Risk-Benefit Analysis of Fish in Finland: Dioxins and Omega-3 Fatty Acids

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Introduction

The aim of this study was to compare risks and benefits of domestic fish consumption. We created a model using Monte Carlo simulation. Risks were estimated for dioxins and PCBs in fish and benefits were attained from omega-3 fatty acids in fish. We selected dioxins and PCBs, because these pollutants are found in high concentrations in fish in the Baltic Sea and therefore pose a potential threat to human health in Finland.

Dioxins are animal carcinogens at high doses and have been linked to many serious health effects in humans, including cancer, reproductive and developmental effects, altered immune function, and disruption of the endocrine system. We restricted this preliminary study to cancer, but other endpoints will be included in subsequent analyses.

2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) is regarded as the most toxic man-made chemical known. Because of its relatively lipophilic properties it has a tendency to bioaccumulate and biomagnify in food chain and in the fat tissue. TCDD is formed in incineration processes as a by-product. Dioxins are metabolised and excreted slowly, which makes them very stable.

The ecosystem of Baltic Sea is highly polluted by dioxin and PCBs. European Commission has set the maximum concentration of 4 pg/g (WHO-TEQ in fresh weight) for dioxin concentration of fish products, which is frequently exceeded by salmon and herring of the Baltic Sea (concentrations up to 35 pg/g WHO -TEQ dioxins). Finland and Sweden have an exemption from this rule for these species until the end of year 2006[1].

A number of studies have shown the beneficial effects of omega-3 fatty acids in reduction of coronary heart diseases (CHD). CHD includes acute myocardial infarction and other ischaemic heart diseases[2]. Especially fatty fish species, like salmon and herring, are rich in omega-3 fatty acids.

Materials and Methods

We selected the most common species available for consumers, including farmed salmon, wild salmon, herring, whitefish, sprat, perch, flounder, pike-perch, bream, pike, vendace and burbot. For demographics statistics we used database of Statistics Finland and for mortality data WHO database

Exposure assessments
We used commercial and recreational fishery catch data of sea and inland water areas to estimate consumption of fish species. Data was supplied by Finnish Game And Fisheries Research Institute[3].

Data of pollutant concentrations of fish was attained from National Food Agency of Finland[1] and additional data from National Public Health Institute. The concentrations were measured per fresh weight. The fat-rich skin and ventral fat were included in the samples although they are usually not consumed for food. Therefore the measured concentrations are likely biased upwards.

For evaluating concentrations of omega-3 fatty acids of fish species, we primarily used nutritional database Fineli, maintained by National Public Health Institute of Finland. In addition we used studies of Din[4] and Kris-Etherton[5], as reference values.

Dose-responsies
We used the low-dose linear extrapolation assumption to ensure that the risk of dioxins and PSBs are not underestimated. Dose-response slope factors for cancer were obtained from U.S.EPA IRIS-database.

Dose-response function of omega-3 comes from secondary prevention trials reviewed by Din[4] and another review by Marckmann and Gronbaek[6]. In addition, we assumed that there exists a maximum amount of fish that is still beneficial, and any increase above that amount will yield no health gain. To maximize uncertainty, we added a factor to reflect the uncertainty whether there is cardiac health benefit for everyone or only for coronary heart disease patients.

We used Monte Carlo simulation with median Latin hypercube sampling. The results were calculated using 20000 iterations. Monte Carlo simulation assumes random distribution of unknown variables, and studies the subsequent distributions.

Results and Discussion

To compare risks and benefits, we used commensurable scale; cancer deaths per year and avoided CHD deaths per year in the general Finnish population. Benefits of farmed salmon were the highest, mean value being 180 [90% confidence interval (CI) 19-440)] avoided CHD deaths per year and pollutant risks of large herring (over 17 cm) were the highest, mean value being 3.2 (90% CI 3.7-1.9) cancer deaths per year. Total health risk of dioxins and PCB:s were 5.0 (90% CI 8.9-2.6) deaths and 0.7 (90% CI 1.1-0.36) deaths, respectively. Mean value of total benefits of all domestic fish species was 410 (90% CI 44-1000) avoided CHD deaths. In all fish species, CHD benefits were clearly higher than pollutant risks (figure 1).

By calculating ratio of CHD benefits and pollutant risks, we found three species with notably high benefit-risk ratio. Top three species with high benefits and low risks were farmed salmon, vendace, and burbot, respectively. There were big differences in benefit-risk ratio among the species of this study, ratio varying from 19 to 440. In this study only dioxin and PCB risks were included. Large pikes for example may have relatively high mercury concentrations, which can cause health risks. So, this benefit-risk ratio is not supposed to act as a nutritional recommendation, just to give perspective of the differences of fish species

By banning commercial fishing of salmon and herring we would save less than four cancer deaths, but at the same time we would have approximately 90 (90% CI 38-1000) CHD deaths more. Net benefit of domestic fish consumption would then decrease from 410 to 320 (90% CI 32-790) avoided deaths.

Figure 1. Risks and benefits of domestic fish consumption in Finland (number of cases per year). Health effects (mean values) of pollutant cancer and omega-3 cardiac benefit are shown assuming current concentration and consumption patterns.

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