjusted for daily energy intake; Model 2: Adjusted for daily energy intake and age; Model 3: Adjusted for daily energy intake, age, education, BMI, residence, job, marital status, using hookah, socio-economic status, physical activity, and family history of hypertension

Salted fish-water: According to the results, males who consumed low amounts of salted fish-water had a 0.41 higher risk of hypertension compared to those who consumed high amounts of salted fish-water (as shown in **Table 3**). After adjusting for daily energy intake and age in model 2 (**Table 4**), the risk for males with low consumption of salted fish-water was 0.54 higher than males consuming high amounts. Additionally, females with low consumption of salted fish-water had a 0.40 higher odds of hypertension compared to females with high consumption (Model 3, **Table 4**).

Shrimp and crab: **Table 2** indicates that women without hypertension had a higher mean consumption of shrimp and crab compared to their counterparts (P<0.001). Furthermore, females with low consumption of shrimp and crab had a 0.48 higher risk of hypertension compared to females who consumed a high amount of these foods (**Table 3**).

Canned fish: The risk of hypertension in males with low consumption of canned fish was 0.55 higher than males who ate a high amount of canned fish (**Table 3**).

Mahyaveh and Suragh: Model 2 (**Table 4**) shows that after adjusting for daily energy intake and age, males with low consumption of Mahyaveh/Suragh had a 0.62 higher odds ratio of hypertension compared to males with high consumption of these sauces. Similarly, females with low consumption of Mahyaveh /Suragh had a 0.40 higher odds ratio of hypertension compared to females with high consumption of these sauces.

Fish Bandar Kong: According to the results of multivariable linear regression (presented in Supplementary **Table 1**), the mean of diastolic BP in females who consumed low amounts of fish Bandar Kong was 1.59 mmHg higher than those who consumed high amounts of this food.

Totally, in Model 3 (**Table 4**), after adjusting covariates of daily energy intake, age, education, BMI, residence, job, marital status, hookah use, socio-economic status, physical activity, and family history of hypertension, the odds of hypertension in males with low consumption of salted fish, mahyaveh, suragh and salted fish-water were 0.49, 0.63, and 0.57 higher than their counterparts with high consumption of these foodstuff. Furthermore, the odds of hypertension in females with low consumption of mahyaveh, suragh and salted fish-water was 0.65 and 0.40 higher than their counterparts with high consumption of these food stuff.

Discussion

The current research studied individuals with an average age of 46.88±8.94 in Bandar Kong region and suggested a remarkable inverse correlation between mahyaveh/suragh sauces consumption and hypertension. In addition, the statistical evidence indicated that the consumption of salted fish-water may be associated with a lower risk of high blood pressure in both males and females. Statistical analysis revealed that the intake of salted fish had a favorable impact on reducing blood pressure in males, but not females. The fully adjusted model revealed that there was an inverse association between the odds of elevated blood pressure and mahyaveh/suragh, and salted fish-water intake.

Most investigations examined the overall associations between marine foods intake, the incidence of BP, and its related diseases (Zhang *et al.*, 2020). Seafood as a source of various nutrients, including protein, amino acids, fiber, vitamins, and minerals can enlighten some of its benefits in a healthy diet (Hosomi *et al.*, 2012, Zhang *et al.*, 2020).

Previously, Angiotensin I-converting enzyme (ACE) inhibitory peptides were isolated from Asian traditional fermented fish sauce, among which Lys-Pro showed a tendency to lower BP in

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spontaneously hypertensive rats (Ichimura *et al.*, 2003). Other studies on fish bioactive peptides show their anti-hypertensive and ACE inhibitory activities (Abachi and Bazinet, 2019, Jensen and Mæhre, 2016). Many fish species, for instance, carp, salmon, tilapia, sardine, tuna and the related hydrolysates have numerous health benefits such as antioxidative, antihypertensive, and cardio protective activities of biopeptides (Festa *et al.*, 2020, Ichimura *et al.*, 2003, Wu *et al.*, 2015). These species' proteinaceous content provides the essential amino acids, and their hydrolysates have antihypertensive biopeptides as well (Houston, 2014, Phadke *et al.*, 2021). The hydrolysates or peptides of these sauces can lower BP via ACE inhibition in renin-angiotensin-aldosterone-system (RAAS). ACE converts angiotensin I (Ang I) to the Angiotensin II (Ang II) causing vasoconstriction and increases the blood pressure. ACE also inactivates bradykinin - a potent vasodilator peptide - in the kinin-kallicrein system (KKS) (Jensen and Mæhre, 2016).

The main ingredients of mahyaveh and suragh sauces are sardines (*Sardinella sp.*) or anchovies (*Stelophorus sp.*) protein hydrolysates or peptides (Moghadam *et al.*, 2019, Zarei *et al.*, 2012). Among decarboxylated amino acids in fermentation processes, histamine was found to be the main biogenic amine in Iranian fish sauce (Moghadam *et al.*, 2019, Zarei *et al.*, 2012). However, there is no consistent data on the antihypertensive effect of histamine. It has been shown that histamine receptors, especially H3 (a type of histamine receptors), can be involved in vasodilation and blood pressure control (C. Reid *et al.*, 2011, Naylor *et al.*, 2020). However, caution should be taken about the toxic amounts of histamine intake based on the Food and Drug Administration (FDA) (U.S. Department of Health and Human Services *et al.*, 2021). The major concern is that other ingredients of fish sauces have possible lowering effects regarding blood pressure. For instance, mustard can alleviate hypertension in an animal model (Godwin *et al.*, 2014). Antihypertensive properties of various spices in mahyaveh sauce were also defined as cumin (Cuminum cyminum) (Kalaivani *et al.*, 2013), coriander (Coriandrum sativum) (Al Disi *et al.*, 2016, Jabeen *et al.*, 2009, Mahleyuddin and Moshawih, 2021), fennel seeds (Foeniculum vulgare) (Aludatt, 2015, Badgujar *et al.*, 2014), black pepper (Piper nigrum) (Taqvi *et al.*, 2008, Wang *et al.*, 2021), and thyme (Thymus capitatus) (Mihailovic-Stanojevic *et al.*, 2013). Despite lacking these additives, suragh can alleviate hypertension in both sexes as well. The same result has been concluded for salted fish-water intake in both genders. It could be suggested that the presence of fish protein hydrolysates or peptides as the main ingredient in these sauces was the primary regulator of hypertension in them.

Moreover, consumption of salted fish showed a negative association with BP in males. However, this finding was not in line with the results of other studies. Most of the studies have shown that high level of NaCl in dried salted fish correlates with the incidence of hypertension (Soleha and Qomaruddin, 2020, Susanna *et al.*, 2019, Zheng *et al.*, 2016). Although the present data showed lower BP in males with higher intake of salted fish, self-reported questionnaires could not exclude the vigilant lower consumption of salted fish or any other salty foods. Thus, the possibility of lower salted fish intake in hypertensive individuals could not be ruled out. To the authors' knowledge, no other study has analyzed the association of traditional Iranian fish sauces with the risk of hypertension. It is also important to consider that this was an observational study, and while it suggested an inverse correlation between mahyaveh, suragh, and salted fish-water consumption and hypertension risk, it cannot establish a cause-and-effect relationship. Further research would be needed to confirm these findings and explore potential underlying mechanisms.

Like any other observational study, the present study had a couple of weaknesses including the possibility of confounding that was not adjusted for. Although the use of standardized methods as well as the adjustment of a wide range of confounding variables had an impact on measures

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of association, confounding by unmeasured factors cannot be ruled out. Also, the assumption of portion sizes, allocations of different fish species in meals, and food contents of nutrients are just estimates to the true values. This survey revealed basic information about the relationship between seafood intake and the risk of hypertension. However, more than the present variables can be considered responsible for the risk of hypertension, and the researchers focused on the relatively obscure seafood variables such as traditional Iranian fish sauces. The present study included a particular population sample and some of their eating habits; therefore, consumption of traditional fish sauces may not be extended to other populations or ethnicities.

Conclusion

The present study discovered that there is an association between the consumption of Iranian traditional fish sauces, including mahyaveh, suragh, and salted fish-water, and a reduction in blood pressure. Although these sauces are mostly consumed in the south of Iran, they are not commonly used in other regions. The statistical findings indicate that there is an inverse correlation between the consumption of mahyaveh/suragh sauces and salted fish-water, and the risk of hypertension in both males and females. Furthermore, the consumption of salted fish has been associated with a reduction in BP in males.

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Conflict of interest

The authors declared no conflict of interests.

Authors' Contributions

Conception of the research, writing, reviewing and editing were carried out by Khaghanzadeh N and Samiei A; Data analysis and data curation were done by Rafati S, Samiei A, Mohammadi M; Methodology was developed by Khaghanzadeh N, Mohammadi M, Samiei A, Rafati S, and Nejatizadeh A. All the authors contributed to the research by providing valuable feedback and assisting in the development of the analysis and manuscript. Furthermore, all the authors read and approved the final manuscript.

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