

Development and evaluation of the Dutch Healthy Diet index 2015

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Abstract

Objective: To update the Dutch Healthy Diet index, a measure of diet quality, to reflect adherence to the Dutch dietary guidelines 2015 and to evaluate against participants' characteristics and nutrient intakes with the score based on 24 h recall (24 hR) data and FFQ data.

Design: The Dutch Healthy Diet index 2015 (DHD15-index) consists of fifteen components representing the fifteen food-based Dutch dietary guidelines of 2015. Per component the score ranges between 0 and 10, resulting in a total score between 0 (no adherence) and 150 (complete adherence).

Setting: Wageningen area, the Netherlands, 2011–2013.

Subjects: Data of 885 men and women, aged 20–70 years, participating in the longitudinal NQplus study, who filled out two 24 hR and one FFQ, were used.

Results: Mean (SD) score of the DHD15-index was 68.7 (16.1) for men and 79.4 (16.0) for women. Significant inverse trends were found between the DHD15-index and BMI, smoking, and intakes of energy, total fat and saturated fat. Positive trends were seen across sex-specific quintiles of the DHD15-index score with energy-adjusted micronutrient intakes. Mean DHD15-index score of the FFQ data was 15.5 points higher compared with 24 hR data, with a correlation coefficient of 0.56 between the scores. Observed trends of the DHD15-index based on FFQ with participant characteristics, macronutrient and energy-adjusted micronutrient intakes were similar to those with the DHD15-index based on 24 hR.

Conclusions: The DHD15-index score assesses adherence to the Dutch dietary guidelines 2015 and indicates diet quality. The DHD15-index score can be based on 24 hR data and on FFQ data.

Keywords
Dietary guidelines
Dietary patterns
The Netherlands
Dutch Healthy Diet
Index

The Dutch Healthy Diet index (DHD-index) is a measure of diet quality as it assesses adherence to the Dutch dietary guidelines published in 2006 by the Health Council of the Netherlands⁽¹⁾. The DHD-index has been used in a variety of applications, including intervention monitoring and epidemiological research^(2–4). A higher DHD-index score has been associated with more nutrient-dense diets⁽⁵⁾ and lower risk of mortality⁽⁶⁾, but not with CVD⁽⁷⁾ or quality-adjusted life years⁽⁸⁾.

In 2015, the Health Council of the Netherlands published an updated version of the Dutch dietary guidelines, based upon the latest scientific evidence⁽⁹⁾. Where the Dutch dietary guidelines of 2006 consisted of food-based and nutrient-based guidelines (e.g. vegetables, fruit, fibre and saturated fat), the 2015 guidelines are completely food-based (e.g. wholegrain products, red and processed meat, and fats and oils)⁽¹⁰⁾. Due to this revision of the Dutch dietary guidelines the DHD-index needed to be

updated. Therefore, we developed the Dutch Healthy Diet index 2015 (DHD15-index) as a tool to measure adherence to the Dutch dietary guidelines of 2015. In the present paper we describe the development of this new score and examine associations of the DHD15-index with participants' characteristics and energy, macro- and micronutrient intakes based on 24 h recall (24 hR) data. Additionally, the DHD15-index score derived from FFQ data is compared with the DHD15-index score derived from the 24 hR data to assess comparability of the index when based on different dietary assessment instruments.

Methods

Study design and population

The Nutrition Questionnaires plus (NQplus) study is a longitudinal study on diet and health in the general Dutch

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population. The NQplus study has been described elsewhere⁽¹¹⁾. Briefly, between May 2011 and December 2013, a total of 2048 men and women were included, all randomly selected inhabitants of the cities of Wageningen, Renkum, Ede, Arnhem and Veenendaal, which are located in the central part of the Netherlands. Inclusion criteria were age 20–70 years and being able to speak and write Dutch.

Baseline measurements consisted of dietary assessment (including supplement use) with multiple 24 hR and FFQ, anthropometric measurements (including height and body weight measurements), blood sampling via a venepuncture, a 24 h urine collection and general questionnaires (including age, sex, highest achieved education level (low: primary school, vocational or lower general secondary education; moderate: higher secondary education or intermediate vocational training; high: higher vocational education or university) and smoking (yes/no)). Participants with data of least two telephone-administered 24 hR and a baseline FFQ (*n* 885) were included for the current analysis.

Dietary assessment

24 h recalls

The 24 hR was administered by means of a telephone interview by trained dietitians of the Division of Human Nutrition of Wageningen University. The dietitian made an unannounced phone call to the participant and asked about the foods and drinks consumed the previous day according to a standardized protocol based on the five-step multiple-pass method⁽¹²⁾. Recalls were at least one month apart and the first two completed 24 hR were used for the present analyses. Energy and nutrient intakes were estimated using the 2011 Dutch Food Composition Table⁽¹³⁾.

FFQ

A 180-item semi-quantitative FFQ was used to assess usual dietary intake and was previously evaluated for energy intake, macronutrients, dietary fibre and selected vitamins^(14,15). Answer categories for frequency questions ranged from 'not in this month' to '6–7 d/week', and portion sizes were estimated using natural portions (bread shapes) and commonly used household measures (e.g. spoon and cup). Average daily nutrient intakes were calculated by multiplying frequency of consumption by portion size and nutrient content per gram using the 2011 Dutch Food Composition Table⁽¹³⁾. We estimated the same micronutrient intakes as for the 24 hR, except for Fe and Mg as the FFQ was not developed to estimate these intakes. The FFQ was administered online using the open-source survey tool Limesurvey.

Development of the DHD15-index

In Table 1 an overview of the components and their cut-off and threshold values can be found. For all fifteen components a maximum of 10 points could be allotted,

resulting in a total score ranging from 0 to 150 points. The components vegetables, fruit, legumes, nuts, fish and tea are adequacy components, and the components red meat, processed meat, sweetened beverages and fruit juices, sodium and alcohol are moderation components. The component dairy is an optimum component with an optimal range of intakes, whereas the fats and oils component is defined as a ratio component to reflect replacement of intake of less desired foods with healthier options in that food group. The coffee component is defined as a qualitative component based on type of coffee. The wholegrain products component is scored based on two sub-components as there are two guidelines for grain products: an adequacy component for wholegrain consumption and a ratio component to reflect replacement of refined grain products by wholegrain products.

Cut-off values represent the minimum (for adequacy components) and maximum (for moderation components) required amount of consumption awarded with 10 points. The threshold values represent the lowest level of intake awarded with 0 points (for moderation components only). For adequacy components, no intake is awarded with 0 points. Intakes between the cut-off and threshold value are scored proportionally. In the text below, for each guideline/component the included food groups, explanation of cut-off and threshold values and adaptations for estimation with an FFQ are discussed, if applicable. This is followed by an explanation of the scoring per type of component.

Vegetables

The first component is based on the recommendation to consume at least 200 g of vegetables daily. Foods for this component are vegetables including frozen and canned vegetables, peas and salads, but not legumes or potatoes. The cut-off was set at 200 g as quantified in the guideline.

Fruit

The second component is based on the recommendation to consume at least 200 g of fruit daily. Fresh fruit intake was included for this component, but not dried fruit as this has a relatively high energy and sugar content compared with fresh fruit⁽¹⁶⁾. In contrast to the previous DHD-index, fruit juices are no longer included. The cut-off was set at 200 g as quantified in the guideline.

Wholegrain products

The third component was based on two guidelines regarding wholegrain foods and therefore scored with two sub-components. The first sub-component was based on the recommendation to consume at least 90 g of wholegrain products daily. The cut-off was set at 90 g as quantified in the guideline. The second sub-component is based on the recommendation to replace refined cereal products by wholegrain products and is scored as a ratio component obtained by dividing intake of wholegrain

Table 1 Components and Dutch dietary guidelines of the Dutch Healthy Diet index 2015 (DHD15-index) and their threshold (minimum score) and cut-off (maximum score) values

Component	Component type*	Dutch dietary guidelines 2015	Minimum score (= 0 points)	Maximum score (= 10 points)
1. Vegetables	A	Eat at least 200 g of vegetables daily	0 g/d	≥200 g/d
2. Fruit	A	Eat at least 200 g of fruit daily	0 g/d	≥200 g/d
3. Wholegrain products†	A	a. Eat at least 90 g of wholegrain products daily	0 g/d	≥90 g/d
	R	b. Replace refined cereal products by wholegrain products	No consumption of wholegrain products OR Ratio of whole grains to refined grains ≤ 0.7	No consumption of refined products OR Ratio of whole grains to refined grains ≥ 11
4. Legumes	A	Eat legumes weekly	0 g/d	≥10 g/d
5. Nuts	A	Eat at least 15 g of unsalted nuts daily	0 g/d	≥15 g/d
6. Dairy‡	O	Eat a few portions of dairy produce daily, including milk or yoghurt	0 g/d OR ≥750 g/d	300–450 g/d
7. Fish§	A	Eat one serving of fish weekly, preferably oily fish	0 g/d	≥15 g/d
8. Tea	A	Drink three cups of black or green tea daily	0 g/d	≥450 g/d
9. Fats and oils	R	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats and vegetable oils	No consumption of soft margarines, liquid cooking fats and vegetable oils OR Ratio of liquid cooking fats to solid cooking fats ≤ 0.6	No consumption of butter, hard margarines and cooking fats OR Ratio of liquid cooking fats to solid cooking fats ≥ 13
			Any consumption of unfiltered coffee	Consumption of only filtered coffee OR No coffee consumption
10. Coffee	Q	Replace unfiltered coffee by filtered coffee	Any consumption of unfiltered coffee	Consumption of only filtered coffee OR No coffee consumption
11. Red meat	M	Limit consumption of red meat	≥100 g/d	≤45 g/d
12. Processed meat	M	Limit consumption of processed meat	≥50 g/d	0 g/d
13. Sweetened beverages and fruit juices	M	Limit consumption of sweetened beverages and fruit juices	≥250 g/d	0 g/d
14. Alcohol	M	If alcohol is consumed at all, intake should be limited to one Dutch unit (10 g ethanol) daily	Women: ≥20 g ethanol/d Men: ≥30 g ethanol/d	Women: ≤10 g ethanol/d Men: ≤10 g ethanol/d
15. Salt	M	Limit consumption of table salt to 6 g daily	≥3.8 g Na/d	≤1.9 g Na/d

*Type of component: A, adequacy component; M, moderation component; O, optimum component; Q, qualitative component; R, ratio component.

†This component comprises two sub-components (a and b). Each sub-component has a maximum score of 5 points.

‡Maximum of 40 g cheese can be included.

§Maximum of 4 g lean fish can be included.

products by intake of refined cereal products. There was no quantitative recommendation, nor information about the level of intake of refined cereal products associated with adverse health effects upon which to base the cut-off or threshold value. Therefore, we used the 15th percentile of the intake distribution of the Dutch reference population based on two-day averages (Dutch National Food Consumption Survey 2007–2010⁽¹⁷⁾) as (arbitrary) cut-off value. The threshold value was equal to the 85th percentile as we also did for the DHD-index. The maximum score for both sub-components is 5 points. By adding the scores of the two sub-components, the score for wholegrain products is obtained. Included food groups were cereal products used as staple component of the diet (e.g. bread products, bread replacement products, muesli, pasta and rice), but no snacks made of cereal products such as biscuits. Foods were categorized as wholegrain product if they contained at least 25% wholegrain flour; otherwise they were categorized as refined grain product.

Legumes

The fourth component is based on the recommendation to consume legumes weekly. As intakes in the score are expressed per day, one portion of legumes (60 g⁽¹⁶⁾) was divided by 7 and rounded to 10 g/d to obtain the cut-off value. Included food groups are pulses, lentils, beans and chickpeas, but not peas and peanuts⁽¹⁸⁾.

Nuts

The fifth component assesses unsalted nut consumption and is based on the recommendation to consume at least 15 g of unsalted nuts daily. The cut-off was set at 15 g as quantified in the guideline. As stated in the guideline, only unsalted nuts were included in this component. However, the FFQ did not distinguish between unsalted and salted nuts. Therefore, total nut consumption was included for this component for the FFQ-based DHD15-index score.

Dairy

The sixth component, dairy, is based on the recommendation to consume a few portions of dairy produce daily, including milk and yoghurt. Included food groups are milk, milk products, yoghurt, cheese, cream, custard and porridge prepared with dairy. This component was interpreted as an optimum component. Two to three portions daily, with a portion size of 150 g per portion (Netherlands Nutrition Centre), resulted in the optimum range of intake (300–450 g/d) and a score of 10 points. An intake of more than two times the average recommended amount was set as threshold value. Cheese intake was also included in total dairy intake, but limited to a maximum of 40 g (as set by the Netherlands Nutrition Centre) to account for differences in portion sizes between milk and cheese. Furthermore, a limitation in cheese intake ensures that the maximum score for dairy can only be obtained when milk

or yoghurt products are consumed, as specified in the recommendation of the Health Council of the Netherlands.

Fish

The seventh component, fish, is based on the recommendation to consume one portion of fish weekly, preferably oily fish. One portion of fish (100 g⁽¹⁶⁾) was divided by 7 and rounded to obtain the cut-off value of 15 g/d for fish. As the recommendation favours intake of oily fish, a maximum for lean fish of 4 g/d was included. This maximum was derived from the ratio of three times oily fish to one times lean fish (per month) as set by the Netherlands Nutrition Centre.

Tea

The eighth component is based on the recommendation to consume three cups of black or green tea daily. Portion sizes set by the Netherlands Nutrition Centre were used to arrive at a cut-off value of 450 g/d (equal to 450 ml/d). As the FFQ does not distinguish between types of tea, total tea consumption was used for this component for the FFQ-based DHD15-index score.

Fats and oils

The ninth component is a ratio component based on the recommendation for fats and oils. The ratio is obtained by dividing intake of soft margarines, liquid cooking fats and vegetable oils by intake of butter, hard margarines and cooking fats. Similar to the ratio sub-component for whole grains, cut-off and threshold values were derived from the 15th percentile and 85th percentile of the intake distribution of the Dutch reference population⁽¹⁷⁾.

Coffee

The tenth component, coffee, is a quality component, based on type of coffee (filtered or unfiltered). Scoring for this component is, contrary to the other components, dichotomous. No consumption of unfiltered coffee or no consumption of coffee at all was set as criterion for the maximum score of 10 points, whereas any consumption of unfiltered coffee is awarded with 0 points. Because both the 24 hR and FFQ do not distinguish between types of coffee consumed, the component score for coffee could not be assessed in the present study.

Red meat

The eleventh component, red meat, is based on the recommendation to limit red meat consumption. Included food products for this component are beef, pork, duck, pheasant, offal and game products. The Netherlands Nutrition Centre advises to consume less than 300 g of red meat weekly (about 45 g/d). The cut-off value was thus set at an intake of 45 g/d. The Health Council of the Netherlands indicated that with a consumption of 100 g/d or more negative health effects were observed⁽¹⁹⁾. Consequently, the threshold value was set at an intake of 100 g/d.

Processed meat

The twelfth component, processed meat, is based on the recommendation to limit consumption of processed meat. Both processed red meat and processed white meat are food groups included in this component. As the Health Council of the Netherlands indicated that especially consumption of processed meat should be limited, the cut-off value was set at no consumption. The Health Council of the Netherlands indicated that negative health effects of processed meat are observed at intakes of 50 g/d or more⁽¹⁹⁾, and therefore this was set as threshold value.

Sweetened beverages and fruit juices

The thirteenth component was based on the recommendation to limit consumption of sweetened beverages and fruit juices. For this component, sugar-sweetened soft drinks, sugar-sweetened dairy drinks and fruit juices were included. No consumption was set as cut-off value and a consumption of 250 g/d as threshold value, as consumption of more than 250 g/d was found to be associated with weight gain⁽²⁰⁾.

Alcohol

The fourteenth component, alcohol, is based on the recommendation to limit consumption to one Dutch unit (10 g ethanol/d), if alcohol is consumed at all. This 10 g ethanol/d was set as cut-off value. Negative health effects occur at different intakes for men and women⁽²¹⁾, therefore the threshold value was differentiated by sex. For women an intake of 20 g ethanol/d was associated with negative health effects, and thus this intake was used as threshold value, whereas for men this was set at 30 g ethanol/d.

Salt

The last component, salt, is based on the recommendation to consume less than 6 g of table salt daily. This corresponds to a recommended consumption of 2.4 g of Na daily or less. For this component the Na content of all consumed foods was summed to obtain Na intake per day. Ideally, salt consumption is assessed with Na content based on a 24 h urine collection. However, this was not available for the Dutch reference population. Therefore, the threshold value is based on the intake distribution of the Dutch reference population assessed with two 24 hR. With Na intakes based on 24 hR and especially FFQ, salt added during cooking and at the dinner table is not taken into account. The contribution of these sources is assumed to be on average 20% of total Na intake in the Netherlands⁽²²⁾. In most studies there are no data available on the amount of salt added during cooking and at the dinner table. Therefore we adjusted the cut-off value representing the recommended maximum Na intake by 20%, to compensate for this.

Scoring

For the adequacy components vegetables, fruit, nuts, legumes, nuts, fish and tea, the minimum score was given when there was no consumption of this component.

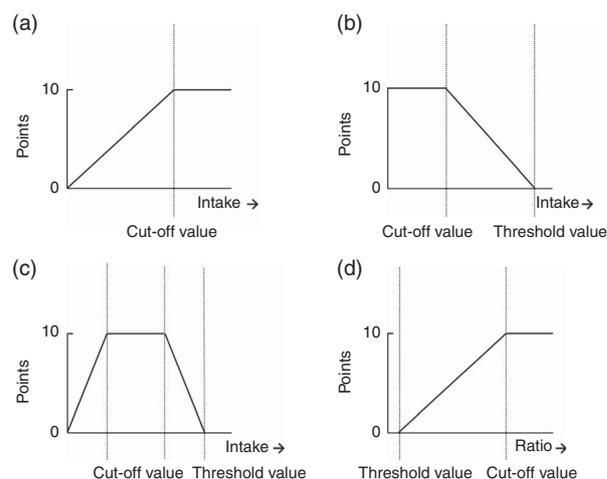


Fig. 1 Graphic presentation of scoring for the DHD15-index for the different type of components: (a) adequacy component; (b) moderation component; (c) optimum component; (d) ratio component

Intake equal to the cut-off value or higher was given the maximum score of 10 points. The score for intake between zero and the cut-off value was calculated by dividing the reported intake by the cut-off value and subsequently multiplying the obtained ratio by 10 (Fig. 1(a)). For the moderation components red meat, processed meat, sweetened beverages and fruit juices, sodium and alcohol, 0 points were assigned if intake was above the threshold value. 10 points were assigned if intake was equal to or lower than the cut-off value. The score for intake between the threshold and cut-off values was calculated by dividing the difference between the intake and the cut-off value by the difference between the threshold value and the cut-off value. This ratio was subsequently multiplied by 10. The obtained score was subtracted from 10 to obtain the component score, as the score for moderation components has to decrease when intake increases (Fig. 1(b)). The maximum score for the optimum component dairy was assigned if intake was within the given range. No consumption was scored with the minimum score of 0 points. Intake lower than the cut-off value was scored by dividing the reported intake by the lower cut-off value of the range and subsequently multiplying the obtained ratio by 10. Intake between the higher cut-off value of the range and the threshold value was scored by dividing the difference between the intake and the cut-off value by the difference between the threshold value and the cut-off value. This ratio was subsequently multiplied by 10. The obtained score was subtracted from 10 to ensure that the score decreases when intake increases. For intake above the threshold value the minimum score of 0 points was given (Fig. 1(c)). Cut-off values and threshold values for the ratio components were set for the calculated ratios, instead of intakes. The maximum score of 10 points was assigned if the ratio was higher than the cut-off value. The minimum score of 0 points was assigned if the ratio

was lower than the threshold value. The score for intake between the cut-off and threshold values was calculated by dividing the difference between the ratio and the threshold value by the difference between the cut-off and threshold value (Fig. 1(d)).

Statistical analysis

All food, energy and nutrient intakes assessed by 24 hR were averaged over two days before being used to score individual dietary intakes. DHD15-index scores reported in the present paper are based on 24 hR unless stated otherwise. Means across sex-specific quintiles of the DHD15-index score were tested using *P* for trend calculated with general linear models. Macro- and micronutrient intakes are reported with and without energy adjustment. Adjusted macronutrient intakes are presented as energy percentage (E%) and adjusted micronutrient intakes are presented as mean intakes per 4.2 MJ.

Concordance of ranking of participants with the DHD15-index scores based on 24 hR data and FFQ data was studied by analysing correlations between the scores and cross-classification of quintiles. Partial correlation coefficients were calculated for the DHD15-index score and its components based on the 24 hR data and the FFQ data, adjusting for energy intake assessed by the 24 hR. Pearson correlations were used for normally distributed variables and Spearman correlations for skewed variables. The 95% confidence intervals were calculated using Fisher's *Z*-transformation. The Wilcoxon signed-rank test was used to test differences between medians. Cross-classification and Kendall's τ_b coefficient were used to assess agreement of participants' ranking for the DHD15-index score based on 24 hR data and on FFQ data. All statistical analyses were performed using the statistical software package SAS version 9.3 and a *P* value of <0.05 was considered statistically significant.

Results

Mean age of the population was 54.0 (SD 11.7) years and mean BMI was 25.9 (SD 4.0) kg/m². Fifty-three per cent of the population were men. Men were significantly older (mean 56.4 (SD 10.8) years) than women (mean 51.4 (SD 12.1) years) and their BMI was significantly higher (mean 26.4 (SD 3.5) kg/m²) than that of the women (mean 25.4 (SD 4.5) kg/m²). More than 60% of the population completed a level of higher education and less than 10% of the population was current smoker; this did not differ between men and women.

The mean DHD15-index score for the total population based on 24 hR data was 73.7 (SD 16.9) points (Table 2). The total DHD15-index score was significantly higher for women than for men (mean difference of 10.7 points). The total DHD15-index score was normally distributed and ranged from 24.3 to 126.2 points. The highest mean component score was that for the component red meat followed by alcohol, whereas the lowest mean component score was observed for the component legumes followed by fish. Women had significantly higher (i.e. better) scores for the components vegetables, fruit, nuts, tea, red meat, processed meat, sweetened beverages and juices, alcohol and salt. Men scored significantly higher on the component wholegrain products. The DHD15-index score was positively correlated with the DHD-index based on the dietary guidelines of 2006 ($\rho = 0.62$; $P < 0.001$).

BMI and smoking were inversely associated with the DHD15-index (Table 3). Age and supplement use were positively associated with the DHD15-index score, whereas education was not associated with the index score. Participants with a higher DHD15-index score had a lower energy intake. Of the macronutrients, animal protein, added sugar, total fat and saturated fat were inversely

Table 2 Mean scores (and standard deviations) of the Dutch Healthy Diet index 2015 (DHD15-index) and its components in 885 Dutch men and women aged 20–75 years*

	Total		Men		Women		<i>P</i> value between sexes†
	Mean	SD	Mean	SD	Mean	SD	
DHD15-index‡	73.7	16.9	68.7	16.1	79.4	16.0	<0.001
Vegetables	6.2	3.2	5.9	3.2	6.6	3.1	0.001
Fruit	6.2	3.7	5.8	3.8	6.7	3.5	<0.001
Wholegrain products	5.7	2.7	6.0	2.5	5.5	2.8	0.006
Legumes	0.8	2.6	0.6	2.4	0.9	2.9	0.055
Nuts	2.6	3.9	2.4	3.9	2.8	3.9	0.023
Dairy	6.0	3.2	5.9	3.2	6.2	3.3	0.189
Fish	2.2	3.8	2.4	4.0	2.0	3.6	0.447
Tea	5.8	4.0	4.7	4.0	7.1	3.7	<0.001
Fats and oils	6.2	4.5	6.2	4.5	6.1	4.5	0.881
Red meat	8.6	3.0	8.2	3.3	9.0	2.6	<0.001
Processed meat	4.3	4.0	3.4	3.8	5.3	4.1	<0.001
Sweetened beverages and fruit juices	5.8	4.0	5.4	4.1	6.2	3.7	0.007
Alcohol	7.1	4.0	6.6	4.0	7.7	3.9	<0.001
Salt	6.2	3.4	5.3	3.4	7.3	2.9	<0.001

*Dietary intakes are based on average intake of two 24 h recalls.

†Independent *t* test comparing men and women for total DHD15-index score and Mann–Whitney *U* test comparing men and women for the individual component scores.

‡DHD15-index score ranging from 0 to 140 points.

Table 3 Distribution of characteristics, macronutrient and selected micronutrient intakes (means and standard deviations, or percentages) across sex-specific quintiles of the Dutch Healthy Diet index 2015 (DHD15-index) in 885 Dutch men and women aged 20–75 years*

	Sex-specific quintile of DHD15-index										P for trend
	Q1 (n 178)		Q2 (n 178)		Q3 (n 175)		Q4 (n 177)		Q5 (n 177)		
Mean DHD15-index score	51.8		64.0		72.7		80.8		96.0		
Mean DHD-index score†	40.0	8.9	44.3	9.2	49.1	9.1	53.3	9.6	58.8	8.7	<0.001
Age (years)	51.4	11.9	52.8	11.6	54.4	12.3	55.7	10.6	55.9	11.5	<0.001
BMI (kg/m ²)	26.7	4.4	26.3	4.4	25.9	3.9	25.8	3.8	25.0	3.2	<0.001
Supplements (%)	34.3		41.0		40.6		46.3		50.1		0.001
Education (%)‡											0.346
Low	7.3		5.1		9.8		5.1		3.4		
Middle	29.9		29.4		24.9		32.7		29.4		
High	63.7		65.5		65.3		62.2		67.2		
Smoking (%)	20.5		8.3		8.0		4.5		5.6		<0.001
Macronutrient intakes											
Energy (MJ/d)	9.3	2.4	8.9	2.1	8.8	2.2	8.7	2.1	8.6	1.9	<0.001
Protein (g/d)	84.8	25.6	81.9	21.7	81.3	21.1	83.6	22.4	81.1	17.0	0.281
Protein (E%)	15.6	3.1	15.8	2.7	16.0	3.1	16.7	3.0	16.5	2.9	<0.001
Vegetable protein (g/d)	32.4	11.1	32.9	10.3	33.2	10.8	33.7	10.6	37.1	11.2	<0.001
Animal protein (g/d)	52.2	21.5	49.0	18.3	48.0	17.1	50.0	19.6	44.1	14.3	<0.001
Carbohydrate (g/d)	236	70	225	66	224	62	225	63	222	58	0.077
Carbohydrate (E%)	43.3	7.3	43.2	7.1	43.8	7.0	44.6	6.8	44.4	6.5	0.035
Added sugar (g/d)	53.3	31.0	47.2	26.9	47.0	28.1	43.2	27.6	37.7	23.0	<0.001
Fibre (g/d)	19.8	6.6	21.4	6.9	22.5	6.7	24.4	6.9	27.0	7.7	<0.001
Total fat (g/d)	86.6	26.8	82.4	24.7	80.7	26.5	78.0	25.8	77.7	23.7	<0.001
Total fat (E%)	33.9	5.4	33.9	5.3	33.4	5.8	32.8	5.7	33.1	5.8	0.042
Saturated fat (g/d)	32.9	10.7	30.6	10.5	30.0	10.8	28.5	10.4	26.4	9.0	<0.001
Saturated fat (E%)	13.1	3.0	12.7	3.0	12.6	2.9	12.2	3.0	11.3	2.7	<0.001
Energy-adjusted micronutrient intakes											
Ca (mg/4.2 MJ per d)	435	144	456	141	505	163	529	174	538	147	<0.001
Folate (µg/4.2 MJ per d)	115	38	130	42	143	59	152	50	169	51	<0.001
Fe (mg/4.2 MJ per d)	5.1	1.1	5.2	1.0	5.5	1.4	5.6	1.2	5.9	1.4	<0.001
Mg (mg/4.2 MJ per d)	152	31	166	25	174	35	186	33	197	36	<0.001
K (mg/4.2 MJ per d)	1473	294	1568	269	1641	389	1731	344	1779	329	<0.001
Riboflavin (mg/4.2 MJ per d)	0.67	0.22	0.68	0.19	0.71	0.22	0.76	0.24	0.74	0.19	<0.001
Thiamin (mg/4.2 MJ per d)	0.48	0.19	0.48	0.15	0.47	0.14	0.48	0.14	0.48	0.13	0.957
Vitamin A (RE/4.2 MJ per d)	455	380	446	338	450	297	495	323	534	496	0.019
Vitamin B ₆ (µg/4.2 MJ per d)	697	377	755	318	763	354	854	367	882	367	<0.001
Vitamin B ₁₂ (µg/4.2 MJ per d)	2.3	1.9	2.1	1.3	2.2	2.1	2.6	2.0	2.5	1.5	0.030
Vitamin C (mg/4.2 MJ per d)	42	27	44	28	48	31	53	31	56	32	<0.001
Vitamin E (mg/4.2 MJ per d)	5.8	2.5	6.1	2.3	6.1	2.0	6.2	2.0	6.8	2.5	<0.001

E%, energy percentage; RE, retinol equivalents.

*Dietary intakes are based on average intake of two 24 h recalls.

†Dutch Healthy Diet index score based on eight components without components physical activity and acidic foods and drinks, with a total score ranging from 0 points (no adherence to Dutch dietary guidelines 2006) to 80 points (maximum adherence).

‡Low education = primary school, vocational and lower general secondary education; moderate = higher secondary education and intermediate vocational training; high = higher vocational education and university.

associated whereas dietary fibre and vegetable protein were positively associated with the DHD15-index score, and these trends remained significant after energy adjustment ($P < 0.05$). For the micronutrients Ca, folate, Fe, Mg, K, vitamin B₆ and vitamin C, significant positive trends were observed across quintiles of the DHD15-score, both crude and after energy adjustment. Thiamin was inversely associated with the index score, but this association disappeared after energy adjustment. For the micronutrients riboflavin, vitamin A, vitamin B₁₂ and vitamin E, significant positive associations were observed for the energy-adjusted intakes, but not for the unadjusted intakes.

The mean DHD15-index score based on FFQ data was 15.5 points higher than that based on 24 hR data ($P < 0.001$; Table 4; online supplementary material, Supplemental Fig. 1). The correlation between the DHD15-index scores based on 24 hR and FFQ data was 0.58 (95% CI

0.53, 0.62), also after energy adjustment (0.56, 95% CI 0.52, 0.61). The correlations between the component scores based on FFQ and 24 hR data ranged between 0.14 and 0.65. The lowest correlations were observed for the components legumes and red meat, while the highest correlations were seen for tea and alcohol. For most components mean component scores were higher based on FFQ data compared with 24 hR data ($P < 0.001$). Largest differences in mean component score were seen for legumes (5.0 points difference) and fish (3.8 points difference). Results from cross-classification showed that 78% of the population was classified into the same or neighbouring quintile and only 1% was classified into the opposite quintile, with Kendall's τ_b coefficient of 0.41 (95% CI 0.36, 0.45).

The mean DHD15-index score based on the FFQ was also significantly higher for women than men (mean difference 9.5 points). Significant differences between men

Table 4 Mean scores (and standard deviations) of the Dutch Healthy Diet index 2015 (DHD15-index) and its components based on two 24 h recalls (24 hR) and on an FFQ, and partial correlation scores (and 95% confidence intervals) between the two scores, in 885 Dutch men and women aged 20–75 years

	24 hR		FFQ		Correlation*	95% CI
	Mean	SD	Mean	SD		
DHD15-index†	73.7	16.9	89.2	15.4	0.56	0.52, 0.61
1. Vegetables	6.2	3.2	6.8	2.7	0.33	0.27, 0.39
2. Fruit	6.2	3.7	7.1	3.4	0.55	0.50, 0.59
3. Wholegrain products	5.7	2.7	5.8	2.0	0.32	0.26, 0.38
4. Legumes	0.8	2.6	5.8	4.5	0.14	0.07, 0.20
5. Nuts	2.6	3.9	3.9	3.6	0.32	0.26, 0.37
6. Dairy	6.0	3.2	6.5	3.1	0.29	0.23, 0.35
7. Fish	2.2	3.8	6.1	3.1	0.26	0.19, 0.32
8. Tea	5.8	4.0	3.6	3.5	0.65	0.61, 0.69
9. Fats and oils	6.2	4.5	6.8	4.0	0.33	0.27, 0.39
10. Red meat	8.6	3.0	9.1	2.1	0.16	0.10, 0.23
11. Processed meat	4.3	4.0	6.0	3.2	0.40	0.34, 0.45
12. Sweetened beverages and fruit juices	5.8	4.0	6.4	3.4	0.51	0.46, 0.56
13. Alcohol	7.1	4.0	7.7	3.6	0.60	0.56, 0.64
14. Sodium	6.2	3.4	7.9	2.7	0.21	0.14, 0.27

Only total DHD15-index score was normally distributed (Pearson correlation).

*Adjusted for energy intake as assessed by 24 hR.

†DHD15-index score ranging from 0 to 140 points.

and women in component scores based on FFQ data were largely similar to the differences between men and women based on 24 hR data (online supplementary material, Supplemental Table 1). Associations and trends observed across quintiles of DHD15-index score based on FFQ data with participant characteristics, macronutrient and energy-adjusted micronutrient intakes showed similar results to those based on 24 hR data (online supplementary material, Supplemental Table 2). The only exception was energy-adjusted vitamin B₁₂ where a positive trend across quintiles of DHD15-index was observed based on 24 hR data but not with FFQ data.

Discussion

The DHD15-index score assesses adherence to the Dutch dietary guidelines 2015 and is able to rank participants according to their adherence, as was reflected by the variation in scores of the individual components of the index and the normally distributed total score. The index was positively associated with age, supplement use, fibre intake and nutrient density, and inversely associated with BMI, energy, total and saturated fat intakes. The most pronounced differences in score based on FFQ compared with 24 hR data were found in the components reflecting episodically consumed foods such as fish, but associations of the DHD15-index with participants' characteristics and nutrient intakes were similar for the scores based on 24 hR data and on FFQ data.

The DHD15-index score was developed as an update of the previously developed DHD-index reflecting adherence to the Dutch dietary guidelines of 2006. Therefore we kept the design aspects of this updated score

similar to the DHD-index: the different components reflected the guidelines as closely as possible, for each component a minimum score of 0 and a maximum score of 10 points could be allotted, and intakes between the minimum and maximum were scored proportionally. Contrary to the dietary guidelines of 2006, the guidelines of 2015 are formulated in terms of foods⁽¹⁰⁾. Only foods and food groups with sufficient scientific evidence for an effect on chronic diseases were included in the dietary guidelines. A consequence of this approach is that the dietary guidelines do not cover the complete dietary intake and recommended intakes in the guidelines apply to the general population. However, subgroups might benefit from a higher or lower intake of a food group to meet specific nutrient recommendations. For example, vegetarians might benefit from a higher legume or nut intake to meet recommended protein intake. This applies to indices based on both foods and nutrients as well, such as the Healthy Eating Index-2010. It should also be noted that within food groups there is still room for discussion about whether all foods within that food group should be included. For example, for dairy it could be argued that only low-fat dairy should be included as some studies show more favourable health effects for low-fat dairy compared with total dairy^(23,24). However, as the evidence is ambiguous and the debate is still ongoing, the Health Council of the Netherlands decided to set the guideline for total dairy⁽⁹⁾ and we stayed as close as possible to the guidelines.

To quantify the guidelines additional information from additional documents from the Health Council of the Netherlands (background documents)^(18–21) and interpretation by experts was sometimes necessary. The evidence regarding intake levels at which adverse health effects occur, as described in the background documents,

was used to set threshold values (i.e. the intake that deserves 0 points). This could be done for the moderation components red meat, processed meat, sweetened beverages and fruit juices, and alcohol. For example, according to the background document, an intake of 250 g of sweetened beverages and fruit juices daily is associated with an increased risk of weight gain and therefore the threshold value for this component was set at 250 g/d. For alcohol, adverse health effects associated with alcohol intake occur at different intake levels for men and women, therefore we set a different threshold values for men and women. For the component salt and the ratio components wholegrain products and fats and oils, there was not enough information to set an evidence-based threshold value. For those components the threshold value was based on the 85th percentile of the intake distribution based on two-day averages of the Dutch reference population⁽¹⁷⁾. This was also done for the DHD-index and is comparable to other indices such as the Healthy Eating Index-2010⁽²⁵⁾. For the ratio components the cut-off value was based on the 15th percentile of this intake distribution as there was no information on the ratio that deserves the maximum score. We used the information regarding standard portion sizes of the Netherlands Nutrition Centre⁽¹⁶⁾ for the components legumes, dairy, fish, tea and red meat, as the guidelines do not specify the recommended intake or only in number of servings.

The DHD15-index score based on 24 hR data showed a moderate correlation (0.56, 95% CI 0.52, 0.61) with the DHD15-index score based on FFQ data and is comparable with the correlation found for the initial DHD-index (0.48, 95% CI 0.33, 0.61)⁽¹⁾. Ranking of participants showed moderate agreement as indicated by Kendall's τ_b coefficient and fairly good concordance as 78% was ranked in the same or neighbouring quintile and only 1% in the opposite quintile. The cut-off and threshold values for the scores are absolute levels of intakes. We assume that a 24 hR is more suitable to estimate dietary intakes on a group level as the used FFQ is designed to cover at least 90% of energy intake, but not able to capture 100% of the total intake⁽¹⁴⁾. However, several components are episodically consumed foods including fish, legumes and nuts. Using two-day averages of the 24 hR can result in excess zeros and maximum scores, whereas an FFQ is better able to assess usual intakes of these episodically consumed foods because it assesses foods eaten during a longer period of time. This could be one explanation for the low correlations seen for these components when comparing the component scores based on 24 hR and FFQ data. Other reasons for the low correlations between the scores based on the two methods are the biases inherent to the 24 hR (e.g. high day-to-day variability) and FFQ (e.g. aggregation of food items, standard portion sizes)⁽²⁶⁾. Surprisingly, also red meat showed a very low correlation and appeared to be an episodically consumed food in this health-conscious population. Mean intakes were

substantially lower than the intake of the Dutch reference population, which could not be explained by a difference in number of non-consumers. A possible alternative to better estimate these episodically consumed foods would be using 24 hR with an additional short propensity questionnaire as also advised for surveillance⁽²⁷⁾. Additionally, the FFQ used in the present study was not able to distinguish between unsalted and salted nuts, and between types of tea, whereas the 24 hR is able to make these distinctions. Both methods were not able to distinguish between types of coffee (filtered *v.* unfiltered). In future studies, an adapted FFQ able to distinguish between types of nuts, tea and coffee as well as an adapted 24 hR to assess type of coffee should be used.

Other limitations of the used dietary assessment methods should also be considered. First, for both the 24 hR and the FFQ, it is known that estimates for Na intake are biased and usually underestimated because information on salt added during cooking and at the dinner table is lacking. By reducing the cut-off level by 20% we tried to adjust for this, but realize this decreases variation between people and thus results on the sodium component should be interpreted with caution. Ideally, Na intake is estimated based on 24 h urinary-N, which is considered the gold standard for estimating Na intake⁽²⁸⁾. Second, for alcohol intake it was not possible to assess binge drinking with only two 24 hR and the used FFQ. Finally, a difficulty arises in the handling of mixed foods (i.e. foods consisting of several (types of) ingredients). These mixed foods were broken down into their ingredients as coded by the Dutch Food Composition Table⁽¹³⁾ and the individual ingredients were used in the calculation of the food intakes. However, some foods in the Dutch Food Composition Table still consist of several different ingredients from different food groups. For these mixed foods, we included the food if more than half of the weight of the mixed food consisted of a food group of one of the components. For example, vegetables on pizza (component vegetables), sausage roll (processed meat) and pea soup (legumes) are not included in calculation of food intake, but porridge is ($\geq 50\%$ dairy).

The DHD15-index score presented in the current study was designed to capture the dietary pattern of the general Dutch population. The components of the DHD15-index are familiar components of Western dietary patterns and similar to components of several well-known and much used indices such as the Healthy Eating Index-2010 (vegetables, fruit, grains, dairy, alcohol, salt, fats and oils, and the components meat, fish, nuts and legumes in the protein foods)⁽²⁵⁾ and the Mediterranean Diet Score (vegetables, fruits, legumes, cereals, dairy, meat, alcohol, and fats and oils)⁽²⁹⁾. However, it might be that for ethnic minorities with non-Dutch eating habits the score is limited in its use⁽³⁰⁾. Furthermore, we evaluated the DHD15-index score in a population that might not be representative of the general Dutch population, as

participants had in general a high level of education. Also, the high proportion of supplement users could indicate that this population is health-conscious. Therefore, we used the intake distribution of the Dutch reference population⁽¹⁷⁾ for the intake-based threshold values in the development of the score instead of the intake distribution of our study population. This also has the advantage that results of future studies can be compared as the same threshold values are used.

Evaluation of indices is necessary to establish whether an index is suitable for further use. In the present study, several types of evaluation were carried out. First of all, we examined the relationship of the DHD15-index with nutrient intakes and observed positive trends between the DHD15-index score and energy-adjusted micronutrient intakes. This indicates that participants with higher DHD15-index scores have a more nutrient-dense diet. We also observed an inverse association with total energy intake, total fat intake and saturated fat intake, and a positive relationship with fibre intake, also suggesting that a higher DHD15-index score indicates a healthier diet. Second, construct validity was examined by assessing the relationship between the DHD15-index score and participants' characteristics such as age, educational level and supplement use. Although the trend observed was not significant, the proportion of highly educated participants increased with higher DHD15-index scores whereas the proportion of lower educated participants decreased. Additionally, supplement users, older participants and participants with a lower BMI had higher DHD15-index scores. Also, the variation in total score and the individual component scores indicates discriminative power of the DHD15-index. Lastly, comparability of the index based on different dietary assessment instruments was satisfactory. In addition, we saw an acceptable correlation between the DHD15-index score and the previously validated DHD-index score based on the 2006 guidelines. Based on these observations we think that the DHD15-index is a good measure of diet quality. Further evaluation steps include assessing the relationship between the DHD15-index and chronic diseases and mortality and its ability to monitor trends in dietary intake over time. As energy intake and BMI are inversely associated with the DHD15-index score, energy adjustment should be considered when studying diet–disease associations to be able to distinguish between effects from energy intake and the effects of diet quality as reflected by the DHD15-index score.

Conclusion

The DHD15-index score assesses adherence to the Dutch dietary guidelines of 2015 and is an indicator of diet quality as it is positively associated with nutrient density. Both 24 hR and FFQ data can be used to assess the DHD15-index score, resulting in some differences in individual components but an acceptable correlation

between the total scores. In future research, the DHD15-index score can be used to study associations between diet quality and chronic diseases.

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Supplementary material

To view supplementary material for this article, please visit <https://doi.org/10.1017/S136898001700091X>

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