Original Article

Arterial pressures in fish-consuming and non-fish-consuming populations of coastal south India

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It has been suggested that fish-consuming populations have lower blood pressure levels. The aim of this study was to determine and compare the mean blood pressure levels among fish-consuming populations with those among populations who do not consume fish, as a risk marker for cardiovascular disease. A cross-sectional study was conducted among 1000 healthy Indian adult men and women (aged ≥ 20 years) randomly chosen from two representative age and sex-matched samples, one of which was fish-consuming ($n = 500$) and the other of which was non-fish-consuming ($n = 500$). The systolic and diastolic blood pressures and pulse rates were studied. The mean systolic and diastolic blood pressures and pulse rates were found to be lower in older men and women who were fish consumers in comparison with those who were non-fish consumers, and the levels increased with advancing age. The population and sex differences were significant for certain age groups. The percentile cut-off values for diagnosis of systolic hypertension showed lower prevalence in fish consumers than in non-fish consumers. The results indicate that people who ate fish regularly appeared to have a better cardiovascular risk profile than did non-fish consumers, which is of public health significance. The relationship between fish consumption and blood pressure deserves further studies in normotensive and hypertensive populations.

Key words: edible marine fish, N-3 fatty acids, blood pressure, systolic, diastolic, hypertension, pulse rate, Andhra Pradesh, India.

Introduction

Hypertension or high blood pressure (BP) is the most common risk factor for cardiovascular disease (CVD) and stroke, affecting 20% of the adult population both in the developed and developing worlds.[1,2] Regional differences in the prevalence of hypertension within countries have been identified.[3–5] One approach to the eventual control of CVD is the identification and analysis of associated risk factors such as hypertension and hyperlipidaemia. In addition to genetic predisposition, diet, stress, body fat, alcohol, inadequate physical activity and smoking have been shown to influence BP.[6] The higher the level of systolic blood pressure (SBP) or diastolic blood pressure (DBP), the greater the risk of subsequent CVD.[7]

Nutritional factors appear to be of significant importance in the pathogeneses of hypertension.[8] The use of dietary modification in the treatment of hypertension has been gaining attention in an effort to reduce the cost and undesirable side effects of drug therapy. In 1951, it was reported that arterial hypertension had never been diagnosed in North Greenland and that essential hypertension was rare.[9] Many reviews have mentioned that Eskimos have low BP.[10,11] However, the results of recent studies of BP in Eskimo populations are conflicting.[12,13] The diets of these populations comprise fish fat and fish oils rich in polyunsaturated fatty acids of the N-3 type (N-3 PUFA); eicosapentaenoic acid (EPA, 20 : 5N-3), docosapentaenoic acid (DPA, 22 : 5N-3) and docosahexaenoic acid (DHA, 22 : 6N-3). Studies on Japanese fishermen have found a lower BP and higher intake of N-3 PUFA than those found in the general Japanese population.[14] Subsequently, a number of well-designed, controlled trials have demonstrated an antihypertensive effect of N-3 PUFA in normotensive[15–17] and hypertensive subjects in some[18,19] but not all intervention trials.[20,21] Dietary PUFA have been suggested as exerting protective effects on BP levels, although this was before the recent interest arose in the reported ability of N-3 fatty acids to lower BP.[22,23] It is less clear whether this is true for normotensive individuals.[24]

The prevalence of hypertension is increasing due to urbanization and the adoption of Western lifestyles in India.[25] The estimated stroke mortality rate is 200% in the 15–44 year age group and 250% in those of or above 45 years of age compared with the rates in industrialised countries.[26] There have been no reports on CVD risk factors among coastal fish-consuming populations. Therefore, this survey was aimed at studying the distribution of BP levels and the prevalence of hypertension in relation to fish consumption in ethnically homogeneous, healthy fish-consuming and non-fish-consuming populations.

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Subjects and methods

The study was designed to be conducted in a random sample of 1000 healthy individuals comprising 266 men and 234 women who consumed fish, and 263 men and 237 women who did not consume fish. The subjects were aged above 20 years and resided in the coastal Nellore district of Andhra Pradesh, the fifth largest state in India. The subjects were selected from 40 villages in the rural area of Andhra Pradesh, 18 of which were coastal fishing villages comprising mainly fish-consuming populations and 22 of which were farming villages of non-fish-consuming agricultural labourers. The objectives of the study were explained in detail and informed consent was given by the subjects before the study procedures were carried out. Subjects were matched for age and sex. They had been selected so that it was possible to identify their dietary habits based on household dietary surveys. Subjects who ate a minimum of three fish meals per week at an average of 25 g/day were classified as fish consumers while subjects who consumed no fish were classified as non-fish-consumers.

Basic demographic data as well as data on levels of physical activity, whether the subject was a smoker and levels of alcohol consumption were collected. Individuals under treatment for hypertension were not included in the investigation. Alcohol and smoking were assessed by an oral questionnaire, which detailed weekly frequency and quantity. In addition, information was also obtained from subjects on their usual dietary habits and consumption of minor food groups, such as seasoning and local foods. Home visits were undertaken and the nutrient intake was obtained using the 24-h recall method; a consecutive 3-day intake record was also used. Cooking methods were almost similar in both populations. The most common method of cooking was boiling; however, dry roasting and frying were occasionally used. Average individual oil consumption was 10–15 g/day and the generally used cooking oils were ground nut, palm and sunflower which were supplied from local Government stock. Total calories as well as the nutrient intake from carbohydrates, protein and fats were estimated from the amount of food served by using food composition tables of nutritive values of Indian foods.[27] Physical activity was measured by work-related and leisure-time activities. The study area and methodology has been described in detail previously.[28,29]

The resting BP measurements were obtained with the subject in a sitting position after 5 minutes rest using a mercury sphygmomanometer. The readings were taken twice with at least 2 min of rest between the readings to reduce variability. The SBP and fifth phase of the DBP were represented by the means of two measurements.[30] At each examination, subjects with SBP values exceeding 140 mmHg and DBP exceeding 90 mmHg were considered hypertensive. Subjects were excluded if they were diabetic, pregnant, suffering from a known lipid disorder or taking antihypertensive drugs. The heart rate was conveniently measured as pulse rate by palpation of the radial artery at the wrist, the number of beats occurring in 30 seconds being counted and doubled to give the pulse rate per minute.

The total sample was subclassified by age and sex. There was a slight preponderance of male subjects in both populations (Table 1). Results were expressed as mean ± SD and percentiles. Statistical analysis was undertaken using χ^2 and Student's *t*-tests. Hypertension was indicated by SBP/DBP above the 95th percentile. All of the differences were considered significant when the P value was ≤ 0.05 or ≤ 0.01 for Student's *t*-test and χ^2, respectively.

Results

The distributions of mean age-specific SBP, DBP and pulse rate among fish-consuming and non-fish-consuming populations are given in Table 1. The SBP levels increased as age advanced in both sexes and populations. The levels of SBP were higher in men than in women of younger age groups whereas in older age groups (40–50, 51–60 and 61–70 years) a reverse trend was observed, though sex differences were significant only in a few age groups. Both men and women in the fish-consuming population tended to have lower SBP levels than those in the non-fish-consuming population. However, these differences were significant only in the 61–70 years age group of men ($P < 0.05$) and women ($P < 0.01$).

The mean levels of DBP both in men and in women progressively increased with increasing age. These levels were found to be higher among men in the 21–30 and 31–40 years age groups than among women, but the older age groups showed an opposite trend. The interpopulation differences were significantly lower among fish-consuming men in the 51–60 years age group and women in the 61–70 years age group population. The overall mean pulse rate was significantly lower in younger men and women in the age groups of 21–30 years and 31–40 years among fish consumers than among non-fish consumers.

The normal limits for SBP and DBP among fish-consuming and non-fish-consuming populations were determined from the percentile cut-off points (Table 2). Median values showed negative skewness among men and women of both populations. The percentile distribution was therefore determined as the mean levels of BP in both population groups that differed from the median. The 50th and 95th percentile cut-off values were lower in fish-consuming men and women than in non-fish-consuming population. χ^2 values indicate that the frequency distribution of these percentiles for SBP of men and for DBP of women were found to be significant statistically ($P > 0.01$) between fish consumers and non-fish consumers.

Following the World Health Organization's (WHO) definition of hypertension (≥ 140/90 mmHg), only 18 subjects (eight men and 10 women) in the SBP category and 21 subjects (6 men and 15 women) in the DBP category were found to be hypertensive in the fish-consuming population as compared with 35 subjects (12 men and 23 women) for the SBP category and 30 subjects (12 men and 18 women) for the DBP category in the non-fish-consuming population (Table 3). This was significant for the prevalence of systolic hypertension. Generally there was a greater prevalence of hypertension in women than in men.

The intake of nutrients and fatty acid profile in serum were determined in a subsample of the study population. The results showed that daily consumption of mean amount of total energy and carbohydrate was significantly low and that protein intake was high in fish consumers as compared with non-fish consumers. There was no significant difference in percentages of saturated and monounsaturated fatty acid

Table 1. Distribution of mean (± SD) blood pressure and pulse rate among fish-consuming and non-fish-consuming populations

Population	21 – 30	31 – 40	41 – 50	51 – 60	61 – 70	21-70 (Total)
			Systolic blood pressure (mmHg)			
Fish-consuming						
Men	109.3 ± 6.4 (56)	113.9 ± 7.1 (57)	115.2 ± 7.1 (53)	120.8 ± 8.1 (53)	124.9 ± 9.2 (50)	116.7 ± 9.2 (266)
Women	105.2 ± 6.7† (46)	112.2 ± 8.4 (42)	116.9 ± 10.5 (54)	112.8 ± 9.9 (48)	123.9 ± 11.3 (44)	116.3 ± 11.7 (234)
Non-fish-consuming						
Men	110.3 ± 5.3 (46)	115.2 ± 6.3 (47)	117.1 ± 9.7 (54)	123.7 ± 10.0 (68)	130.9 ± 14.9* (48)	119.9 ± 12.1 (263)
Women	107.6 ± 7.1 (49)†	113.3 ± 7.2 (48)	118.6 ± 11.7 (51)	126.7 ± 13.9 (49)	137.8 ± 15.5* (40)	120.2 ± 15.3* (237)
			Diastolic blood pressure (mmHg)			
Fish-consuming						
Men	71.5 ± 4.2	74.3 ± 5.3	75.0 ± 5.5	78.4 ± 5.6	80.8 ± 7.1	75.9 ± 6.5
Women	69.9 ± 5.5	72.8 ± 77.3	77.3 ± 9.4	80.4 ± 7.4	82.1 ± 8.7	76.6 ± 9.8
Non-fish-consuming						
Men	69.7 ± 4.1*	74.4 ± 4.2	75.4 ± 6.2	80.9 ± 7.3*	82.7 ± 7.5	77.1 ± 7.9
Women	69.0 ± 5.2	72.3 ± 6.9	77.7 ± 0.3	80.8 ± 8.8	86.0 ± 8.3*	76.9 ± 9.6
			Pulse rate (beats/min)			
Fish-consuming						
Men	71.1 ± 4.1	72.8 ± 3.1	73.5 ± 3.7	75.8 ± 3.3	73.7 ± 4.2	73.7 ± 4.2
Women	70.6 ± 3.3	73.5 ± 3.6	74.3 ± 3.7	75.6 ± 3.2	76.1 ± 3.6††	74.0 ± 4.0
Non-fish-consuming						
Men	74.2 ± 4.4**	74.8 ± 3.3**	74.2 ± 3.8	75.2 ± 4.0	74.7 ± 4.6	74.7 ± 4.1**
Women	74.1 ± 4.8**	75.1 ± 3.7**	75.6 ± 3.8	75.8 ± 3.9	76.5 ± 3.6†	75.5 ± 4.1**

Age group in years. Significance of difference between populations: *$P < 0.05$; **$P < 0.01$. Significance of difference between sexes: †$P < 0.05$; ††$P < 0.01$. Figures in parenthesis indicate number of individuals.

levels between population groups. However, the percentage of N-6 PUFA as well as linoleic (18 : 2N-6), adrenic (22 : 4N-6), and osmond (22 : 5N-6) acids were lower, and dimomogamma linolenic (20 : 3N-6) acid was higher, in fish consumers. The sum of the long-chain N-3 PUFA series in fish consumers (EPA, DPA and DHA) were, significantly, four-fold greater than were those in non-fish consumers (data not shown).

Discussion

Blood pressure has been shown to be affected by the amount as well as the type of dietary fat consumed, such as the N-3, N-6 and N-9 series fatty acids.[31] Linoleic acid (18 : 2N-6) has been reported to decrease[32] as well as to increase BP,[33] and also to have no effect.[34] Blood pressure has been shown to be negatively associated with the intake of fish and N-3 PUFA.[23] We observed a positive relationship between fish intake and concentrations of long-chain N-3 PUFA, EPA, DPA and DHA in serum phospholipids which showed approximately three-fold and six-fold greater levels, respectively, in the fish-consuming population.[29] The apparent increase in the N-3 PUFA was correlated with a concomitant decrease in N-6 PUFA. The effect of N-3 PUFA on BP is still controversial. Eating fish or fish oils modifies membrane phospholipid composition, enriching them with N-3 PUFA at the expense of reducing the N-6 PUFA content.[35,36]

The fish-consuming population had lower BP levels compared with those of non-fish consumers, at least among older people. An epidemiologic study of Japanese fishermen found a lower BP with a higher intake of N-3 fatty acids than that found in the general Japanese population.[14] However, in another study, such an association was not noticed.[37] A large study from Tromso in Norway is the most conclusive to date with the decrease in BP being proportional to the increase in plasma phospholipid N-3 fatty acids.[38] Fish oils do lower BP but the effect may be obscured in other population studies by the more potent hypertensive effects of other dietary components, such as sodium.[39] No significant difference in BP was

Table 2. Percentile cut-off points of systolic and diastolic blood pressure (mmHg) among fish-consuming and non-fish-consuming populations

Population	5th percentile		50th percentile		95th percentile	
	Men	Women	Men	Women	Men	Women
			Systolic blood pressure (mmHg)			
Fish-consuming	100.2 (5)	98.1 (3)	113.6 (244)	102.2 (208)	130.0 (17)	132.6 (23)
Non-fish-consuming	100.2 (12)	93.7 (3)	115.4 (228)	114.8 (216)	138.9** (23)	143.4† (18)
			Diastolic blood pressure (mmHg)			
Fish-consuming	66.6 (11)	61.1 (9)	73.1 (217)	73.4 (193)	84.3 (38)	89.4 (32)
Non-fish-consuming	65.1 (12)	58.5 (23)	74.0 (222)	74.1 (201)	88.8† (29)	91.2** (13)

50th percentile values are slightly different from the mean values. χ^2 values show statistical significance of difference between populations (**$P < 0.01$).
†Not significant. Figures in parenthesis indicate number of individuals.

Table 3. Mean (±SD) levels of defined hypertension among fish-consuming and non-fish-consuming populations

Blood pressure	Fish-consuming population		Non-fish-consuming population	
	Men	Women	Men	Women
Systolic	144.0 ± 4.39 (8)	148.6 ± 3.50 (10)	149.3 ± 12.27* (12)	157.8 ± 8.68** (23)
Diastolic	93.1 ± 3.56 (6)	96.3 ± 9.17 (15)	94.1 ± 6.24 (12)	98.3 ± 4.43 (18)

Significance between populations (Student's *t*-test): $^*P < 0.05$; $^{**}P < 0.01$. Figures in parenthesis indicate number of individuals.

reported in a group living in a Norwegian coastal fishing area when compared with the inlanders of the same district who ate less than one-fourth as much omega-3 fatty acids.[40] In three populations living in fishing and farming areas in China it was found that the BP of the population in the fishing area was lowest. The prevalence of hypertension of people in the fishing area, Baoshan, was negatively correlated with fish intake.[41] This may be due to genetic, environmental and nutritional factors. It seems that habitual intake of fish may contribute significantly to a decrease in the risk of hypertension. Hence, our findings are in general agreement with some of the studies.

When classified using WHO criteria,[42] the present data showed the risk of hypertension to be present in 4.6% for SBP and 4.2% for DBP in fish-consuming populations and 7.0% for SBP and 6.0% for DBP in non-fish-consuming rural populations. In India, the prevalence of hypertension varies from a low of 0.44% in the rural Orissa tribal population of eastern India[43] to 8.8% in Rajasthan, western India.[44] A recent study in Kerala reported a 17.9% prevalence of hypertension in a rural south Indian population.[45] Therefore, the present data indicate, in both populations, a prevalence of hypertension that is well within the Indian ranges but that is relatively lower in fish consumers compared with non-fish consumers.

Both SBP and DBP levels and pulse rate were lower, though not uniformly significant, in fish consumers. The increase in BP and pulse rate with age in both populations was confirmed by correlation coefficients (data not shown). Studies have consistently demonstrated a positive relation between age and BP in most populations with diverse geographical, cultural and socioeconomic characteristics.[46] Blood pressure levels increased with age in both sexes, with women showing a steeper increase. Prior to menopause, women have significantly lower BP levels than do men. Postmenopausal changes in women may be attributed to lower levels of oestrogen.[47]

Several studies have demonstrated a significant lowering of BP with food preparations with fish oil and a decrease in SBP upon fish oil consumption.[16,31,48,49] Reductions in BP were observed in healthy volunteers given codliver oil.[50] Some studies have found that high doses of fish oil can lower BP in men with mild essential hypertension,[51,52] although lower doses of fish oil resulted in little change.[31] Such doses have been reported to be both effective[17] or ineffective[20] in reducing BP. Potential mechanisms for the lowering of BP by N-3 PUFA present in fish oils have been described.[31,53]

Possible mechanisms of BP-lowering action include attenuation in the response of vascular resistance, vascular reactivity and blood viscosity, among others. Since eicosanoids are known to exert potent effects in many vascular control process, changes in their synthesis are often invoked to explain the changes seen with dietary PUFA.[15,54–57] However, the results of these studies were sometimes contradictory and there is as yet no general agreement on the hypotensive mechanism of a fish diet. Such variability may be explained by the complex and sometimes opposing effects of N-3 PUFA on biochemical pathways influencing the BP regulating mechanism related to the roles of specific endogenous synthesis of vasoactive eicosanoids.[58] The overall evidence in humans and animals suggests that the antihypertensive effect may be explained by an influence of N-3 PUFA on vasoreactivity both on vascular contraction and vascular relaxation.[59,60]

It appears from our data and other studies that BP does vary with changes in plasma levels of N-3 PUFA due to the consumption of fish oils. It is likely that the way in which fish is prepared and consumed varies and may be responsible for some of the apparent contradictions. However, controlled clinical studies are needed to determine the effects of Indian cultural practices and eating habits in determining this cardiovascular risk marker.

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References

1. The World Health Report. Conquering suffering enriching humanity. Report of the Director General. Geneva: World Health Organization, 1997; 45.
2. Kannel WB, Higgens M. Smoking and hypertension as predictors of cardiovascular risk in population studies. J Hypertens 1990; 8: S38.
3. HsuHage BHH, Wahlqvist ML. Assessing food and health relationships: a case study of blood pressure determination in adult Melbourne Chinese. Asia Pacific J Clin Nutr 1994; 3: 103–110.
4. Liu LS. Epidemiology of hypertension and cardiovascular disease: China experience. Clin Exp Hypertens 1990; 12: 831–844.
5. Reddy KS. Cardiovascular diseases in India. World Health Stat Q 1993; 46: 101–107.
6. World Health Organization. Hypertension control. Report a WHO Expert Committee. WHO Tech Rep Ser 1996; 862: 1–83.
7. Stamler R, Neaton JD. Blood pressure, systolic and diastolic and cardiovascular risk. US population data. Arch Intern Med 1993; 153: 598–615.
8. Beilin LT. Diet and hypertension: critical concepts and controversies. J Hypertens 1987; 5: S447–S457.
9. Ehrstrom MC. Medical studies in North Greenland 1948, 1949. Blood pressure, hypertension and arteriosclerosis in relation to food and mode of living. Acta Med Scand 1951; 140: 416–422.
10. Leaf A, Weber PC. Cardiovascular effects of N-3 fatty acids. N Engl J Med 1988; 318: 549–557.
11. von Schacky C. Prophylaxis of atherosclerosis with marine omega-3 fatty acids: a comprehensive strategy. Ann Intern Med 1987; 107: 890–899.
12. Bjerager P, Kroman N, Thygesen K, Harward B. Blood pressure in Greenland Eskimos. Ugeskr Laeger 1980; 142: 2278–2292.
13. Jorgensen KA, Nielson AH, Dyerberg J. Haemostatic factors and renin in Greenland Eskimos on a high EPA intake. Results of the Fifth Umanak Expedn. Acta Med Scand 1986; 219: 473–480.

14. Kagawa Y, Masatoyo N, Suzuki M. Eicosapentaenoic acids of serum lipids of Japanese Islanders with low incidence of cardiovascular disease. J Nutr Sci Vitaminol (Tokyo) 1982; 28: 441–453.
15. Knapp HR, FitzGerald GA. Dietary polyunsaturates, blood pressure and vasodilator prostanoids. Clin Res 1988; 36: 357–361.
16. Lorenz R, Spengler U, Fischer S, Dunn J, Weber PC. Platelet function, thromboxane formation and blood pressure control during supplementation of the western diet with codliver oil. Circulation 1983; 67: 504–511.
17. Mortensen JZ, Schmidt EB, Nielson AH, Dyerberg J. The effect of N-6 and N-3 PUFA on hemostasis, blood lipids and blood pressure. Thromb Haemost 1983; 50: 543–546.
18. Singer P, With M, Voigt S. Blood pressure and lipid lowering effect of mackerel and herring diet in patients with mild essential hypertension. Atherosclerosis 1985; 56: 223–224.
19. Norris PG, Jones CJH, Weston MJ. Effect of dietary supplementation with fish oil on systolic pressure in mild essential hypertension. BMJ 1986; 293: 104–105.
20. Houwelingen ACV, Nordoy A, Vander Beek E, Houtsmuller U, De Metz M, Hornstra G. Effect of moderate fish intake on blood pressure, bleeding time, hematology and clinical chemistry in healthy males. Am J Clin Nutr 1987; 46: 424–436.
21. Demke DM, Peters GR, Linet OT, Metzler CM, Klott KA. Effects of fish oil concentrate in patients with hypercholesterolemia. Atherosclerosis, 1988; 70: 73–80.
22. Appel LF, Miller ED, Sedler AJ, Whelton PK. Diet supplementation with fish oil and blood pressure reduction. A Meta-analysis. Ann Intern Med 1994; 120: 9–11.
23. Norum KR, Drevon CA. Dietary N-3 fatty acids and cardiovascular disease. Arteriosclerosis 1986; 6: 352–355.
24. Bonaa K. Epidemiological and intervention studies on the effect of marine polyunsaturated fatty acids on blood pressure. J Intern Med 1989; 225 (Suppl.): 105–110.
25. Joshi PP, Kate SK, Shegokar V. Blood pressure trends and lifestyle risk factors in rural india. J Assoc Physician India 1993; 41: 579–581.
26. Murray CJL, Copez AD. Global comparitive assessment in the health sector. Disease burden, expenditure and intervention packages. Geneva: WHO, 1994; 21–54.
27. Gopalan C, Ramasatry BV, Balasubramanian SC. Nutritive value of Indian foods. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India. 1989: 11–56.
28. Bulliyya G. Studies on atherogenic markers with reference to serum lipid profiles among fish consuming coastal and non-fish consuming inland populations, PhD Thesis. Sri Venkateswara University, Tirupati, India 1991.
29. Bulliyya G, Reddy PC, Reddanna P. Traditional fish consumption and fatty acid composition in fish consuming and non-fish consuming populations. Asia Pacific J Clin Nutr 1997; 6: 230–234.
30. Rose GA, Blackburn H, Gillium RF, Prineas RJ. Cardiovascular survey methods, 2nd edn. WHO publication no 56, Geneva, 1982.
31. Knapp HR, FitzGerald GA. The antihypertensive effects of fish oils. N Engl J Med 1989; 320: 1037–1043.
32. Fleishman AT, Bierenbaum ML, Strier H, Somol SH, Watson P, Naso AM. Hypotensive effects of increased dietary linoleic acid in mildly hypertensive humans. J Med Soc N J 1979; 76: 181–183.
33. Malhotra SL. Dietary factors causing hypertesion in India. Am J Clin Nutr 1979; 23: 1353–1363.
34. Margets BM, Beilin LJ, Amsrong BK. Blood pressure and dietary polyunsaturated and saturated fats: a controlled trial. Clin Sci 1985; 69: 165–175.
35. Bjerve KS, Brubakk AM, Fougner KJ, Johnsen H, Midthjell K, Vik T. Omega 3 fatty acids: essential fatty acids with important biological effects and serum phospholipid fatty acids as markers of dietary omega 3 fatty acid intake. Am J Clin Nutr 1993; 57S: 801–806.
36. Anderson LF, Solvoll K, Drevon CA. Very long chain N-3 fatty acids as biomarkers for intake of fish oil and N-3 fatty acid concentrates. Am J Clin Nutr 1996; 64: 305–511.
37. Yamori Y, Nara Y, Iritani N, Workman RJ, Inagami T. Comparision of serum phospholipid fatty acids among fishing and farming Japanese populations and American inlanders. J Nutr Sci Vitaminol (Tokyo) 1985; 31: 417–422.
38. Bonaa KH, Bjerve KS, Straume B, Gram IT, Thelle D. Effect of eicosapentaenoic and docosahexaenoic acids on blood pressure in hypertension. N Engl J Med 1990; 332: 795–801.
39. Tseng WP. Blood pressure and hypertension in an agricultural and fishing population in Taiwan. Am J Epidemiol 1967; 86: 513–525.
40. Simons T, Vartum A, Lyngmo V, Nordoy A. Coronary heart disease, serum lipids, platelets and dietary fish in two communities in northern Norway. Acta Med Scand 1987; 222: 237–245.
41. Zhang XH, Cai RS, Zhou BF. The relationships of dietary protein, serum and urine amino acids and blood pressure in three populations. Acta Nutrimenta Sinica 1993; 15: 117–123.
42. World Health Organization and International Society of Hypertension. Guidelines for the management of mild hypertension. Memorundum from a WHO/International Society of Hypertension meeting. J Hyperten 1993; 7: 689–693.
43. Dash SC, Swain PK, Sundaram KR, Malhotra KK. Hypertesion epidemiology in an Indian tribal population. J Assoc Physicians Ind 1986; 34: 567–570.
44. Badva VS, Gupta BS, Bhargava V, Sanghvi S. Prevalence of hypertension in a rural community of Rajasthan. J Assoc Physicians Ind 1984; 32: 1042–1047.
45. Kutty VR, Balakrishnan KG, Tyasree AK, Thoman J. Prevalence of coronary heart disease in the rural population of Tiruvananthapuram district of Kerala. India Int J Cardiol 1993; 39: 59–70.
46. Whelton PK. Epidemiology of hypertension. Lancet 1994; 344: 101–106.
47. Sanchette A, Kiran C, Sanchette S. Cardiovascular changes in menopausal women. Ind Med Gazette 1988; 122: 268–272.
48. Gill JS, Beevers DG, Zezulka AV, Davis P. Relation between initial blood pressure and its fall with treatment. Lancet 1988; 1: 567–569.
49. FitzGerald GA, Braden G, FitzGerald DJ, Knapp HR. Fish oil in cardiovascular disease. J Inern Med 1989; 225: 25–29.
50. Singer P, Richter Heinrich E. Stress and fatty liver possible indications for dietary long-chain N-3 fatty acids. Med Hypotheses 1991; 36: 90–94.
51. Zinger P, Wirth M, Voigt S, Barleben H, Taube Ch, Naumann E. Effect of a diet rich in eicosapentaenoic acid on arterial blood pressure and blood lipid levels in patients with essential hypertension. Ter Arkh 1986; 58: 42–49.
52. Toft I, Bonaa KH, Ingebretsen OC, Nordoy A, Jensen T. Effect of N-3 polyunsaturated fatty acids on glucose haemostasis and blood pressure in essential hypertension. A randomized controlled trial. Ann Intern Med 1995; 123: 911–918.
53. Morris MC, Sacks F, Rosner B. Does fish oil lower blood pressure. A meta-analysis of controlled trials. Circulation 1993; 88: 523–533.
54. Schoene NW, Fiore D. Effect of fish oil diet on blood pressure in spontaneously hypertensive rats. Prog Lipid Res 1982; 20: 596–572.
55. Scherhag R, Kramer HJM, Duising R. Dietary adminstration of EPA and linolenic acid increased arterial blood pressure and suppress vascular synthesis in rats. Prostaglandins 1982; 23: 369–383.
56. Iacano JM, Dougherty RM. The role of dietary polyunsaturated fatty acids and prostaglandins in reducing blood pressure and improving thrombogenic indices. Prev Med 1983; 12: 60–69.
57. Smith MC, Dunn MJ. Role of prostaglandins in human hypertension. Am J Kidney Dis 1985; 5: 32–39.
58. Comberg HU, Hyden S, Hames CG, Vergoesen AJ, Flieschman AI. Hypotensive effects of dietary prostaglandin precursor in hypertensive man. Prostaglandins 1978; 15: 193–197.
59. Kinsella JE. Food components with potential therapeutic benefits. The N-3 PUFA of fish oil. Food Technol 1986; 40: 89–97.
60. Vandongen R, Mori TA, Burke V, Beilin LJ, Morris J. Effect of omega-3 fats in subjects at increased cardiovascular disease. Hyperten 1993; 22: 371–379.