RISK-BENEFIT ANALYSIS REGARDING SEAFOOD CONSUMPTION: A TOOL FOR COMBINED INTAKE ASSESSMENT

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Introduction

The aim of food consumption is to provide people with the daily necessary energy, macro- and micronutrients in order to meet recommendations and to be able to execute daily tasks. What people need are the beneficial compounds that can be found in food products. Nevertheless, people risk to ingest simultaneously compounds that can have toxicological effects. These harmful compounds can on the one hand occur naturally in food, but on the other hand anthropogenic or man-made processes can lead to contamination of food products[1]. As such, food items can contain benefits as well as risks for consumers.

A food group for which this nutritional-toxicological conflict is well-known and largely discussed in the scientific world and in the media is fish and shellfish, also named seafood or marine food. On the one hand, fish and shellfish represent a unique source of long chain poly-unsaturated fatty acids of the omega-3 family, particularly EPA and DHA. Moreover, they also contain a number of other valuable nutrients, like high quality amino acids and micronutrients like vitamin D and iodine. Therefore, it is generally accepted that seafood is important in a healthy and balanced omnivorous human diet. But on the other hand, this favourable health perception of seafood is troubled by less favourable information regarding the potential adverse health impact of chemical contamination of marine foods. Persistent organochlorine compounds, like PCBs, dioxin-like substances, and organochlorine pesticides (DDT/DDE) as well as heavy metals, e.g. mercury, accumulate in the marine food chain. This overall picture forms the basis for a conflictuous model between dietary recommendations and toxicological safety assurance.

Therefore, it is useful to carry out a risk-benefit analysis to quantify the nutritional-toxicological conflict linked with seafood consumption. One important step in this risk-benefit analysis is a detailed intake assessment of nutrients and contaminants of interest by fish consumption. The model used for this intake assessment as well as the created output is described in this abstract, with a focus on the methodology and not on the results as such.

Materials and Methods

The following simulation model, combining fish consumption data with nutrient and contaminant concentrations, is used for the intake assessment:

$$Y_i = \frac{\sum_a \sum_v \sum_t (\mathrm{b}_{\mathrm{v,a}} \cdot X_{v,i,t} \cdot C_{v,a})}{T \cdot BW_i}$$

where Y_i= average daily intake of subject i; $X_{v,i,t}$= amount (g) of fish v consumed by subject i (with body weight BW_i), at day t ($t = 1,\ldots,T$); $b_{v,a}$= probability determining whether fish v comes from region a and $C_{v,a}$= concentration of a specific nutrient/contaminant in fish v from region a.

Moreover, a probabilistic approach is applied for the simulations. Such an approach is essential to represent the complexity of real occurring situations and takes into account the variability of the consumption, the body weight and the concentration data. The variability of the consumption data is taken into account in a non-parametric way (i.e. all the individual data as such instead of assuming a probability distribution). The variability of the nutrient and contaminant concentrations is taken into account by representing them by parametric probability distributions. This seems very relevant in the case of contaminant concentrations in fish since it is more realistic to represent for example the dioxin concentration of herring in the Baltic Sea per gram herring by a distribution expressing the natural variability than representing it by one single data point (e.g. the mean or the 97.5th percentile value). To execute such probabilistic simulations for a wide range of food-related risks, a software program was developed at Ghent University, called ProbIntake^{UG}. This program combines each data point out of a consumption database with concentration data of multiple compounds in order to calculate a combined intake assessment. The model can be used for real intake assessments as well as for scenario analyses.

In this abstract, intake assessment results will be described based on food consumption data collected during 7 days from 341 boys and girls between 13 and 18 years old. Data were collected in Ghent (Belgium) between March and May 1997. The intake is assessed on the basis of seafood consumption only (no other food items are taken into consideration) for the following compounds: mercury, seven indicator PCBs, dioxin-like PCBs (12 congeners), dioxins (17 congeners), total dioxin-like compounds (combination of dioxin-like PCBs and dioxins, 29 congeners), EPA&DHA, vitamin D and fat. The used concentrations of these compounds originate from two newly compiled databases containing published data on nutrient and contaminant concentrations in fish[2,3]. A distinction for contaminant concentrations in fish species according to origin was only possible for a very limited number of species because of a lack of origin-specific contaminant concentrations.

For the purpose of optimising integration of respectively the intra-individual and inter-individual variability in food consumption as well as the variability in the nutrient and contaminant concentrations in the probabilistic exposure assessment model, the number of subjects was artificially extended to 3410 (by copying subjects 10 times) and the 7-day diary per individual was extended to a fictive 35-day diary (by simply copying the diary five times). The former procedure accounted predominantly for the uncertainty arising from a relatively small sample size. A good convergence on the population intake estimates was reached when copying the food consumption database 10 times. The latter procedure increased the likelihood of a good description of the variability of the nutrient/contaminant concentration on the level of individual intake assessment; a good convergence of the individual estimates was reached when copying all individual diaries five times. This led to a total of 119,350 runs to be executed.

Results and Discussion

Figure 1 shows a scatterplot visualising the log-transformed results of the combined intake assessment executed for the eight compounds of interest, on the basis of seafood consumption only. On the diagonal axes of the scatterplot, frequency distributions of the intake assessments of all individual compounds are shown (axes on log-scale). In the triangle left-at the bottom, 28 scatterplots show the ratio of the intake of one compound to the intake of another one. In the triangle right-on top, the correlation coefficients of the shown ratios are given; for ease of interpretation, the larger the font of the number shown, the larger the correlation coefficient.

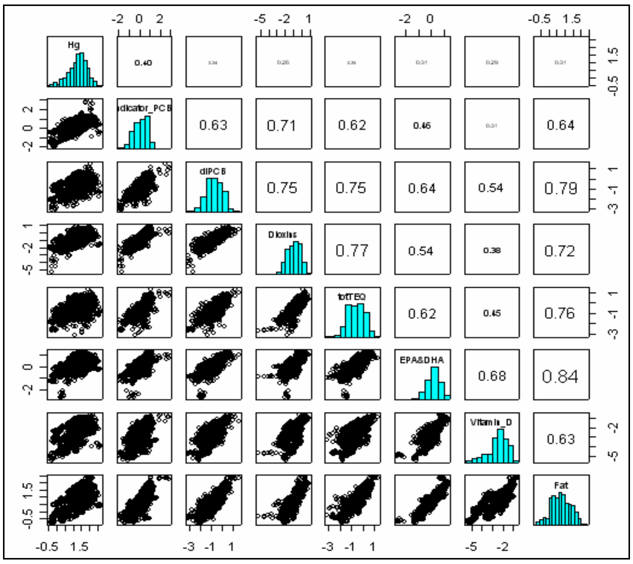

Figure 1 Scatterplot visualising the log-transformed results of the combined intake assessment for the eight compounds of interest; from left on the top to right at the bottom: mercury (Hg), the seven indicator PCBs (indicator_PCB), 12 dioxin-like PCBs (dlPCB), 17 dioxin congeners (Dioxins), 29 dioxin-like compounds (totTEQ), EPA and DHA, vitamin D and fat

The highest correlations are found between the assessed intake of several fat-soluble compounds, e.g. r^2(indicator PCBs versus dioxins) = 0.62, r^2(total dioxin-like compounds versus fat intake) = 0.76. The observed correlation coefficients can be explained (1) by the fact that a higher seafood consumption will lead in all cases to a higher nutrient and contaminant intake; and (2) people consuming more fatty fish species will have both a higher fat intake, as well as a higher intake of fatty acids and fat-soluble contaminants, reflecting the fact that these substances are jointly present at the level of the seafood species themselves.

Figure 2 provides a detail of the scatterplot, focussing only on two compounds, being the total of dioxin-like compounds (total TEQ) on the one hand and EPA&DHA on the other hand. This graph shows the ratio of the intake of total TEQ divided by the TDI (2 pg TEQ/kg bw/day) and the intake of EPA&DHA divided by the requirement (0.3% of the total energy requirement). By expressing the intake divided by the TDI or requirement, the limit value for being at the benefit or risk side is 1 on both axes. As such, four quadrants are obtained, all with a relevant meaning: (1) consuming enough seafood to meet the EPA&DHA requirement, without exceeding the 2 pg TEQ/kg bw/day limit; (2) consuming enough seafood to meet the EPA&DHA requirement, but exceeding the 2 pg TEQ/kg bw/day limit; (3) consuming too little seafood to meet the EPA&DHA requirement, and not exceeding the 2 pg TEQ/kg bw/day limit; and (4) consuming too little seafood to meet the EPA&DHA requirement, but exceeding the 2 pg TEQ/kg bw/day limit.

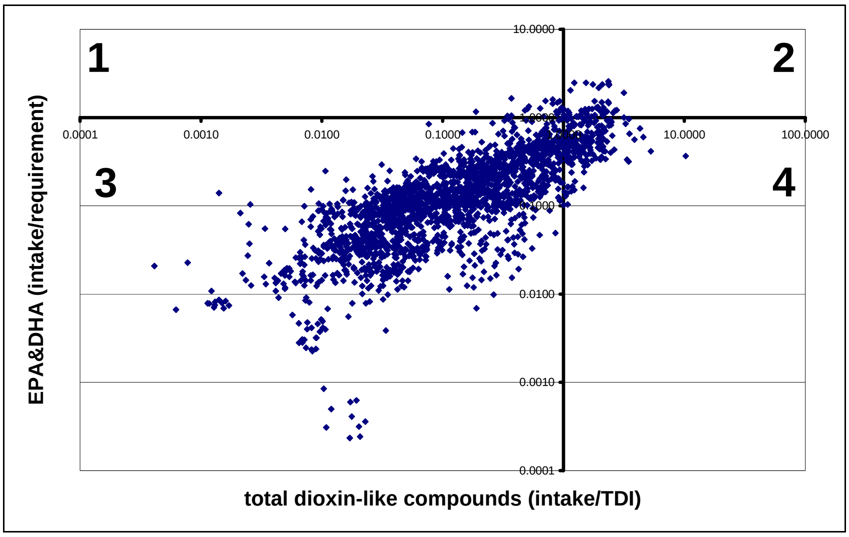

Figure 2 Ratio of the intake of total TEQ divided by the TDI (2 pg TEQ/kg bw/day) and the intake of EPA&DHA divided by the requirement (0.3% of the total energy requirement) as a result of the real seafood consumption of Belgian adolescents (log-scale). The numbers 1-4 indicate four situations (see text).

Figure 2 shows that a large part of the studied population (Belgian adolescents) has a seafood consumption leading to an intake of dioxin-like compounds lower than the TDI as well as an intake of EPA&DHA lower than the requirement. Only a few people meet their EPA&DHA requirement without exceeding the limit for total dioxin-like compounds. However, due to the rather high correlation between the intake of these two compounds (r^2=0.62), it can be assumed that an increase of seafood consumption in order to increase the omega-3 fatty acid intake will lead to an increase of the intake of dioxin-like compounds. This assumption is confirmed by a scenario analysis performed with the ProbIntake^{UG} model, of which a fragment of the results is shown in figure 3.

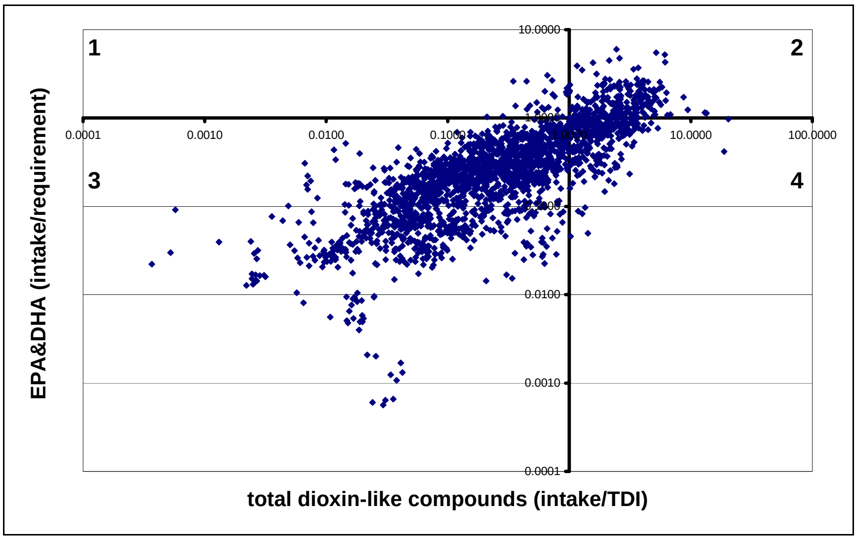

Figure 3 Ratio of the intake of total TEQ divided by the TDI (2 pg TEQ/kg bw/day) and the intake of EPA&DHA divided by the requirement (0.3% of the total energy requirement) as a result of a doubled seafood consumption of Belgian adolescents (log-scale)

Figure 3 shows the same parameters as figure 2, thought with values resulting from a scenario analysis in which the seafood consumption of the adolescents is doubled without any other changes to their dietary pattern (no alterations of the species consumed). The cloud of points representing the EPA&DHA on total TEQ intake ratio just shifted to the upper right corner, meaning that more individuals meet their EPA&DHA intake, but at the same time increase their intake of dioxin-like compounds proportionally. These results show that the problem of the low intake of omega-3 fatty acids can not be solved just by promoting seafood consumption in general, since this will increase the probability of a lot of people for being at risk of a too high contaminant intake. More detailed recommendations are needed, focussing on species having a relatively high concentration of healthy compounds and a rather low concentration of harmful contaminants.

In conclusion, ProbIntake^{UG} is a very useful tool for executing combined intake assessments leading to better insight in the problematic nature of food items containing nutritional benefits as well as safety risks. In the case study presented in this abstract, i.e. seafood consumption, the results made clear that the intake of the different compounds is highly correlated. This has to be taken into consideration when formulating health and dietary recommendations to the public.

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