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Conditions for health effect calculations on nutritional factors

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Contents

Summary

Health effect calculations for nutritional factors can be helpful to understand the effects of dietary interventions or policy measures on public health. These health effect calculations require a substantial amount of information and are complicated to perform. The purpose of this report is to describe the process and conditions of health effect calculations for individual nutritional factors.

Short-term health effects are the effects of an intervention or policy measure on the food or nutrient intake distribution. The interventions or policy measures are described by scenarios. Food consumption survey data and food composition tables are used to calculate the nutrient or food group intake distribution for the different scenarios. Scenario development depends on various assumptions and uncertainties. The food group or nutrient intake distribution of each scenario can be compared with the reference situation or with dietary guidelines and will be used to evaluate the effect of an intervention on nutrient or food group intake distribution.

The long-term health effects are the effects of an intervention or policy measure on overall health, which can be calculated using the RIVM Chronic Disease Model. The model is based on certain assumptions and has some inherent limitations. The nutritional scenarios are essential input for health effect calculations, as well as risk estimates between nutritional factors and chronic disease. The outcomes of the model are the prevalence and incidences of chronic diseases, on which integrative measures can be calculated. Already, health effect calculations for fruit, vegetables, fish, saturated fat and trans fatty acids have been conducted using the CDM. Before a new nutrient or food group can be incorporated, the model conditions should be considered carefully. It is likely that the model can be expanded for sodium, and unsaturated fat. Health effect calculations for dietary patterns are not possible using the present model and the model should be newly structured for health effect calculations for dietary patterns taking into account combinations of nutritional factors.

Samenvatting

Gezondheidswinstberekeningen geven inzicht in de effecten van voedingsinterventies of beleidsmaatregelen op de volksgezondheid. Een grote hoeveelheid informatie moet worden ingevoerd worden om de gezondheidseffecten te kunnen berekenen. Daarbij zijn de berekeningen redelijk ingewikkeld. Het doel van dit briefrapport is om het proces en de voorwaarden voor gezondheidswinstberekeningen voor individuele voedingsfactoren te beschrijven.

De gezondheidseffecten van een voedingsinterventie of beleidsmaatregelen op de korte termijn kunnen worden geëvalueerd met een verandering van de innemingverdeling van een nutriënt of voedingsmiddel. Deze interventies of beleidsmaatregelen worden beschreven door scenario's. Gegevens uit voedselconsumptiepeilingen en de voedingsmiddelentabel worden gebruikt om de innemingverdeling van een nutriënt of voedingsmiddelengroep te berekenen in de scenario's. Tijdens het ontwikkelen van een scenario worden aannames gedaan en zijn er onzekerheden. De verdeling van de voedingsmiddelengroep of nutriënt van elke scenario wordt vergeleken met een referentie inneming of met de richtlijnen goede voeding. Hiermee kan het effect van een interventie of beleidsmaatregel op de nutriëntinneming worden geëvalueerd.

Gezondheidseffecten op de lange termijn zijn de effecten van een interventie of beleidsmaatregel op de volksgezondheid. Deze effecten kunnen berekend worden met het RIVM Chronische Ziekten Model. Dit model heeft verschillende aannames en daarmee samenhangend enkele beperkingen. De voedingscenario's zijn essentieel voor gezondheidswinstberekeningen wanneer men de gezondheidseffecten van voedingsfactoren wil evalueren. Ook de relatieve risico's tussen voedingsfactoren en chronische ziekten zijn nodig om de effecten van een voedingsfactor op de volksgezondheid te kunnen berekenen. De uitkomsten van het model zijn de prevalenties en incidenties van chronische ziekten per jaar, op basis waarvan geïntegreerde gezondheidsmaten berekend kunnen worden. Momenteel zijn al gezondheidswinstberekeningen voor groente, fruit, vis, verzadigde vetten en transvetzuren uitgevoerd met het RIVM Chronische Ziekten Model. Voordat een nieuwe voedingsfactor aan het model toegevoegd kan worden, moeten de voorwaarden van het model worden nagegaan. Het lijkt aannemelijk dat het model kan worden uitgebreid voor natrium en onverzadigde vetzuren. Gezondheidswinstberekeningen voor voedingspatronen, waarbij combinaties van voedingsfactoren worden gebruikt, zijn niet mogelijk met het huidige model. Het model zal daarvoor opnieuw moeten worden opgebouwd.

1   Background

In 2006 the Dutch Health Council published new guidelines for a healthy diet emphasizing the need to prevent chronic diseases including cancer, cardiovascular diseases and type 2 diabetes in the Netherlands [1]. Unfavourable trends in the intake of fruits and vegetables have been observed over the past decades, as well as a probable increase of salt intake [2]. In contrast, the intake of saturated fat and trans fatty acids have decreased, and the intake of fish has slightly increased [3]. However, the intake of most (macro)nutrients still not meets the recommended dietary guidelines [2]. Therefore, policy measures and interventions are needed aiming to improve the dietary intake of the Dutch population. In order to underpin national nutrition policy it is necessary to have a detailed understanding of the effects of dietary intake on public health. Health effect calculations are a method to gain insight in the effect of a certain nutritional factor on health and are described in this short report.

Health effects for nutritional factors can be assessed in the short-term and long-term. Short-term health effects are the effects of an intervention or policy measure on the food or nutrient intake distribution. For example, it can be calculated to what extent the population-wide salt intake would decrease when the salt content of bread is reduced by 10%. The interventions or policies are described by scenarios. The altered intake of a nutrient or food due to the intervention or policy measure can be compared with the current situation and with the recommended intake or upper tolerable level.
Long-term health effects are effects on public health resulting from the altered food or nutrient intake. These long-term health effects mainly relate to chronic diseases and can be estimated using mathematical model simulations. In this short report we discuss the RIVM Chronic Disease Model (CDM), which was developed by the National Institute for Public Health and the Environment (RIVM) to assess the future impact of changes in risk factors (including nutritional factors) *over time* on chronic diseases development in the Dutch population, taking into account the population size, risk factor distribution and prevalence of chronic diseases. For example, the CDM can be used to estimate the effect of a too high intake of trans fatty acids on the prevalence and incidence of coronary heart disease.

Health effect calculations using the CDM provide insight in the effects of nutritional interventions and nutritional policy measures and can establish which interventions are most effective in terms of morbidity and mortality. However, health effect calculations require a substantial amount of information and are complicated to perform.

This report aims to provide an overview of the process for performing health effect calculations for individual nutritional factors and describes the conditions for these calculations. Chapter 2 discusses the process of calculating short-term health effects by formulating nutritional reference and alternative scenarios and describes the various steps involved in scenario development as well as the underlying assumptions and implications. Chapter 3 covers the process of the actual long-term health effect calculations. It provides a short background of the CDM and discusses the limitations and assumptions of the model. Subsequently, it outlines the necessary steps that need to be taken before actual health effect calculations for nutritional factors can be made. Finally, chapter 4 presents recommendations for health effect calculations of nutritional factors.
This report is written as part of the project "Herformuleren van voedingsmiddelen" (Reformulation of Foods) 2009-2012, an umbrella-project between TNO, Wageningen University and RIVM.

2   Nutritional effects as result of scenario development

The effect of an intervention or policy measure on the food or nutrient intake distribution can be regarded as a short-term effect on health and can be considered as a nutritional effect. The potential effect of an intervention or policy measure for individual nutritional factors is assessed by comparing two or more scenarios. One scenario describes how the intake distribution of a nutritional factor will change when the policy measure or intervention is implemented, the other when it is *not* implemented. These scenarios are called the alternative scenarios and the reference intake. Scenarios describe what will happen due to different actions and are thus inherently hypothetical and uncertain. Various situations can be described by scenarios for individual food groups or nutrients. Usually, the reference intake represents the current situation or trend of an individual nutrient or food group, while one or more alternative scenarios are developed to describe the intake of an individual nutrient or food group under various circumstances (for example after an intervention). Best-case and worst-case comparisons can be used to assess the range of the intake distribution of a nutritional factor and describe the extent of the problem. In that situation the reference intake does not reflect the current intake or expected trend, and the alternative scenario does not resemble a policy measure or intervention. The best-case scenario represents the situation in which everyone meets the dietary recommendations, while the worst-case scenario represents the situation in which the total population fails to meet the dietary recommendations. More realistic scenarios can be formulated that are considered as attainable scenarios in practice. The intake distribution scenarios provide the essential input for health effect calculations for nutritional factors in the CDM.

The process of formulating nutritional scenarios and calculating the nutrient or food group intake distributions requires an extensive amount of information. During this process several assumptions need to be made. This process is described in this chapter, as well as the difficulties encountered and assumptions made during the process.

2.1   Description of process for establishing nutritional scenarios

2.1.1   Process of establishing reference intake and alternative scenarios

The reference intake and alternative scenarios describe the intake distribution of a certain nutrient or food group in various situations. In the present short report, the current intake will be considered as the reference scenario. First, the (sub)population should be identified and characterized. Next, the intake distribution of the (sub)population in the reference scenario needs to be calculated using the food consumption survey data and the food composition table. Then alternative scenarios will be established. The following step is to calculate the new food or nutrient intake distribution for the various alternative scenarios. In this paragraph the difficulties in developing reference intake and alternative scenarios will be discussed as well.

Step 1: Characterisation of (sub)population
The first step is to characterize the study (sub)population, which may be the total population or a certain targeted or affected subgroup of the population. For example, the nutrient intake of young children may be studied, the fruit and vegetable consumption of immigrants, or the salt intake among the total population.

Step 2: Calculation of food group or nutrient intake distribution in reference intake
Estimates of the intake distribution of a certain nutrient or food group need to be obtained or calculated for the reference scenario. In the reference intake, the food group intake distribution can be directly estimated from the food consumption survey. The nutrient intake distribution may be calculated by multiplying the food consumption data with the food composition data. The second step requires the availability of recent intake data and recent food composition data for the (sub)population concerned.

Food Consumption Survey
The Food Consumption Survey provides data on the intake distribution of foods in the Netherlands and is based on two non-consecutive independent 24h dietary recalls. The consumption of foods or food groups is directly estimated from the food consumption survey. The nutrient intake can be calculated using the food consumption survey data and the food composition database. In order to evaluate the proportion of the population that adheres to the dietary guidelines, the habitual intake should be derived. The habitual intake reflects the average intake over a longer period of time, in stead of the actual intake over two days.
Occasionally, dietary assessment methods used in food consumption surveys are unable to accurately estimate intake distributions. For example, assessment of salt intake by dietary assessment methods is hard due to difficulties in assessing the amount of discretionary salt (salt that is added during food preparation and consumption at home). Therefore, other approaches, which will probably require additional assumptions and uncertainties, need to be applied to calculate the salt intake distribution. Another example is the fish consumption. Fish consumption has not been estimated in the recent food consumption surveys because many subjects do not eat fish on a regular basis (including non-consumers). This may be overcome by using food frequency questionnaires, either used in population-based cohort studies or additionally administered in food consumption surveys, in order to estimate the habitual fish consumption.

The most recent Food Consumption Survey for the total population was conducted more than 10 years ago, in 1997/1998. It is likely that the intake of certain foods and nutrients, such as ready-to-eat meals and fortified foods, has changed since then. So, if it is to be expected that the intake of certain food groups has changed, then the food consumption data that are currently available are outdated. More recent food consumption surveys are available for the specific subgroups young adults (2003) [4] and young children (2005/2006) [5]. Data from the new Dutch food consumption survey will be available by 2011.

Food composition database
The food composition database (e.g. NEVO table) contains data on the nutrient composition of various types of foods and may be used to calculate the nutrient intake distribution from the consumed foods estimated in the food consumption survey.
Most nutrients relevant for health effect calculations are available in the food composition database. An exception is the level of *added* sugar. The total amount of carbohydrates is available, but it is currently not possible to estimate the proportion of *added* sugar from the total amount of carbohydrates. Thus, the calculation of the intake distribution of *added* sugar will involve additional assumptions and uncertainties.
Furthermore, a food composition database often presents an average level of a nutrient in a food. For some foods there may be a wide range of nutrient levels for which the variability is currently not available in the food composition database. It should be evaluated whether the available nutrient levels in foods can be used for scenario development and health effect calculations. If not, the food composition table may require an update to ensure the quality of the data.

Step 3: Formulation of alternative scenarios
Alternative scenarios are determined by the aim of the study. It depends on whether the maximum attainable health gain or loss, or more realistic interventions or policy measures will be studied. Input for these alternatives scenario's can be obtained from literature, but may also be provided by stakeholders or experts in the field. In alternative scenarios for nutritional factors a change in food consumption or food composition may be developed. The box below provides some examples of alternative scenarios.

Box 1: Examples of alternative hypothetical scenarios

Recommendation (best-case scenario): Everyone meets the recommendation for saturated fat intake (<10en%)

Feasible scenario: Salt in bread will be reduced by 20%.

Feasible scenario: A fruit consumption intervention among young children increases the consumption of fruits with 50 gram per day.

Worst case scenario: The consumption of fish for the total population decreases to 0 grams per day

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Step 4: Calculation of food or nutrient intake distribution in alternative scenarios
A new nutrient or food group intake distribution will be calculated for the alternative scenario(s). The description of the alternative scenario sets the limitations and determines the information needed to calculate the new nutrient or food group intake. Intake distributions in alternative scenarios may also have indirect effects on health resulting from substitution, compensation and additional effects on consumption. For example when sugar is replaced in foods by artificial sweeteners, people may compensate for the lack of energy by eating more other energy-dense foods. Also, when people eat more fish they probably eat less red meat, lowering their saturated fat intake and their associated adverse health effects such as reduced cardiovascular disease risk. If these effects are expected to be substantial, they should, if possible, be accounted for in the scenarios or the assumptions should be described carefully.

Food consumption
The food consumption of subjects may change in an alternative scenario. For example, the intake distribution of saturated fat may decrease when products high in saturated fat are replaced with low-saturated fat products.
It should be decided on who is expected to change their food intake. This could be the total population or a targeted or unintentionally affected subgroup of the population. For example, an intervention aimed at increasing fruit consumption does not necessary lead to an increase in fruit consumption among those who have a habitual low fruit intake.

Food composition
In an alternative scenario the food composition may change (food reformulation or fortification). It should be specified which foods will be reformulated or fortified. It should be noted that within a certain food group hardly ever all products will be reformulated or fortified, usually only some brand-specific products will. Furthermore, the level of reformulation or fortification may differ between food

categories or within food categories. For example, the level of salt reduction may differ in various kinds of bread.

Substitution
Substitution is the effect which occurs when during an intervention subjects replace a food product for another food product. For example, if salt is reduced in bread, people may shift away from bread consumption to whole-grain cereals and thus the percentage of consumers that will substitute bread needs to be estimated. Furthermore, this substitution can induce additional health effects since the added sugar and saturated fat content in whole-grain cereals may be higher than in bread.

Compensation
Compensation takes place when the effect of an intervention is counterbalanced by a change in behaviour of individuals. For example, an intervention to increase fruit consumption at school may cause a decrease of fruit consumption at home and as a result the overall fruit consumption may not increase at all. Another example is that reduced salt levels in soups may be compensated for increased discretionary salt use at home. The percentage of consumers compensating their intake as well as the level of compensation needs to be estimated.

The difficulties encountered in the establishment of reference intake and alternative scenarios are summarized in box 2. The uncertainties involved in each part are difficult to quantify and need assumptions, which should be clearly described. When there are many uncertainties involved, probabilistic modelling (for example Monte-Carlo approaches) can be used to compute intake distributions caused by uncertain intakes.

Box 2: Summary of information needed and effects that have to be accounted for in establishing reference and alternative scenarios

- Availability of food group or nutrient intake from food consumption survey
- Availability of nutrient levels in food composition table
- Compensation effects
- Substitution effects

2.1.2 Process of comparing the intake distributions of reference intake with alternative scenarios

Finally, the results of all alternative scenarios are compared with the reference scenario. *Figure 1* presents an overview of the change in intake distribution of folic acid in the reference intake (i.e. no fortification of folic acid in bread) and alternative scenarios (gradual increase of folic acid in bread). Intake distributions of reference intake and alternative scenarios can be compared to the recommended intake (if it is expected that the intervention or policy measure will improve the dietary intake) or to the upper level (when it is expected that the intervention or policy measure may exceed the upper level). Based on these comparisons, it can be assessed whether an intervention or policy measure will have its desirable effect on nutritional intake.
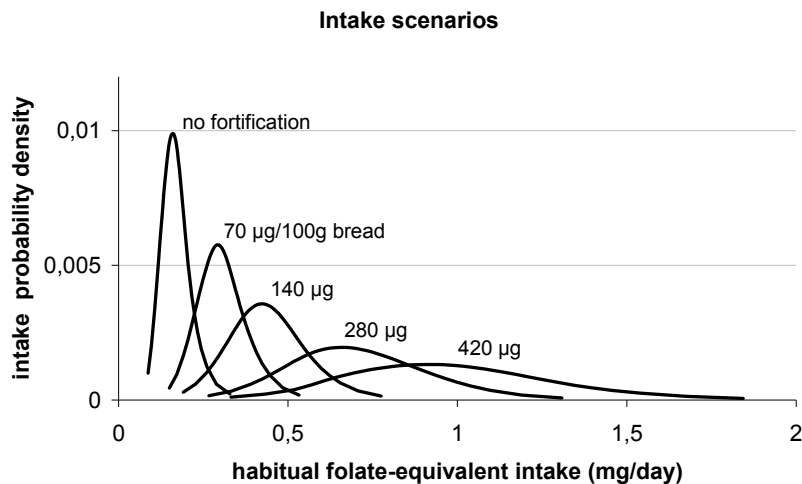
Intake scenarios

Figure 1: Habitual intake of folate-equivalent (folate and folic acid) for the reference intake (i.e. no folic acid fortification) and four simulated folic acid fortification scenarios (70, 140, 280 and 420 µg/100 g bread). Adapted from Hoekstra et al [6].

2.2 Conclusion

The determination of nutritional scenarios requires a certain amount of data. In the process of establishing the scenarios and calculating the nutrient or food group intake distributions several decisions should be made. First, the food groups or individual nutrients that the study will focus on will be determined. Second, the (sub)population that is targeted and affected is established. Third, the nutrient or food group intake distribution for the reference and alternative scenario will be assessed. It should be taken into account that the data needed to establish the nutrient or food group intake distribution is not always available for each subgroup in the population. The nutrient intake distribution in reference intake and alternative scenarios can be difficult to estimate when there is no adequate availability of these nutrients in the food consumption survey or the food composition table, like sodium and *added* sugar. The alternative scenario is usually based on an intervention of which the effects are uncertain and also substitution and compensation effects are generally difficult to estimate. When there are many uncertainties involved, probabilistic modelling (Monte-Carlo approaches) should be used to compute intake distributions to take into account these uncertain effects.

Currently, determination of scenarios for individual nutrients or food groups seems reasonable, given certain difficulties encountered in the establishment of a reference or alternative scenario.

3 Health effect calculations for nutritional factors using chronic disease modelling

The long-term, ultimate effect of nutritional factors on health can be calculated using the CDM. The CDM may simulate effects of nutritional factors on chronic disease morbidity and mortality. Based on these figures, the disability adjusted life years (DALY's) or costs of illness can be calculated. Lifestyle factors such as nutrition, as described by reference and alternative scenarios (chapter 2), are the essential input for the CDM. A schematic overview of health effect calculations is presented in *figure 2*.

The CDM is a model, and as any model a simplification of reality. The model is based on several assumptions. First, we will discuss the concept of the CDM together with its limitations and assumptions. Next, the process and information needed, as well as the conditions of using nutritional factors to calculate the health effects in the CDM are described.
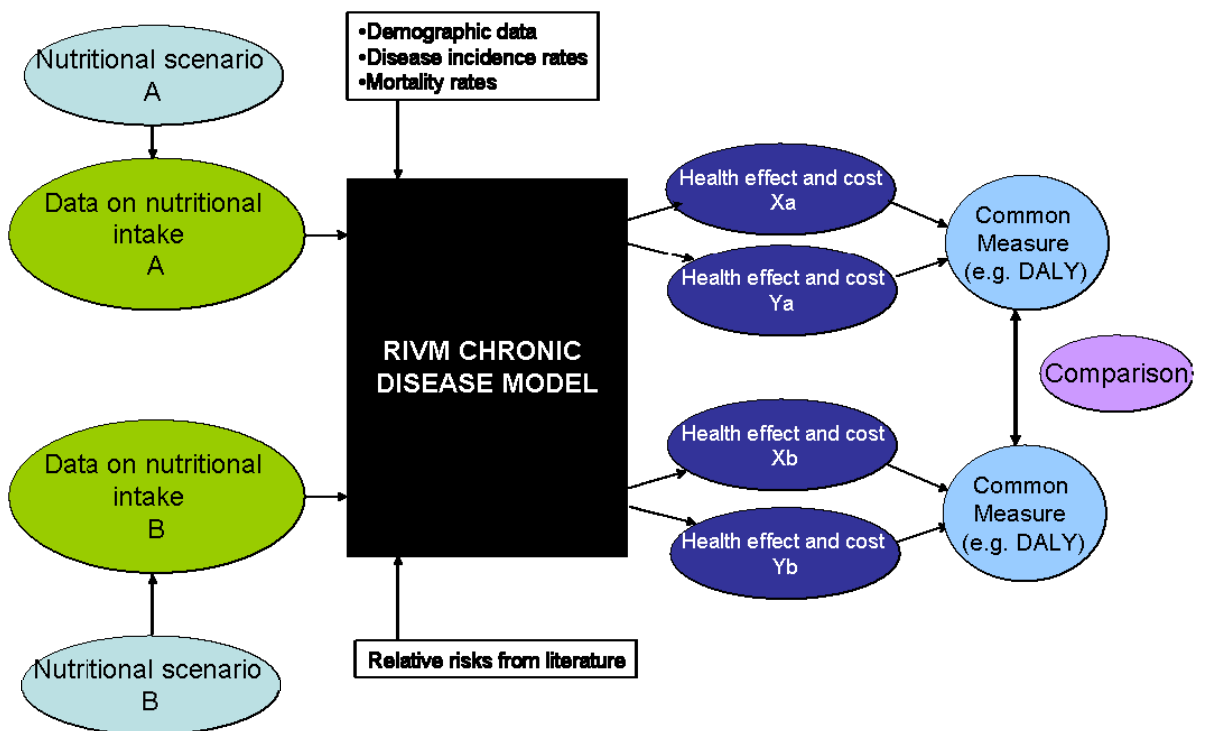

Figure 2: Concept of health effect calculations, where X and Y are examples of chronic diseases

3.1 Concept of the RIVM's Chronic Disease Model

3.1.1 General introduction

The CDM is a tool that simulates the development of morbidity and mortality in a (sub)population *over time*, due to changes in risk factors for chronic disease. To date the parameters are specific for the Dutch (sub)population. The currently implemented lifestyle factors and chronic diseases in CDM are presented in table 1. Thus far the nutritional factors fruit, vegetables, fish, saturated fat[1] and trans fatty acids have already been included in the CDM.

The input for the model exists of: 1) demographic data, such as age and sex and may depend on the type of scenario, fertility, immigration and/or emigration; 2) risk factor behaviour (such as nutritional factors); 3) current disease incidence, prevalence and mortality; and 4) risk estimates between risk factors classes and disease, and for mortality from diseases. The main model outcomes are the prevalence of disease and death, for each age and sex class, for each year the model runs. Thus, the age- and sex-dependent disease incidence and mortality rate are also known. Integrative measures such as disability or quality adjusted life years (DALYs/QALYs) and (healthy/quality adjusted) life expectancy can be calculated based on the prevalence and incidence rates of the diseases in the model. Furthermore, health care costs and consequently economical evaluations, such as cost-effectiveness studies, can be performed using the outcomes of the CDM.

The model simulation can be described as follows: in each year, a proportion of the (sub)population changes its state (risk factors classes and health), for example from healthy to suffering from lung cancer. The changes of state are modelled through transition probabilities, which are derived from the risk estimates between risk factor classes and disease, and between disease and mortality. For example, in the CDM the probability is modelled that the proportion of the population with a low fruit intake will develop coronary heart disease. At the start of the model, the risk estimate to develop coronary heart disease due to a low consumption of fruit is 1.2, and the risk estimate to develop coronary heart disease due to high fruit consumption is 1.0. Each consecutive year, the same probability is modelled until an individual has either developed coronary heart disease, or has died. The outcome is the number of new cases of coronary heart disease, and deaths in each year. In an alternative scenario, a smaller proportion of the population has a low fruit intake. Again, the probability is modelled that the proportion of the population will develop coronary heart disease. The outcome in the alternative scenario is the corresponding number of new cases of coronary heart disease and deaths in each year. The difference in coronary heart diseases between the first scenario and the alternative scenario is calculated and is considered as the health effect of increased fruit consumption.
The period that is simulated can differ. If a cohort is simulated until all subjects have died, indirect effects are incorporated and life expectancies can be calculated. The period of the simulation can also be the duration of the intervention or as long as effects are expected. In such situations life expectancy cannot be calculated.

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[1] The risk estimate of saturated fat on cardiovascular disease is derived by a combination of the effect of saturated fat on cholesterol levels and the effect of cholesterol levels on cardiovascular disease.

Table 1: Current risk factors and chronic diseases in the CDM

Risk factors	Chronic diseases			
1. Smoking	1. Cardiovascular diseases	Acute myocardial infarction	3. Cancer (continued)	Kidney
2. Physical activity		Chronic heart failure		Pancreatic
3. Overweight (BMI)		Stroke		Oral cavity
4. Blood pressure	2. Respiratory diseases	COPD		Endometrium
5. Cholesterol	3. Cancer	Lung	4. Musculoskeletal diseases	Arthrosis hip
6. Alcohol intake		Colorectal		Arthrosis knee
7. Vegetable intake		Stomach		Lower back pain (dorsopathy)
8. Fruit intake		Oesophagus	5. Diabetes mellitus type 2	
9. Trans fatty acid intake		Breast		
10. Saturated fatty acid intake		Prostate		
11. Fish intake		Larynx		
12. Blood glucose levels (HbA1c)		Bladder		

3.1.2 Assumptions and limitations

The CDM is based on some general assumptions and thus has some inherent limitations. First, the change in the diseases status, thus the change from being healthy to being ill, depends on the absolute probability of developing a particular disease, that in turn is deduced from the current incidence of the diseases, the current risk factor prevalence and on the risk estimates for the classes of intake and the concerning disease. Uncertainties in each of these variables will affect the outcome of the CDM. Next, a risk factor can increase the incidence of a disease directly as well as indirectly. For example, the consumption of fish has an effect both on other coronary heart disease risk and acute myocardial infarction. However, people suffering from another coronary heart disease have a higher risk on myocardial infarction (see figure 3).
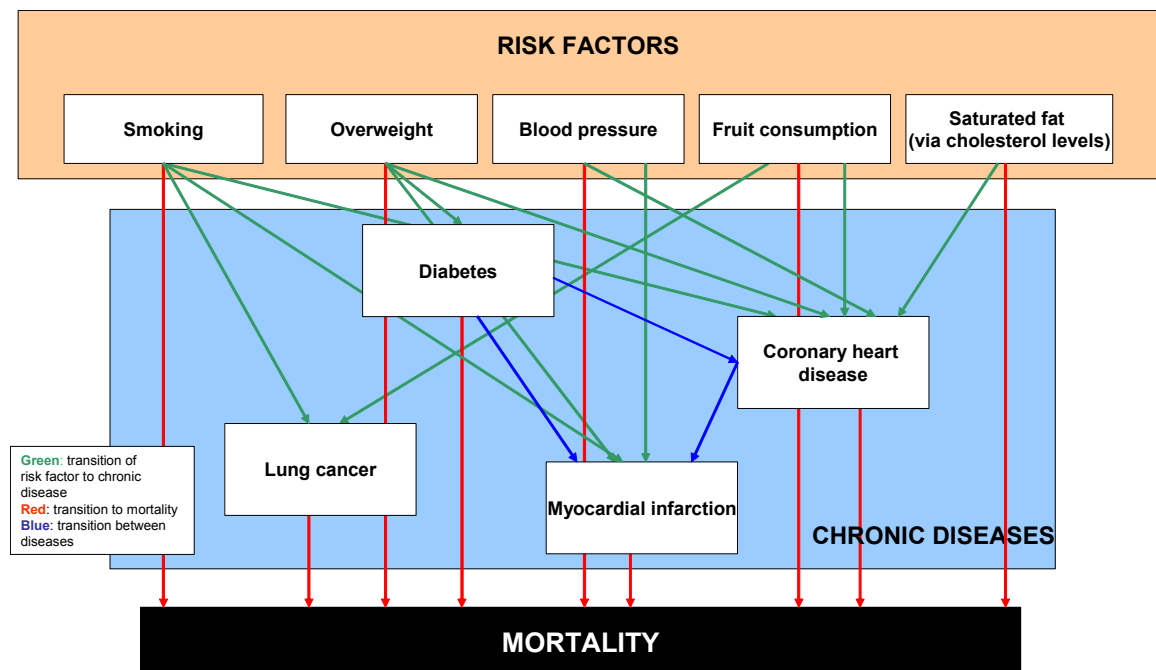
Figure 3: Simplified model structure of the CDM

Third, if a subject suffers from one or more specific diseases, the change to death is determined by the mortality risk of the specific disease (the excess mortality of the disease).
Moreover, the risk factors are assumed to be independent. The model allows that a change in nutrient or food group can only influence a disease, and does not affect other risk factors. It means that if a particular disease depends on two or more risk factors, the probabilities are added. Major adjustments to the CDM are needed to model the effect of a nutrient (risk factor) on a risk factor and on chronic diseases. Health effect calculations can be made with the current version of the CDM when a nutrient is only associated with a risk factor and not with any chronic disease. However, other pathways by which a nutrient affects a disease and a risk factor, are not possible.
Next, all risk factors and chronic diseases are discretely distributed. This allows the model to simulate whether a disease is present (yes) or not (no); different stages of a disease cannot be simulated unless

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they are explicitly modelled and associated with risk factors. Currently every disease is modelled at one stage only. Furthermore, the risk factor distribution is categorized into classes, which means that cut-off points are introduced. It should be noted that an effect of an intervention that is smaller than the range of the classes will have no effect on the final outcome. The following limitation is that the model does not allow for "lag times" between the change in risk factor and the incidence risks of the disease. This means that a subject with a high fruit consumption of several years has the same probability to develop a disease as a subject who changed his fruit consumption from low to high only a year ago. And finally, because individual life courses are independent, the model is not suited to describe diseases where interactions between subjects play a role, like infectious diseases.

Box 3: Important assumptions and limitations in the CDM which may influence health effect calculations for nutritional factors

- Probability to change from disease state depends on relative risk of certain risk factor class, incidence of disease and current intake of nutrient or food group;
- Independency between risk factors;
- Discrete distribution of risk factors and chronic diseases;
- No "lag-times" between risk factors and diseases.

3.2 Description of process of calculating health effects using the CDM

This paragraph describes the process of health effect calculations in the CDM. This process can be divided into two parts. The first part describes the input for nutritional factors, while the second part describes general data that needs to be included in the model.

3.2.1 Input for health effect calculations related to nutritional factors in the CDM

Step 1: Categorize the nutrient intake distributions data into prevalence distributions
Obviously, the nutritional input is essential for health effect calculations for nutritional factors. The distribution of the (nutritional) risk factors is described by the scenarios (discussed in Chapter 2). The CDM requires nutrient or food group intake distributions that are discretely distributed over classes of intake. The range of the classes of intake should be defined for nutrients not yet included in the model. For the nutritional factors already included in the model, the current cut-off points should be evaluated whether they are still applicable.
The prevalence of a certain class in the population should be specified for each sex and age-category. An example of input is shown in table 2.

Table 2: Distributions of saturated fat intake in the Netherlands: % per age and sex group, based on Food Consumption Survey 1997/1998 (Adapted from Our food, our health ([2])

| | Risk classes (energy%) | | | | | | | | | |
| | <10.0 | | 10.0-12.5 | | 12.5-15.0 | | 15.0-17.5 | | ≥17.5 | |
Age	M	F	M	F	M	F	M	F	M	F
20-30	13	9	27	20	28	37	22	23	11	11
30-40	6	8	20	16	33	32	28	25	13	20
…										
70+	6	7	19	13	29	27	26	28	21	26

As the model calculates the effect of food groups or nutrients on chronic diseases each consecutive year, it is possible to change the intake prevalence distributions in the reference scenario according to assumed time trends in the model. However, this brings about additional uncertainties to the outcome of the model.

Step 2: Determine strength of evidence for the associations of nutritional factors with chronic diseases
The associations of nutritional factors with chronic diseases are derived from extensive literature studies and meta-analyses. Only associations that can be considered at least possible are modelled in the CDM. These assessments are based on the WHO criteria for strength of evidence [7]. In "Our food, our health" the association of saturated fat with coronary heart disease was rated as convincing; the intake of fish was convincingly associated with coronary heart disease and stroke [2].
Because the CDM is modelled for the Dutch population, only associations that have been described in (Western) populations resembling the Dutch are selected.

The associations and risk estimates for nutritional factors that have been included in the model (fruit, vegetables, fish, saturated fat and trans fatty acids) require regular updates. The strength of evidence and the risk estimates may change when more data becomes available, as has been shown by a recent update for fruits and vegetables [8]. Nutrients that have not been included in the model require an extensive literature review to establish the strength of evidence and the value of the risk estimate.
It should be noted that if a risk factor is associated with a chronic disease which has not been included in the model, this effect cannot be modelled at present. The CDM requires major adjustments if a new chronic disease would be incorporated.

Step 3: Establish risk estimates for at least possible associations, specified for age and sex
The transitions of stage in the CDM will be quantified by risk estimates. Risk estimates can only be established if the strength of evidence is assessed as "convincing" or "probable" (see previous step). A meta-analysis presents a weighted average of the overall risk estimate and most often presents the most accurate association. Preferably, these data will be used. If meta-analyses are not available, then the risk estimate that most likely resembles the association for the Dutch population will be used. In the CDM the risk estimates should be specified for each sex and age category (see table 3).
The majority of risk estimates in the literature are based on adult study populations. Children have lower risks of developing chronic diseases than adults. Therefore, the risk estimates of developing a disease based on an adult population should be modified for young children. The fruit and vegetable risk factor classes for children <15y are considered to be 1. Furthermore, the elderly have more competing risk factors contributing to disease development than adults. Hence, the risk estimates of developing diseases based on an adult population should be adapted for the elderly as well. The WHO has proposed a correction factor to adapt risk estimates for age, when necessary. These correction factors have been described and used by Büchner et al, 2007 [3].

Table 3: Risk estimates of coronary heart disease according to the trans fatty acid intake (Adapted from Buchner et al, 2007 [3])

	Age			
	<15	**15-69**	**70-79**	**>80**
Coronary heart disease[1]	1	0.95	0.96	0.97

[1]: an increase of 2 en% of trans fatty acids increases the risk of developing coronary heart disease by 1.25

3.2.2   General input for health effect calculations in the CDM

The general input for the CDM consists of demographic data, distributions of the risks factors, the prevalence and incidence of disease status, the risk estimates for the associations between the risk factors and the diseases, between diseases mutually and between diseases and mortality. The input data for the model should be specified for sex and age categories. The model simulates the health effects for men and women separately and per 5-year age classes.

Step 4: Demographic data
The demographic composition (age and sex distribution) of the (sub)population is included in the model. Depending on the scenarios either a cohort or a (sub)population is modelled. If a (sub)population is modelled then expected changes in demography due to newborns, immigration and emigration need to be described. Mortality is simulated by the model. Age and sex distributions, fertility and immigration and emigration estimates are available from Statistics Netherlands. These data are already included in the CDM

Step 5: Baseline disease incidence, prevalence and mortality
The baseline prevalence and incidence of diseases are based on the records and reports of general practitioners, Statistics Netherlands and cancer registrations. Mortality is based on data from Statistics Netherlands.

Step 6: Current risk factor behaviour other than nutritional factors
The initial distribution of risk factors is specified based on the current prevalence within the Dutch (sub)population. The information is available from cohort studies or monitoring studies in the Netherlands. These risk factor behaviours are discretely distributed. Also the changes over time of risk factors need to be specified based on the reference and alternative scenario. For risk factors that are not directly incorporated in the scenario current trends can be extrapolated.

3.3 Health effect calculations in the CDM

Once all information is collected, it can be incorporated into the CDM. Subsequently the model can simulate each scenario and calculate the health effects in morbidity and mortality rates. Per scenario the prevalences and incidences of the chronic diseases are calculated per year for each of the years the model is run. The prediction of the model for the reference scenario are compared with the prediction of the (various) alternative scenarios. The difference in incidence and prevalence of chronic diseases between the reference and alternative scenarios is the actual health effect that can be attributed to the interventions described in the alternative scenarios.
Based on incidence and prevalence rates, integrative measures such as disability adjusted life years *(see box 4)*, disease-free life expectancy and the costs of both direct and indirect related diseases can be calculated.

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The impact of different health effects can be compared using a single measure. Among these measures are disability adjusted life years (DALYs) or quality adjusted life years (QALY). A DALY is a measure to quantify the impact of premature death and disability on a population. In fact, a QALY can be seen as the inverse of a DALY, which quantifies the impact of healthy years lived. Figure 4 shows a graphical interpretation of the DALY and the QALY
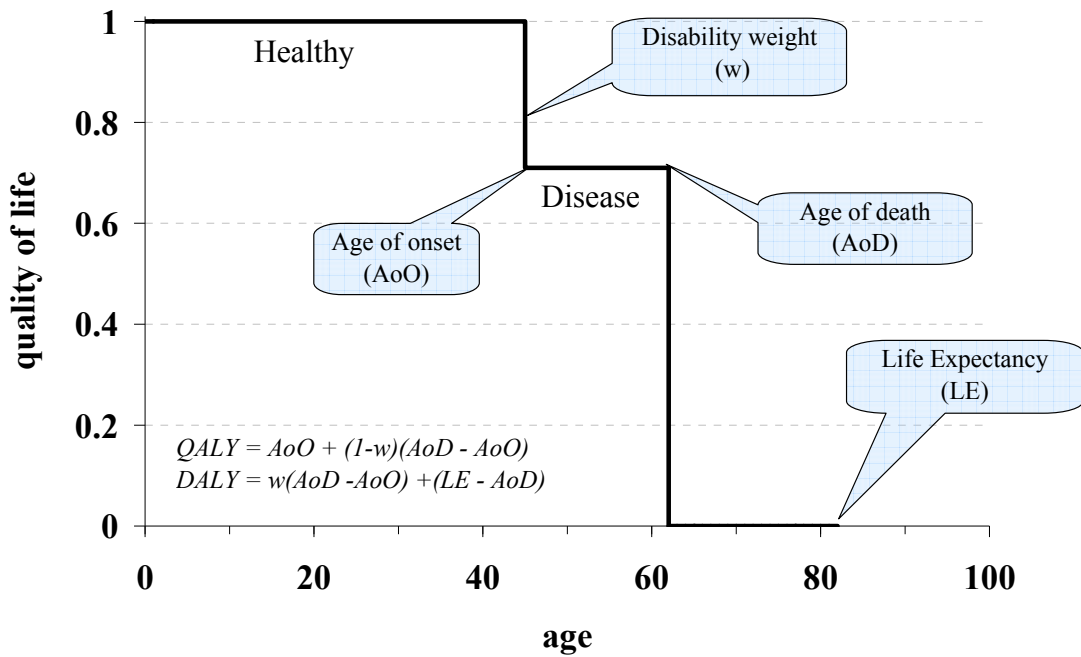

$QALY = AoO + (1-w)(AoD - AoO)$
$DALY = w(AoD - AoO) + (LE - AoD)$

Figure 4: Graphical interpretation of the DALY and the QALY

3.4   Conclusion

The CDM is a model that can be used to simulate the health effects of certain risk factors, including nutritional factors, for the Dutch (sub)population, given the current assumptions and limitations. Due to the assumptions and limitations there is uncertainty in the prediction of the effect.
For health effect calculations, much data is needed before the calculations can take place. Up-to-date consumption data and risk estimates between nutritional factors and diseases are needed to calculate accurate health effects for nutritional factors. Additional information, such as recent demographic data, disease prevalence figures and risk factor distributions are also required.

Currently, fruit, vegetable, fish, saturated fat and trans fatty acids are incorporated in the model. Other nutrients, such as salt, added sugar and fibre have not been incorporated yet. Before a new nutritional factor can be incorporated, all model conditions, as described in this short report, should be considered carefully. However, this will be challenging for nutrients or food groups that have a strong correlation with nutritional factors or risk factors that are already incorporated in the model, such as fibre or added sugar.

4 Recommendations

Health effect calculations for nutritional factors require a certain amount of data and are based on several assumptions. Care should be taken to clearly point out the assumptions made in the calculations in order to provide the reader a clear notion of the uncertainty in the final prediction. It is not known beforehand whether or not a nutrient or food group will meet the conditions for incorporation in CDM in order to perform health effect calculations. This will become evident during the process. Nevertheless, given the conditions used in the CDM and its uncertainties, nutritional health effect calculations are a useful tool to underpin nutritional policy recommendations in the Netherlands.

4.1 Recommendations

In principle, the CDM can be expanded for new nutritional factors, such as sodium and unsaturated fat, but it is difficult to establish in advance whether these factors will fulfil all conditions for inclusion in the CDM. It is already anticipated that it will be a challenge to calculate the health effects for *added* sugar, because the level of *added* sugar in food products is currently not available in the Dutch food composition table and because of its correlation with energy intake (body weight), and for fibre because of its correlation with fruit and vegetables in the model. Accurate health effect calculations for nutritional factors require up-to-date food consumption and food composition data. Moreover, it is important to regularly update the input for the nutritional factors already included in the CDM, as intake data and/or risk estimates may change during the course of time, which means the current model may no longer hold.

In this short report, the nutritional scenarios and health effect calculations of individual nutrients and food groups are discussed. At present, it is not possible to calculate the health effects of dietary patterns. First, there is no unambiguous methodology for the definition of dietary patterns that can be used to formulate nutritional scenarios. More importantly, the assumption of independency between risk factors in the CDM violates with the combined effects of nutrients in dietary patterns. A new CDM needs to be developed where clusters of nutritional factors can be studied. This requires a more in-dept study on the methodology to categorize dietary patterns and its relation to chronic diseases. Furthermore, more research will be needed to cluster the nutritional factors as risk factors in the CDM.

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Appendix

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Reformulation of commonly eaten foods to achieve population nutrient goals

Rationale
Population nutrient goals consistent with the prevention of diet-related chronic diseases include reductions in intake of saturated fat, *trans* fatty acids, sugar and salt

Objective
Assess to what level reformulated foods might bring such nutrients in line with population nutrient goals

Reformulation can be defined as reformulating existing foods to remove or reduce certain food components while maintaining characteristics such as flavour, texture and shelf life.

Example of general approach**

	Daily nutrient intake based on representative daily diet	Daily nutrient intake based on reformulated foods intake	WHO recommendations
Total energy intake (kcal/d)	2119	1783	2000-2500
Saturated fatty acids (en%)	15.7	8.7	<10
Trans fatty acids (en%)	1.2	0.1	<1.0
Free sugars (en%)	13.2	5.8	<10
Fibre (g/d)	18	25	>25
Sodium (mg/d)	2858	2335	<2400

** Leon Jansen. Scherpere criteria voor meer productgroepen; achtergronden bij de nieuwe criteria voor Ik Kies Bewust-logo. Voeding Nu 2006 4: 21-23

General approach to assess the potential impact of reformulated foods on nutrient intakes*
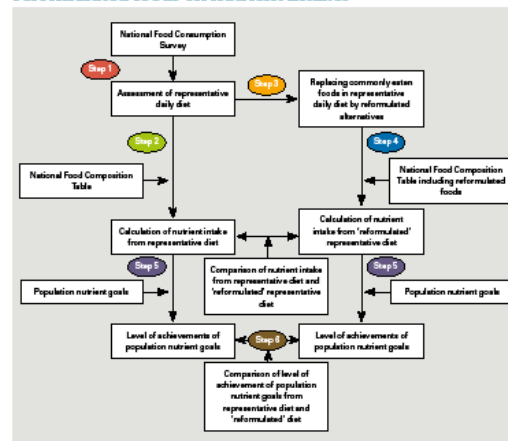
* Joop van Raaij, Marieke Hendriksen, Hans Verhagen. Potential for improvement of population diet though reformulation of commonly eaten foods. Public Health Nutrition 2009 Mar; 12 (3):325-30

Proposed modified approach to assess the potential impact of reformulated foods on nutrient intakes
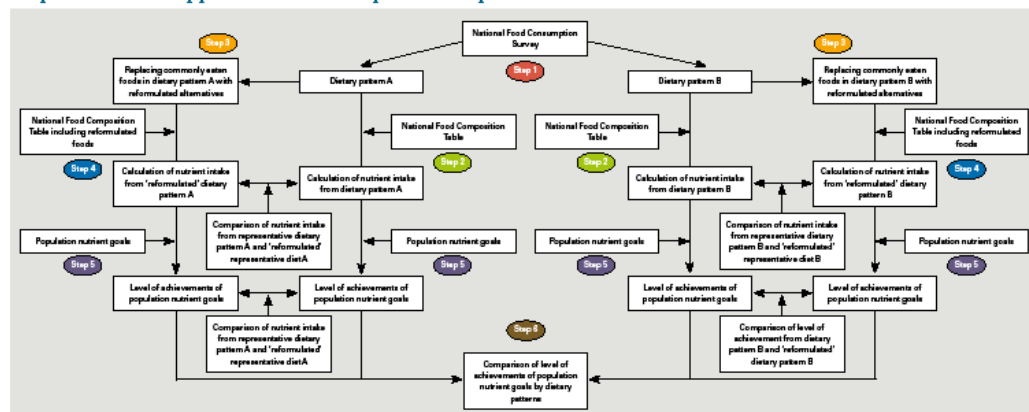
Conclusion
- Reformulation is quite rightly considered a key option to achieve population nutrient goals
- It is plausible that the level to which reformulation might help to achieve population nutrient goals depends on the dietary patterns

Challenges
- Identification of dietary patterns within the population(group)
- Assessing the role of commonly eaten foods appropriate for reformulation
- Assessing to what level food reformulation scenarios for each dietary pattern might bring nutrient intake closer to population nutrient goals
- Examine to what level food reformulation within dietary patterns may result in health improvements.

27

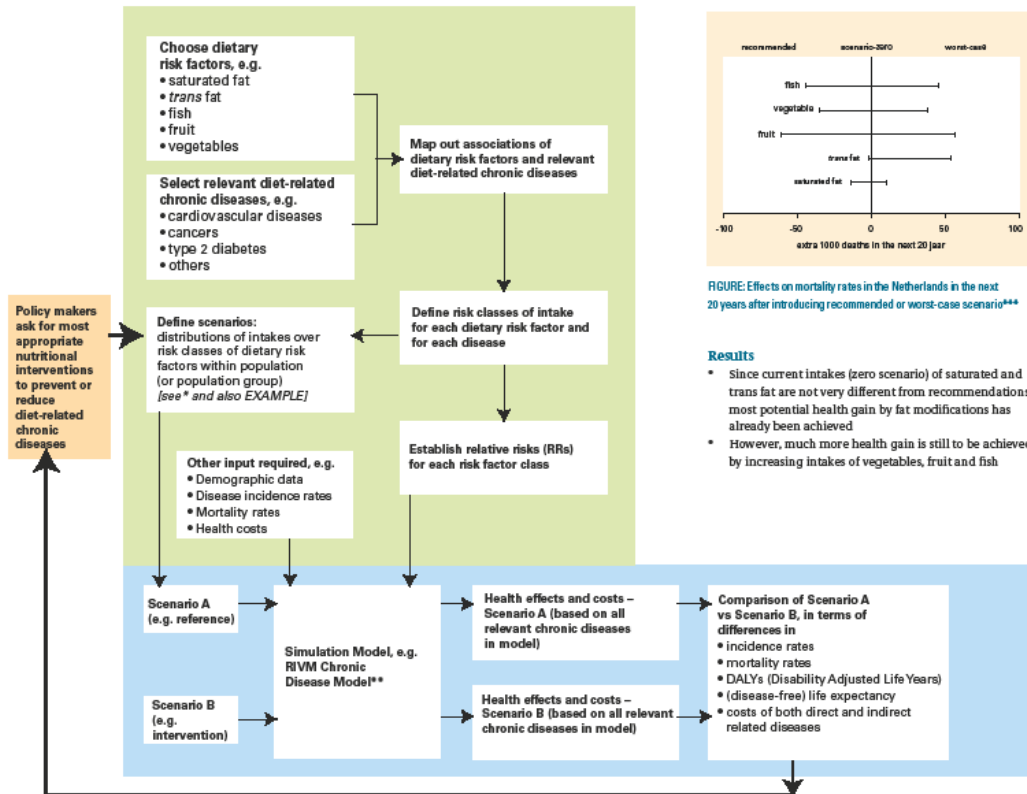CTM van Rossum, FL Büchner, J Hoekstra, SW van den Berg, H. Verhage, JMA van Raaij

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Much health gain still to be achieved by increasing consumption of vegetables, fruit and fish

Rationale & Objective

* Policy makers need to know the health effects of current food intakes and the health effects of changes in food intake to prevent or reduce diet-related chronic diseases
* However, health effects of such nutritional interventions only become visible in the long term
* Rapid quantification of expected health effects might be obtained by simulation models, such as the RIVM Chronic Disease Model

Methods

Policy makers ask for most appropriate nutritional interventions to prevent or reduce diet-related chronic diseases

Choose dietary risk factors, e.g.
* saturated fat
* *trans* fat
* fish
* fruit
* vegetables

Select relevant diet-related chronic diseases, e.g.
* cardiovascular diseases
* cancers
* type 2 diabetes
* others

Map out associations of dietary risk factors and relevant diet-related chronic diseases

Define scenarios: distributions of intakes over risk classes of dietary risk factors within population (or population group) [see* and also EXAMPLE]

Define risk classes of intake for each dietary risk factor and for each disease

Other input required, e.g.
* Demographic data
* Disease incidence rates
* Mortality rates
* Health costs

Establish relative risks (RRs) for each risk factor class

Scenario A (e.g. reference)

Scenario B (e.g. intervention)

Simulation Model, e.g. RIVM Chronic Disease Model**

Health effects and costs – Scenario A (based on all relevant chronic diseases in model)

Health effects and costs – Scenario B (based on all relevant chronic diseases in model)

Comparison of Scenario A vs Scenario B, in terms of differences in
* incidence rates
* mortality rates
* DALYs (Disability Adjusted Life Years)
* (disease-free) life expectancy
* costs of both direct and indirect related diseases

Example

Scenarios used

* zero scenario – all subjects in their current intake class
* recommended scenario – all subjects in recommended intake class
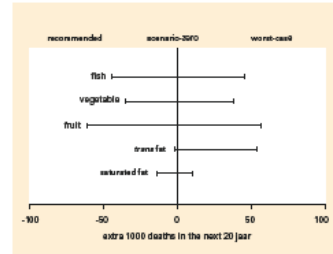* worst-case scenario – all subjects in most unfavourable intake class

FIGURE: Effects on mortality rates in the Netherlands in the next 20 years after introducing recommended or worst-case scenario***

Results

* Since current intakes (zero scenario) of saturated and trans fat are not very different from recommendations, most potential health gain by fat modifications has already been achieved
* However, much more health gain is still to be achieved by increasing intakes of vegetables, fruit and fish

Conclusion

Simulation models are very helpful to provide quick answers on quantification of long-term potential health gain by nutritional interventions

Challenges

* More dietary factors should be incorporated in simulation models (e.g. salt, fibre, sugar)
* Scenario development procedures should be further explored (e.g. on food enrichment and food reformulation)
* Crucial challenge is to include dietary patterns into scenarios and into the simulation models, in order to compare health effects of complete dietary patterns

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*** FL Büchner, J Hoekstra, SW van den Berg, FW Ieleman, CTM van Rossum. Kwantificeren van de gezondheidseffecten van voeding. RIVM Report 350080001/2007

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28