The Nutritional Benefits of Shellfish (Part 2) (IPF_A081)

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THE ROLE OF SHELLFISH IN REDUCING THE RISK OF CANCER

There is increasing evidence from laboratory studies indicating that n-3 fatty acids, especially the long-chain polyunsaturated fatty acids EPA and DHA present in many shellfish and seafood inhibit carcinogenesis [68, 69]. Populations with diets containing high levels of seafood and hence high n-3 fatty acid consumption have been shown to have lower risk of developing certain cancers including colorectal, breast and prostate cancer [70-73].

Research from Japan provides a good illustration; the westernisation of the Japanese diet among Japanese women since the 1960’s has resulted in a decrease in the consumption of shellfish and other seafood; this has been paralleled with an increase in the consumption of vegetable oils rich in n-6 fatty acids, and has been linked to an increase in breast cancer rates [73, 74].

A number of pathways have been proposed through which long-chain n-3 fatty acids play a role in preventing the development and progression of cancer. These include their role in eicosanoid biosynthesis [69, 75], antioxidant action in lipid peroxidation [76], and protection of signal transduction pathways [75, 76].

n-3 and n-6 fatty acids are used by the human body as substrates for the production of eicosanoids including prostaglandins, thromboxanes and leukotrienes, which are directly involved in immunomodulation, inflammation and tumour formation [77]. Eicosanoids synthesised using n-6 fatty acids as a substrate stimulate inflammation and tumour angiogenesis (the development of blood vessels to the tumour), whereas eicosanoids produced from the n-3 fatty acids, EPA and DHA, are anti-inflammatory and do not stimulate angiogenesis [78, 79].

n-3 fatty acids may provide protection against some cancers by switching the cyclooxygenase-2 (COX-2) enzyme away from the production of n-6 derived eicosanoids [69, 80]. The n-3 and n-6 fatty acids compete for enzymes which convert shorter- to longer-chain fatty acids [69] as well as the COX-2 enzyme [81, 82], which convert these longer-chain fatty acids to eicosanoids. Therefore, higher n-3 fatty acid intake may decrease the production of proinflammatory eicosanoids that could play a role in the development of certain cancers [83-85].

In addition to the protective effects of n-3 fatty acids found in shellfish, they are also sources of antioxidants in the form of essential minerals and vitamin E which may be important in the prevention of certain cancers. All shellfish are good sources of selenium, copper, manganese and zinc which have antioxidant properties when combined with certain enzymes. Antioxidant minerals have been shown to reduce the risk of cancer in some sections of the population and particularly men by 31% [86, 87]. Vitamin E, found in prawns and other shellfish, is a fat-soluble vitamin and a powerful membrane-bound antioxidant employed by human cells [88].

Colorectal Cancer

There is evidence of an association between reduced colon cancer risk and elevated seafood intake but it is somewhat inconsistent. An association between reduced colorectal cancer risk and high seafood consumption has been observed in several prospective studies [84, 89-98], and the association was statistically significant in a number of them [84, 94, 98]. Seafood consumption was not associated with reduced colorectal cancer risk in some other prospective studies [99-101]. However, a recent Europe wide study found a highly statistically significant trend in the association between increased fish consumption and decreased colorectal cancer risk [102]. The opposite was true for the consumption of red meat [102].

A 22 year prospective study of seafood and n-3 fatty acid consumption and colorectal cancer risk in men demonstrated that intake of seafood and long-chain n-3 fatty acids from seafood may decrease the risk for colorectal cancer [84]. There are a number of studies that report anticancer effects of marine n-3 fatty acids in the colon [69, 80, 103].

It is likely that it is the high n-3 fatty acid content in shellfish and other seafood which reduces the risk of colorectal cancer through the action of n-3 fatty acids diverting the COX-2 enzyme away from the production of n-6 derived eicosanoids [80, 83, 84]. Shellfish such as crab and oysters are rich sources of n-3 fatty acids providing 1650 mg per 140 g serving. Most other shellfish such as squid, shrimps, cockles, lobster and prawns are considered to be good sources of n-3 fatty acids providing more than 350 mg per 140 g serving.

Breast Cancer

A number of studies have shown that diets high in seafood and shellfish containing n-3 fatty acids may protect against breast cancer [72, 104-107]. A recent study found that high consumption of seafood rich in n-3 fatty acids was associated with a reduced risk of breast cancer, and that the consumption of n-3 fatty acids from seafood was inversely associated with postmenopausal breast cancer risk [104]. Laboratory studies have shown that n-3 fatty acids or a diet rich in EPA or DHA can suppress tumour growth and inhibit metastases formation [108-110].

The protective actions of shellfish and seafood derived n-3 fatty acids have been linked to the ratio of n-3:n-6 fatty acids in the diet; a low n-3:n-6 ratio has been associated with a reduced risk of developing breast cancer [18]. A study including 24 European countries revealed an inverse correlation with seafood and marine n-3 fatty acid consumption, when expressed as a proportion of total or animal fat and the incidence of breast cancer. The same study established a positive correlation between animal fat and the incidence of breast cancers [111, 112].

The authors suggested that the consumption of seafood and seafood derived n-3 fatty acids may offer protection against the cancer-promoting effects of animal fat in breast carcinogenesis. Shellfish rich in n-3 fatty acids such as crab and oysters can play an important part in lowering the n-3:n-6 ratio in the diet.

Prostate Cancer

Shellfish and seafood rich in n-3 fatty acids may prevent or delay the progression of prostate cancer. There are a number of studies demonstrating an inverse relationship between consumption of seafood including shellfish and the risk of prostate cancer development [113-116].

The results from a 22 year study of seafood consumption in relation to prostate cancer incidence and mortality suggested that seafood consumption was not related to the incidence of prostate cancer in participants but may improve survival from prostate cancer [117]. The study revealed that consuming seafood more than 5 times per week lowered the risk of prostate cancer death by 48% compared to men consuming fish less than once per week.
The mechanism by which consumption of seafood may lower risk of death from prostate cancer is unclear but may be a combination of dietary factors. There is strong evidence that reduction of the total energy consumption, a diet comprising less than 30% fat, and increased intake of phytoestrogens, vitamins D and E and selenium result in decreased prostate cancer incidence [119, 120]. An increase in the amount of shellfish in the diet can help to achieve many of these targets.

All shellfish are low in fat and are good sources of protein and can be key foods in a healthy diet. They are also good sources of selenium, zinc and to some extent vitamin E which have been demonstrated to have antioxidant and anticancer properties [121]. Both selenium and vitamin E inhibit specific cellular processes in the development of cancer [122].

Zinc supplementation has been shown to reduce the risk of the development and progression of prostate cancer [123]. Selenium has been shown to reduce the risk of prostate cancer by 65% in trials where participants received 200 μg supplements [124, 125]. Shellfish such as crabs, octopus, squid, mussels and scallops are a particularly good source of selenium and zinc; 238 g of crab meat yields 200 μg of selenium and 100 g of oysters provides 59.2 mg of zinc (623% RDA for a man).

Further studies suggest that protective or anticancer role in reducing prostate cancer risk or death may be linked to dietary marine n-3 fatty acids [126-128]. Laboratory experiments have confirmed that n-3 fatty acid derived metabolites can directly impact on prostate cancer cells and that sufficient dietary amounts of n-3 enable the process [129]. Shellfish such as crab and oysters are considered to be rich sources of n-3 fatty acids providing 1650 mg per 140 g serving. Most other shellfish such as squid, shrimps, cockles, lobster and prawns are considered to be good sources of n-3 fatty acids providing more than 350 mg per 140 g serving.

JOINT HEALTH

Osteoarthritis is one of the most common and disabling chronic diseases affecting people over the age of 60. Osteoarthritis manifests in the progressive destruction of articular cartilage in the joints resulting in impaired joint motion, severe pain, and, in extreme cases, disability. Rheumatoid arthritis is a systemic inflammatory disorder that mainly affects the joints leading to damage of the articular cartilage.

Diet can play a key role in the management of both osteo- and rheumatoid- arthritis [130, 131], and there is some evidence suggesting that shellfish, in particular some species of mussel, can provide protective and anti-inflammatory benefits to osteoarthritis sufferers [132, 133] and that increased intake of n-3 fatty acids found in shellfish can provide therapeutic benefits to rheumatoid arthritis patients [134-137]. Populations with a high seafood and associated high n-3 fatty acid consumption often have a lower prevalence of both osteo- and rheumatoid arthritis [138, 139].

Extract of the New Zealand green lipped mussel is commonly believed to be beneficial in the relief of arthritis and inflammation related joint pain. The lipid fraction of green lipped mussel, patented as Lyprinol®, has been demonstrated in laboratory experiments to have anti-inflammatory properties [140-142] and trials in humans have had some positive results in reducing the symptoms of inflammation and pain associated with osteo- and rheumatoid - arthrits [133, 143-145]. Recent research has questioned the efficacy of green lipped mussel extracts over other shellfish n-3 fatty acid sources [146]. The blue mussel, common in the UK and Northern Europe, has been shown in some studies to contain similar n-3 fatty acids as the green lipped mussel but in higher concentrations [147]. Extracts of blue mussel have been shown to have similar potential for anti-inflammatory effects as green lipped mussel extracts [148].

A review of over 15 clinical trials and 2 meta-analyses favour the use of marine n-3 fatty acids for the treatment of rheumatoid arthritis [138, 149]. High n-3 fatty acid intake was consistently linked with modest clinical improvement and a reduction in the use of nonsteroidal anti-inflammatory drugs in randomized clinical trials. One trial compared the use of a marine n-3 oil supplement with a placebo in 64 patients with stable rheumatoid arthritis. After 3 months, the marine n-3 group showed significant reduction in the use of drugs compared with the placebo group [150]. Another trial showed that a daily intake of marine n-3 fatty acids decreased the number of tender joints, duration of morning stiffness, and arthritis related pain compared to the placebo group [151].

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It has been shown that oxygen free-radicals may be important in affecting disease severity, reducing joint inflammation and connective tissue damage [152-154]. Antioxidant micronutrients including selenium, zinc and vitamin E found in all shellfish may also have a therapeutic role in controlling the development of chronic conditions.

CARDIOVASCULAR DISEASE

The cardioprotective effects of regular consumption of shellfish and seafood rich in n-3 fatty acids on coronary heart disease (CHD) were first suggested after epidemiological studies revealed low rates of CHD in Alaskan and Canadian Inuits [156-158]. Studies of Greenland Inuit and mainland Danish people of similar ages established that despite a diet high in saturated fat and cholesterol but low in fruit, vegetables and complex carbohydrates, the Greenland population had a significantly lower risk of heart attack (myocardial infarction) [159-162]. Further epidemiological studies have revealed similar results in other populations such as in Japan, Norway and The Netherlands where high shellfish and seafood consumption is common [163-165].

Long-chain n-3 polyunsaturated fatty acids, including EPA, DHA and DPA, which are almost exclusively derived from marine sources [166], have been accepted to be the key nutrients in fish responsible for the cardioprotective effects of shellfish and seafood consumption [167, 168]. A review of 25 trials assessing the association between the risk of CHD and tissue levels of n-3 fatty acids revealed an inverse relationship between tissue levels of EPA and DHA with major cardiovascular events [169].

There is emerging evidence that the protective effects of dietary shellfish and seafood may also be due to other nutrients such as selenium which is found in high levels in shellfish [170].
There are a large number of trials which have demonstrated an inverse relationship between dietary n-3 fatty acids derived from shellfish and other seafood with the risk of CHD [171-180]. For example, a 30 year epidemiological study of 1,822 men aged 40-55 demonstrated an inverse relationship between shellfish and seafood intake and death from CHD, especially death from myocardial infarction [177].

A more recent prospective study of 39,367 middle-aged and older Swedish men established that a moderate intake of n-3 rich seafood and marine n-3 fatty acids was associated with lower rates of heart failure [181]. High risk groups such as smokers and the obese can also gain cardioprotective effects from the consumption of shellfish and seafood [182, 183]. In addition to the primary protective benefits of regular consumption of n-3 fatty acid rich in shellfish and seafood, studies have also shown similar benefits in patients already suffering from CHD or recovering from a myocardial infarction [173]. In a trial of 2,033 men who had recovered from a myocardial infarction, the group selected to increase their n-3 fatty acid rich seafood intake suffered a 29% reduction in 2 year mortality compared to the control groups [173].

A large Italian study provided 11,323 recovering myocardial infarction patients with dietary marine n-3 fatty acid supplements and vitamin E and compared them to groups receiving standard care [184].

After a follow-up period of 1 year, patients receiving the marine derived n-3 fatty acid supplement had a 15% reduction in death, including 21% and 6% reductions in total and cardiovascular mortality, respectively.

Long-term follow-up of the same patients continued to show reductions in major clinical events after 3.5 years [185].

**Figure 23. Potential beneficial effects of EPA and DHA on cardiovascular disease and symptoms.**

<table>
<thead>
<tr>
<th>Potential EPA and DHA effects on Cardiovascular Disease</th>
<th>Explanation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antiarhythmic effects</td>
<td>Cardiac arrhythmia is a term for any of a large group of conditions in which symptoms are abnormal electrical activity in the heart resulting in irregular heart rate.</td>
<td>[186-188]</td>
</tr>
<tr>
<td>Decreased Blood Pressure</td>
<td>EPA/DHA can lower blood pressure in hypertensive patients</td>
<td>[189-191]</td>
</tr>
<tr>
<td>Reduced atherosclerosis</td>
<td>Regular intake of n-3 fatty acids can reduce the risk of plaque formation</td>
<td>[192-193]</td>
</tr>
<tr>
<td>Decreased platelet aggregation</td>
<td>Reduction in clot formation particularly in patients suffering from atherosclerosis</td>
<td>[194]</td>
</tr>
<tr>
<td>Plaque stabilization</td>
<td>n-3 fatty acids can enhance the stability of atherosclerotic plaques (the fatty acids deposits responsible for blocking arteries) from rupture, a cause of heart attack and stroke</td>
<td>[195-196]</td>
</tr>
<tr>
<td>Reduced cholesterol, free fatty acids and triglycerides</td>
<td>Regular intake of n-3 fatty acids can reduce triglyceride and affect the cholesterol levels in the blood</td>
<td>[197-200]</td>
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<tr>
<td>Anti-inflammatory effects</td>
<td>Marine n-3 fatty acids promote production of anti-inflammatory eicosanoids and downregulation of proinflammatory n-6 eicosanoids</td>
<td>[201]</td>
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<tr>
<td>Vasodilation</td>
<td>The dilation of blood vessels thus reducing arterial pressure – important in transplant patients</td>
<td>[202-204]</td>
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Recent evidence suggests that a proportion of the cardioprotective effect of n-3 fatty acids from shellfish and seafood is mediated by a relatively small but significant decrease in blood pressure (BP) level [189, 205, 206]. This effect may be brought about via a wide-range of biological actions of n-3 fatty acids particularly EPA and DHA.

These include competition with n-6 fatty acids for common metabolic enzymes resulting in decreased production of vasoconstrictor rather than vasodilatory and anti-inflammatory eicosanoids [189], reducing the activity of factors involved in vasoconstriction such as angiotensin-converting enzyme (ACE) and angiotensin II formation [207, 208].

n-3 fatty acids may also enhance endothelial nitric oxide generation, a factor involved in vasodilation [209], and activate the parasympathetic nervous system [210]. The combined actions result in improved vasodilation and the ability of both small and large arteries to respond to changes in pressure and an overall small but important reduction in blood pressure.

A review of trials concluded that increased consumption of fish oil resulted in, on average, a 2 mmHg reduction in both systolic and diastolic blood pressure [211].

Recent international cross-sectional epidemiologic study of 4,680 men and women aged 40 to 59 from 17 population-based samples in China, Japan, United Kingdom, and the United States reported that dietary intake of marine n-3 fatty acids demonstrated an inverse relationship to blood pressure, including non-hypertensive persons [212].

**Figure 24. Molecular structure of EPA**

An arrhythmia is a disturbance of the normal electrical rhythm of the heart suffering from CHD and is associated with sudden cardiac death [213-215]. Laboratory experiments have established that marine n-3 fatty acids, specifically EPA and DHA, have the ability to modulate conductance currents, especially of the fast voltage-dependent sodium and the L-type calcium channel, in the membranes of heart cells [216-219]. It is this ability that may underlie the basis of the anti arrhythmic action of the fatty acids. A number of prospective and epidemiological trials have shown that marine derived n-3 fatty acids have been shown to prevent fatal ventricular arrhythmias in patients recovering from myocardial infarction [214, 215, 220, 221].
Atherosclerosis, the narrowing of the arteries with plaques formed of fats and white blood cells, is one of the most common underlying conditions in CHD. Rupture of atherosclerotic plaques can lead to thrombosis or blood clot resulting in an interruption of blood supply to the heart and a myocardial infarction or heart attack.

N-3 fatty acids from shellfish and seafood have a number of biological effects which protect against thrombosis. These include the inhibition of platelet aggregation and anti-inflammatory effects [194, 222, 223]. Shellfish and seafood derived dietary n-3 fatty acids have also been shown to stabilise atherosclerotic plaques and thereby prevent their rupture [195, 196].

High levels of triglycerides and cholesterol are well established predictors of CHD risk, particularly of myocardial infarction. Triglycerides are the main form of lipid in the blood and are involved in the metabolism as energy sources and in the transport of dietary fats including cholesterol.

Cholesterol is a lipid manufactured by the liver and is vital for a variety of functions in the body. Cholesterol is a structural component of cell membranes, insulates nerve fibres, and is essential for hormone synthesis. Cholesterol is transported by 3 types of lipoproteins; Low density lipoprotein (LDL); High density lipoprotein (HDL), and; triglycerides. It is well established that total cholesterol, LDL-cholesterol, low HDL-cholesterol and calculated indices such as total cholesterol:HDL-cholesterol ratio or less commonly used indices such as non-HDL cholesterol are strongly predictive of cardiovascular events [224].

The LDL form of cholesterol has been associated with atherosclerosis when present in high levels; conversely high HDL ratios have been associated with reduced risk of atherosclerosis and CHD.

The authors of a recent review of 25 trials examined the effect of marine n-3 fatty acids on the levels of triglycerides and cholesterol in the blood and established that increased intake of dietary marine n-3 fatty acids containing DHA and EPA reduced both triglyceride and cholesterol levels [225].

The authors reported that the majority of studies found at least a 15% net reduction in plasma triglycerides with increased marine n-3 fatty acid intake. The majority of studies reviewed reported that the net effects on total cholesterol levels were small (<5%) but this did not discriminate between changes in the individual levels of LDL and HDL [225].

**Figure 25. Molecular structure of DHA**

Research has established that plant derived n-3 fatty acids such as those from rapeseed and flax seed fail to provide many of the cardioprotective effects of marine n-3 fatty acids [4, 226, 227]. Marine sources of n-3 fatty acids such as shellfish are superior to other plant based ones as sources of DHA and EPA [228]. Although both DHA and EPA can be synthesised by the body from alpha-linolenic acid (ALA) which is the most common n-3 fatty acid in plants, dietary derived n-3 fatty acid studies have shown that even with increased intake of ALA through supplementation there is little corresponding increase in blood DHA or EPA levels [229].

Historically there has been some confusion of the health benefits of shellfish in the diet as, although they are low in fat and saturated fat, some are high in cholesterol. Plasma levels of cholesterol is linked to the amount of dietary saturated fat and not to dietary cholesterol such as that found in eggs, liver and some shellfish.

Recent research confirms that there are no CHD risks associated with shellfish consumption and that the overwhelming evidence is for cardioprotective effects from their consumption [230]. Furthermore, studies suggest that shellfish derived cholesterol is poorly absorbed, and can act to reduce dietary and/or endogenous cholesterol absorption in the intestine [231, 232].

**BRAIN HEALTH AND PHYSIOLOGICAL CONDITIONS – LIFE LONG BENEFITS**

The human brain, its cells and neurons, is composed largely of n-3 lipids with the most abundant fatty acid in the brain being DHA accounting for between 25-35% dry weight of PUFAs in the brain and up to 50-60% of the total PUFAs in the retina. DHA is a long-chain n-3 fatty acid commonly found in shellfish and seafood such as crab, oysters and mussels and is a major structural component of cell membranes. Laboratory studies have revealed that low intake of n-3 fatty acids, particularly DHA, may predispose the brain to weak anti-inflammatory as well as strong pro-inflammatory signals [233]. Neurological disorders, including Alzheimer’s disease, Parkinson’s disease and major depression often display a neuro-inflammatory component. It has been suggested that increased intake of shellfish and other seafood rich in n-3 fatty acids may have a role in the prevention and treatment of neurological disorders [233, 234].

The consumption of shellfish and seafood rich in n-3 fatty acids, particularly DHA, is vital for pregnant women and healthy neurological development of the foetus. The role of DHA in infant nutrition is particularly important as DHA is specifically accumulated in the membrane lipids of the brain and retina, where it is important in neural and visual function [235].

It is important that there is sufficient DHA and other n-3 fatty acids in the maternal diet as it is the only source of essential fatty acids for infant development both before and after birth, as recent studies have addressed the role of maternal intake and milk DHA levels associated with risk of low infant neural system maturation [235-237].

A series of studies have established a link between maternal and infant dietary DHA intake with the development of visual acuity and neural pathways associated with the developmental progression of language acquisition [238-243]. Elevated IQ of children aged 4 has been linked to maternal intake of DHA during pregnancy, suggesting that intake of n-3 fatty acids during pregnancy and lactation by the mother may be beneficial for later mental development of children [244].

The regular consumption of shellfish and seafood rich in n-3 fatty acids may delay spontaneous delivery and prevent recurrence of preterm delivery. A study of 8,729 Danish women determined that a low consumption of fish was associated with a strong risk factor for preterm delivery and low birth weight [245]. In women with zero or low intake of fish, small amounts of shellfish or other seafood which are rich in n-3 fatty acids may confer protection against preterm delivery and low birth weight [14].
Pregnant women may also benefit from increased consumption of shellfish and seafood rich in n-3 fatty acids. Recent studies have revealed an association between low n-3 fatty acid intake from seafood with an increased risk of high levels of depressive symptoms during pregnancy [246-248]. It is possible that the benefits of n-3 fatty acid rich shellfish and seafood continue post pregnancy as there is emerging evidence that low DHA content in mothers’ milk and low seafood consumption is associated with higher rates of postnatal depression [249-251].

There have recently been widely publicised concerns over the levels of methylmercury and polychlorinated biphenyls (PCBs) in some oily fish and their consumption during pregnancy [252-254]. Predatory oily fish such as swordfish and marlin tend to be placed higher on the food chain and therefore are more susceptible to accumulating pollutants such as methylmercury and PCBs. Analysis of 47 fish and shellfish species by the UK Food Standard Agency revealed that shellfish contain very low levels of environmental pollutants, far below the European regulatory limits for fish [255]. Shellfish, due to their feeding ecology and position in the food chain, generally have very low levels of environmental pollutants in their meat and therefore may be a particularly useful source of n-3 fatty acids for pregnant and breast feeding women.

Low seafood and n-3 intake has been linked with behavioural and learning problems in childhood, particularly those associated with developmental co-ordination disorder (DCD), dyslexia and attention deficit hyperactivity disorder (ADHD) [256-258]. A study of 41 children aged between 8 –12 years with specific learning difficulties and above-average ADHD ratings were randomly given either n-3 fatty acid supplements or a placebo; after 12 weeks the group receiving the marine n-3 fatty acid supplements demonstrated significantly lower mean scores for cognitive problems and general behaviour [259].

Similar results indicating that increased marine n-3 fatty acid intake has beneficial effects on children with ADHD have been reported in further studies [260, 261]. Developmental coordination disorder (DCD) which affects coordination of motor functions, and is commonly associated with difficulties in learning and behaviour, affects approximately 5% of school-aged children [262]. A number of studies have suggested that low n-3 fatty acid consumption is associated with DCD and that increased intake can have therapeutic benefits [263]. A study of 117 school-aged children with DCD revealed significant improvements in reading, spelling, and behaviour over 3 months in the group receiving marine n-3 fatty acid supplements [262].

Populations with diets high in the consumption of shellfish and seafood and therefore a high DHA and overall n-3 fatty acid intake, have been shown to have a lower incidence of depression in epidemiological studies [264-268]. The link between levels of seafood or n-3 fatty acid intake and depressive disorders has been established in a number of studies [269-271] including adult and childhood depression [246, 267, 268, 272, 273], including bipolar depression [274].

Laboratory studies have established that DHA deficiency is associated with dysfunctions of neuronal membrane stability and that transmission of neurotransmitters such as serotonin, norepinephrine and dopamine, which may influence mood and incidence of depression [275]. Similarly, EPA has a key role in balancing immune function and physical health by reducing membrane arachidonic acid (an n-6 fatty acid) and n-6 prostaglandin production, which might be linked to physical somatic symptoms of depression [275, 276].

Patients suffering from schizophrenia have been shown to have reduced levels of polyunsaturated fatty acids, particularly DHA and arachidonic acid, in the cell membranes of their red blood cells [277]. There is evidence from clinical trials that marine n-3 fatty acids rich in EPA, such as those present in shellfish, confer a beneficial effect [278, 279] and can reduce the risk of participants from developing overt psychosis [279]. Brain function can be profoundly altered by slight changes in neuronal cell membrane metabolism and therefore neurotransmission, changes which can promote symptoms such as those seen in schizophrenic patients. Neuronal cell membrane metabolism is dependent on blood plasma levels of the essential fatty acids such as DHA and EPA which can only be derived from the diet. Antioxidants such as selenium, copper, manganese and zinc may have a role in the management of schizophrenia by ameliorating the effects of oxidative stress [280-283]. The combination of dietary antioxidants and n-3 fatty acids in the early stages of illness has been shown to have particularly successful clinical outcomes in some studies [280, 283]. This is a relatively new area of research but early results indicate that a diet including shellfish and seafood rich in n-3 fatty acids and antioxidants may provide protective effects from schizophrenia.

There is a growing body of research including laboratory, observational and epidemiological studies suggesting that there is a protective effect of n-3 fatty acids, derived from shellfish and other seafood, against dementia [284]. Although some of the evidence is contradictory [285, 286], a number of research studies suggest that dietary seafood and n-3 fatty acid intake is inversely linked with the onset and development of dementia and Alzheimer's disease [233, 287-291]. In a study of 8,085 participants aged 65 and over from the French cities of Bordeaux, Dijon, and Montpellier weekly consumption of seafood including shellfish was associated with a reduced risk of dementia and Alzheimer’s disease [287].

The same study reported that regular intake of marine n-3 fatty acids was associated with a decreased risk of dementia [287]. Another prospective study concluded that dietary intake of n-3 fatty acids and weekly consumption of seafood could reduce the risk of incident Alzheimer’s disease [292].

There is emerging evidence suggesting that consumption of shellfish and seafood rich in n-3 fatty acids and antioxidants may provide protection from Parkinson’s disease [12, 293, 294]. Prospective studies in the US have reported an inverse risk of Parkinson’s disease with seafood consumption in the population [295].

Laboratory experiments have demonstrated neuroprotective actions of dietary n-3 fatty acids such as those from shellfish sources [13, 296]. There is further evidence that dietary n-3 fatty acids can address some of the symptoms of Parkinson’s disease such as depression [297].
STROKE

Consumption of shellfish and seafood rich in n-3 fatty acids has been associated with a reduced risk of ischemic stroke [298-303].

Epidemiological studies revealed that populations with a high seafood and shellfish consumption had lower incidence of various chronic diseases including stroke [164, 304]. These protective actions of n-3 fatty acids may be particularly beneficial among the elderly; a 12 year study of 4,775 Swedish adults over 65 revealed that those participants with an intake of seafood 1 to 4 times a week had a 27% lower risk of suffering an ischemic stroke [298].

Risk of stroke in some sections of the population has been shown to be halved by regular consumption of seafood; women aged between 45 and 74 who consumed seafood once a week were shown to have a stroke risk half that of women who ate no seafood [300]. Intake of n-3 fatty acids has been linked to the protective effects of shellfish and seafood consumption as studies have shown that a higher consumption of shellfish and seafood rich in n-3 fatty acids tends to be associated with a reduced risk of ischemic stroke [301, 302].

EMERGING RESEARCH

The health benefits of eating shellfish are by no means fully explored by the research community. Current research is constantly revealing the benefits of the regular inclusion of shellfish in the diet. This section briefly describes some of these emerging areas of research [305].

Diabetes

There is growing evidence suggesting that diets with a high shellfish and seafood intake may reduce the risk of type 2 diabetes in populations with a high prevalence of obesity [306].

A lower prevalence of impaired glucose tolerance and diabetes has been reported from populations with a traditional high seafood consumption such as native Alaskans [307].

These protective effects are supported by laboratory studies that show a diet with high n-3 fatty acid intake induces not only insulin release by β-cells, but also optimizes insulin action in the body [308-311]. Preliminary evidence suggests increased consumption of marine n-3 fatty acids with reduced intake of saturated fat may reduce the risk of conversion from impaired glucose tolerance to type 2 diabetes [305].

Inflammatory Bowel Disease

There is some evidence that n-3 fatty acids derived from shellfish and seafood can have beneficial in inflammatory bowel diseases such as ulcerative colitis and Crohn’s disease [312-315]. The ratio of n-6 fatty acids in the diet has been associated with Crohn’s disease in Japan and it has been suggested that an increased n-3 fatty acid intake may be of benefit [316]. Laboratory studies have reported beneficial effects of marine n-3 fatty acids on animal models of chronic colitis [317]. Current evidence is weak and some is contradictory [318, 319] and therefore there is a need for larger clinical trials to elucidate the therapeutic benefits of marine n-3 fatty acids for these conditions.

Allergic diseases, Asthma, Eczema and Psoriasis.

There have been a variety of studies on the protective effects of regular shellfish and seafood consumption from the development of allergic diseases such as asthma and eczema [320-322]. Observational studies have proposed that there is a protective effect of oily fish on the incidence of adult asthma [323] and of asthma in 8-11 year old children [324]. This is an emerging area of research and the associations between shellfish and seafood intake and allergic diseases have not yet been fully detailed, nevertheless the evidence to date is encouraging.


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