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Development of the food-based Lifelines Diet Score (LLDS) and its application in 129 369 Lifelines participants

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Running title: Lifelines Diet Score: development and application

Abstract

Objective: Many diet quality scores exist, but fully food-based scores based on contemporary evidence are scarce. Our aim was to develop a food-based diet score based on international literature and examine its discriminative capacity and socio-demographic determinants.

Methods: Between 2006–2013, dietary intake of 129 369 participants of the Lifelines Cohort (42% male, 45±13 years (range 18-93)) was assessed with a 110-item food frequency questionnaire. Based on the 2015 Dutch Dietary Guidelines and underlying literature, nine food groups with positive (vegetables, fruit, whole grain products, legumes&nuts, fish, oils&soft margarines, unsweetened dairy, coffee and tea) and three food groups (red&processed meat, butter&hard margarines and sugar-sweetened beverages) with negative health effects were identified. Per food group, the intake in grams/1000 kcal was categorized into quintiles, awarded 0 to 4 points (negative groups scored inversely) and summed. Food groups with neutral, unknown or inconclusive evidence are described but not included.

Results: The Lifelines Diet Score (LLDS) discriminated well between high and low consumers of included food groups. This is illustrated by e.g. a 2-fold higher vegetable intake in the highest, compared to the lowest LLDS quintile. Differences were 5.5-fold for fruit, 3.5-fold for fish, 3-fold for dairy and 8-fold for sugar-sweetened beverages. The LLDS was higher in females and positively associated with age and educational level.

Conclusions and perspectives: The LLDS is based on the latest international evidence for diet-disease relations at the food group level and has high capacity to discriminate people with widely different intakes. Together with the population-based quintile approach, this makes the LLDS a flexible, widely applicable tool for diet quality assessment.

Introduction

The importance of nutrition in the development of non-communicable diseases and in the overall burden of disease has been well established. A recent development in this field is the focus on specific foods and dietary patterns. There is increasing evidence that foods and dietary patterns substantially affect chronic disease risk, whereas the relations with individual nutrients are less pronounced. [1,2] This superiority of foods and dietary patterns may in part be explained by the concept of food synergy, which underlines the additive or more than additive influence of foods and food constituents on health. [3]

Following these recent developments, many countries, including the United States, Australia and Nordic countries, now provide food-based dietary guidelines.[4] In the Netherlands, the Dutch Health Council issued their food-based dietary guidelines in 2015. The guidelines are the result of a systematic and critical evaluation of international peer-reviewed literature on relations of foods, dietary patterns and nutrients with causal risk factors and chronic disease risk.[1]

Worldwide, numerous dietary indices have been developed to measure adherence to dietary guidelines or dietary patterns, such as the Healthy Eating Index (HEI)[5,6] and the Mediterranean Diet Score (MDS)[7,8]. Both scores were inversely associated with the risk of chronic diseases and all-cause mortality in prospective cohort studies.[8–10] However, the different versions of the HEI and the MDS are not completely food-based and in line with current scientific evidence. For example, besides food products, both scores also consider intake of saturated or unsaturated fatty acids. Furthermore, the MDS recommends low dairy intake although there is prospective cohort evidence for the inverse relation of milk with colorectal cancer, and yoghurt with diabetes. [11,12] In addition, the MDS does not include sugar-sweetened beverages of which detrimental effects on obesity and diabetes risk are well established.[13,14]

72   The present study aimed to develop a food-based diet quality score in accordance with

73   the current international evidence on diet-disease relations, presented in the 2015 Dutch

74   Dietary Guidelines. The score should be compatible with data obtained through common

75   dietary assessment methods. The discriminative capacity of the diet score and its association

76   with socio-demographic determinants was evaluated in the Lifelines Cohort, and the score

77   was therefore named the Lifelines Diet Score (LLDS). The large Lifelines cohort, established

78   in 2006, is a contemporary observational population-based cohort study and biobank in the

79   Northern part of the Netherlands, including approximately 10% of the region's population.

80   The overall aim of this resource is to gain insight into the etiology of healthy aging[15], and it

81   therefore also covers nutrition.[16] A detailed description of food consumption in this cohort

82   will be presented in this article.

83   **Methods**

84   *Cohort design and study population*

85   The Lifelines cohort study is a multi-disciplinary prospective population-based cohort study

86   examining in a unique three-generation design the health and health-related behaviors of

87   167 729 persons living in the North of the Netherlands. It employs a broad range of

88   investigative procedures in assessing the biomedical, socio-demographic, behavioral, physical

89   and psychological factors which contribute to the health and disease of the general population,

90   with a special focus on multi-morbidity and complex genetics. The overall design and

91   rationale of the study have been described in detail elsewhere.[15,17] Participants were

92   included in the study between 2006 and 2013, and written informed consent was obtained

93   from all participants. Dietary information was available for 144 095 adults. The reliability of

94   reported dietary intake was based on the Goldberg cut-off method, which relies on the ratio of

95   reported energy intake and basal metabolic rate [18], calculated with the Schofield

4

96   equation.(19) 14 726 participants with a ratio below 0.87 or above 2.75 were excluded (<0.89

97   or >2.66 for participants >75 years), leaving 129 369 participants in the study. The LifeLines

98   study is approved by the medical ethical committee of the University Medical Center

99   Groningen, The Netherlands.

100   *Data collection*

101   Self-administered questionnaires were used to collect data regarding demographics (ethnicity,

102   education) and lifestyle (smoking, alcohol, diet). Height and body weight without shoes and

103   heavy clothing were measured at one of the Lifelines research sites, with the SECA 222

104   stadiometer and the SECA 761 scale. Body mass index (BMI) in kg/m^2 was calculated.

105   *Dietary assessment*

106   To assess dietary intake in the Lifelines Cohort, a 110-item semi-quantitative baseline food

107   frequency questionnaire (FFQ) assessing food intake over the previous month was developed

108   by Wageningen University using the Dutch FFQTOOL™, in which food items were selected

109   based on the Dutch National Food Consumption Survey of 1997/1998.(20) The Lifelines FFQ

110   was designed to include food groups that account for at least 80% of the variance and 80% of

111   the population intake of both energy and macronutrients. Seven response categories were used

112   to assess consumption frequency, ranging from 'not this month' to '6-7 days a week'. Portion

113   size was estimated by fixed portion sizes (e.g. slices of bread, pieces of fruit) and commonly

114   used household measures (e.g. cups, spoons). Energy and macronutrient intake was estimated

115   from the FFQ data by using the Dutch food composition database of 2011.(21) Alcohol

116   consumption was also estimated based on FFQ data.

117   *2015 Dutch Dietary Guidelines*

118   The food-based 2015 Dutch Dietary Guidelines represent an overview of the current

119   internationally available scientific evidence on the relation of foods and dietary patterns with

120 chronic diseases.(1) The Dutch Health Council selected 10 major diet-related chronic diseases

121 based on mortality, life-years lost and burden of disease in the Netherlands: coronary heart

122 disease, stroke, heart failure, diabetes mellitus type 2, chronic obstructive pulmonary disease,

123 breast cancer, colon cancer, lung cancer, dementia and depression. Three intermediate risk

124 factors (systolic blood pressure, LDL-cholesterol, body weight) were considered because of

125 their causal relation with coronary heart disease, stroke, heart failure or type 2 diabetes. The

126 Council performed 29 systematic reviews of international peer-reviewed meta-analyses of

127 prospective cohort studies and randomized controlled trials on relations of foods, dietary

128 patterns and nutrients with these risk factors or chronic diseases risk were evaluated. In

129 establishing the Guidelines, strength of available scientific evidence was considered.

130 Evidence was considered strong when high quality meta-analyses were available and

131 heterogeneity was either absent or could be explained. This procedure leads to evidence-based

132 guidelines, as opposed to guidelines which are based on cultural preference or expert

133 opinions.

134 *Development of the Lifelines Diet Score*

135 The 110 FFQ items were categorized into 22 food groups (**Supplementary Table 1**). Based

136 on the evidence provided by the Guidelines(1), the food groups were categorized as positive,

137 negative, neutral or unknown. Nine positive groups (vegetables, fruit, whole grain products,

138 legumes & nuts, fish, oils & soft margarines, unsweetened dairy, coffee and tea), one neutral

139 group (eggs), three negative groups (red & processed meat, butter & hard margarines and

140 sugar-sweetened beverages) and nine unknown groups for which evidence is either absent or

141 weak (potatoes, refined grain products, white unprocessed meat, cheese, savory & ready

142 products, sugary products, soups, sweetened dairy, artificially sweetened products) were

143 identified (**Figure 1**). The nine positive and three negative food groups were combined into

144 the LLDS. An overview of the health effects of these food groups is presented in

145 **Supplemental Table 2**.

146   For the LLDS to represent relative diet quality, taking into account differences in

147 energy intake between individuals, intake of the food groups was expressed in grams per 1000

148 kilocalories (kcal) instead of grams per day. For each food group, intake was divided into

149 quintiles to score an individual's consumption compared to others in the study population.

150 The quintiles ranged from 0 to 4, with 4 points being awarded to the highest quintile of

151 consumption for positive food groups, and to the lowest quintile for negative food

152 groups.(22–24) The sum of the 12 component scores resulted in a LLDS score ranging from

153 zero to 48. Sensitivity analysis was performed to investigate whether gender stratification as

154 an alternative for energy adjustment, would categorize participants similarly.

155 *Data analysis*

156 The average intake of energy (kcal), carbohydrates, fat and protein (energy%) were

157 calculated. Food group consumption in grams/1000 kcal was calculated and presented in

158 medians and interquartile ranges, because of the skewed distribution of the majority of the

159 food groups. Participant characteristics and food group consumption were presented stratified

160 by age (18-40, 40-59, $\geq$ 60 years) and gender to get more insight into the subpopulations of

161 the cohort. Median consumption per component was presented across quintiles of the LLDS,

162 separately for men and women. Furthermore, mean LLDS scores were visualized, stratified by

163 gender, age and educational level. Correlations between components of the LLDS were

164 assessed to ensure the independent contribution of all components to the score.

165   The chances of rejecting the null hypothesis with negligible differences is high in a

166 population-based cohort study of 129 369 participants, so p-values were not included in this

167 paper.(25) Data analysis was performed in IBM SPSS 23 (SPSS, Chicago Illinois, USA).

Results

This study included 129 369 participants (41.5% males, 58.5% females) with a mean age of 44.8 (SD = 13.1, range 18-93). **Table 1** shows an inverse relationship between educational level and the three age groups, especially in women. Mainly in men, energy intake was lower in higher age groups. Contributions of macronutrients to total energy intake were comparable between groups. Body Mass Index (BMI) and the prevalence of obesity was higher in older age groups. The percentage of current smokers and alcohol users was lower in higher age groups.

Food groups

The median consumption per food group in grams/1000 kcal shows that consumption of the food groups differs by gender and age (**Table 2**). For example, the female diet was characterized by a higher intake of vegetables, fruit, unsweetened dairy and tea, whereas intake for sugar-sweetened beverages was higher for men. In the higher age groups, consumption was higher for vegetables, fruit, unsweetened dairy, coffee, tea and potatoes, while it was lower for sugar-sweetened beverages, savory & ready products and artificially sweetened products.

Lifelines Diet Score

The LLDS ranged from 1 to 46 in men (mean 22.6, SD 5.70) and from 3 to 46 in women (mean 25.0, SD 6.09). The correlation between components ranged from r=0.005 between tea and legumes & nuts, to r=0.364 between tea and coffee, explaining up to a maximum of 13% of variance. Cross-classification of energy adjusted scores to gender-stratified scores showed that 91.5% of participants was categorized in the same or adjacent quintile. Only 0.02% was categorized in extreme quintiles. Median consumption of the included food groups across quintiles of the total score are presented in **Table 3**, for men and women separately. In the

192   total study population, intake of positive components in the highest quintile was between 1.5

193   times (whole-grain products) and 6 times (tea) higher than in the lowest quintile. For the

194   negative components, intake in the highest quintile was between 8 times (sugar-sweetened

195   beverages) and 1.5 times (red & processed meat) lower than intake of the lowest quintile. The

196   LLDS was higher in women and positively associated with age category and educational level

197   (**Figure 2**). For men, mean LLDS ranged from 19.5 (SD = 5.30) in males aged below 40 with

198   low educational level, to 25.9 (SD = 5.50) in highly educated males aged 60 or higher. For

199   women, this range is 20.8 (SD = 5.74) to 29.1 (SD = 5.61).

Discussion

201   The food-based LLDS is a tool to rank participants on relative diet quality and is based on

202   solid contemporary evidence on diet-disease relationships. The large differences in

203   consumption of the included positive and negative food groups over quintiles of the LLDS

204   demonstrate its discriminative capacity. The LLDS was higher in women and positively

205   associated with age and educational level. The international literature underlying the LLDS,

206   together with the population-based quintile approach, make the LLDS an internationally

207   applicable tool to rank individuals on diet quality.

208   Although many diet scores exist, the current emphasis on food-based analyses created

209   the need for a fully food-based diet score in line with contemporary evidence. In the

210   development of the LLDS, nine positive, three negative, one neutral and nine unknown food

211   groups were identified based on the evidence from the 2015 Dutch Dietary Guidelines and its

212   underlying literature. (1) Analysis of the intake of these food groups in the Lifelines Cohort,

213   revealed gender and age specific dietary patterns. For example, the female diet was high in

214   vegetables, fruit and tea, whereas the male diet consisted of higher amounts of sugar-

215   sweetened beverages and oils & soft margarines. Higher consumption of potatoes and several

216   positive food groups, and lower sugar-sweetened beverage and artificially sweetened product

217   consumption characterized the diet of the elderly. This food consumption in the Lifelines

218   population is in agreement with consumption reported in the Dutch National Food

219   Consumption Survey (DNFCS) 2007-2010 (26), which is considered representative for the

220   Netherlands.

221   The LLDS scored individuals on diet quality, by ranking their relative consumption of

222   positive and negative food groups. All food groups contributed independently to the LLDS,

223   indicated by the weak correlations between the groups. Comparing the quintiles of the LLDS,

224   the range of consumption varied widely for all food groups, demonstrating good

225   discriminative capacity. The wide range of consumption between the quintiles also

226   emphasizes that there is room for improvement. For example, vegetable intake differed 2-fold

227   between the lowest and highest LLDS quintile. Differences were 5.5-fold for fruit, 3.5-fold

228   for fish, 3-fold for dairy and 8-fold for sugar-sweetened beverages. At the individual level, the

229   room for improvement depends on how an individual's score is built up. To illustrate, a

230   median score of 24 could indicate intermediate consumption of all food groups (e.g. two

231   points awarded to all 12 components) leaving some room for improvement for all

232   components, or a large room for improvement for some (e.g. zero points awarded to six

233   components), but no improvement for other food groups (e.g. four points awarded to the other

234   six components).

235   A relative approach rather than classification of absolute intake using pre-defined cut-

236   offs was chosen to calculate the LLDS. This approach scored an individual's consumption of

237   the included food groups, compared to others in the study population. Comparable to the A

238   Priori Diet Quality Score(3,24), quintiles rather than medians or tertiles were used to score

239   intake, to better approximate a diet quality continuum. Because of the relative quintile approach,

240   the LLDS depends on the population characteristics, which makes it flexible for use in other

241   populations. Furthermore, the use of quintiles rather than pre-defined cut-offs allows a level

242 of uncertainty in the intake estimates of the included food groups. This makes the LLDS

243 approach compatible with data obtained through varying dietary assessment methods. A

244 limitation of this approach is that comparison of scores across studies is difficult, since cut-

245 offs are population-dependent. Reporting the intake of components per quintile of the LLDS

246 can provide insight into differences across studies.

247 Expressing food intake in grams per 1000 kcal prevented the score from favoring

248 those with higher overall food consumption, and measures the relative contribution of the

249 positive and negative food groups to the total diet. An alternative for energy adjustment is

250 ranking intake in gender-specific quintiles, as this will also adjust for a great part of variation

251 in energy intake. The strong agreement in classification according to the two approaches

252 suggests that gender-stratification may be a suitable alternative when proper estimation of

253 energy intake is not possible. For example, this could be the case for short dietary screeners

254 that substitute extensive FFQs, for which there is an upcoming interest (27,28).

255 The LLDS was higher in women and positively associated with age and educational

256 level. Other dietary quality scores, such as the Healthy Eating Index, the Alternate Healthy

257 Eating Index, Mediterranean Diet Score and A Priori Diet Quality Score have all shown

258 similar associations with educational level (29–33), sex (30,32,34) and age (30,34). This

259 shows that the association of the LLDS with socio-demographic determinants is comparable

260 to those found for other widely used diet quality scores.

261 The Guidelines recommend the consumption of filtered coffee because unfiltered

262 coffee increases LDL-cholesterol in controlled dietary experiments. (35) However, in

263 prospective cohort studies, coffee consumption, independent of the type of coffee, was

264 associated with lower risk of coronary heart disease, stroke, cardiovascular diseases and type

265 2 diabetes.(36,37) Combined with the methodological constraint that most dietary assessment

266 methods do not distinguish between the type of coffee, we decided to include all types of

267   coffee in the LLDS.

268   Legumes and nuts were combined in one food group. A meta-analysis of prospective

269   cohort studies showed that nut consumption was associated with lower coronary heart disease

270   risk(38). The Dutch Health Council rated the evidence for the effect of legumes on coronary

271   heart disease risk as less reliable, which would favor separating legumes and nuts. However,

272   groups were combined because both are rich in plant-based protein and meta-analyses showed

273   that both reduced LDL-cholesterol.(39,40) Also, combining the groups was expected to

274   enhance discriminative power because consumption of both groups is low.

275   The Lifelines FFQ does not distinguish between whole grain and refined cereal

276   products. In the Netherlands, whole meal and brown bread account for approximately 70% of

277   bread consumption and with an estimated mean intake of 95 grams per day, it is the largest

278   contributor to total whole grain consumption in the Netherlands.(41) Therefore, bread

279   consumption was used as a proxy for whole grain consumption in this study. The remaining

280   cereal products included in the FFQ (crackers/biscuits, croissants & other bread-rolls,

281   breakfast cereals, pasta and rice) were classified as refined grain products as the Dutch

282   population predominantly consumes refined variants of these items.(41) Alcoholic beverage

283   consumption was not included in the LLDS as it was considered a lifestyle factor, rather than

284   a food group.

285   In conclusion, the LLDS is a flexible tool to rank individuals on relative diet quality.

286   This fully food-based score is in line with the recent international literature which was

287   critically reviewed in the 2015 Dutch Dietary Guidelines, making the LLDS a tool of

288   international relevance. Application of the LLDS in the contemporary Lifelines cohort

289   showed that the score was higher in women and positively associated with age and

290   educational level. The LLDS can be calculated with data derived through different dietary

291   assessment methods, but adaptation of the calculation method is desired when available data

292   is not sufficient to estimate energy intake.

302   *Conflict of interest*

303   The authors declare no conflict of interest.

304   Supplementary information is available at *European Journal of Clinical Nutrition's* website.

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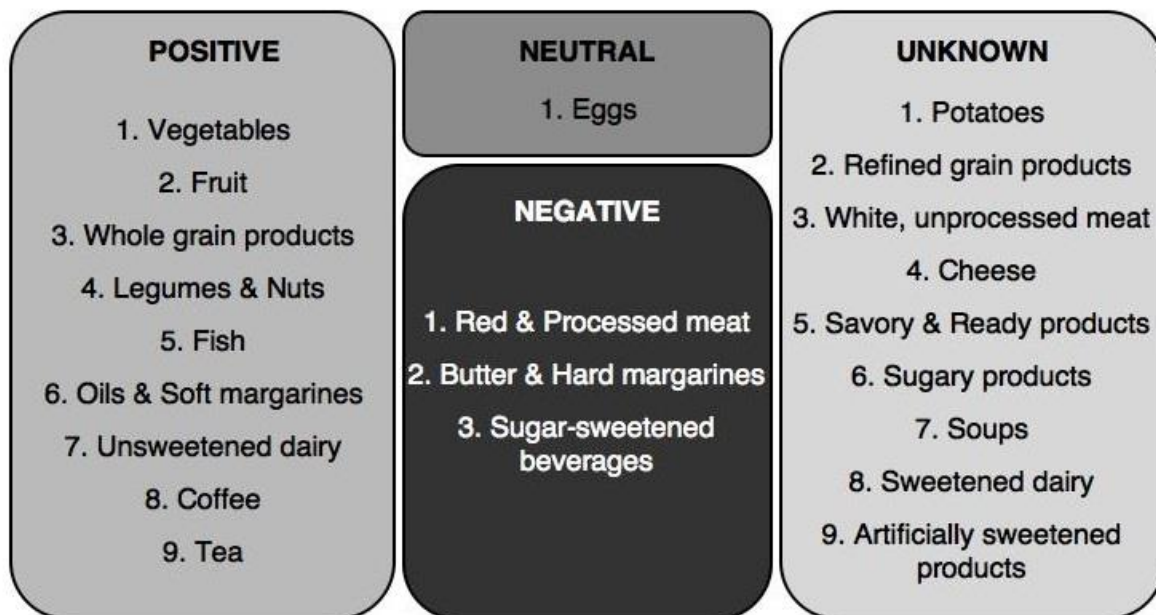
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434   **Figure 1:** Overview of the food groups.

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POSITIVE	NEUTRAL	UNKNOWN
1. Vegetables	1. Eggs	1. Potatoes
2. Fruit		2. Refined grain products
3. Whole grain products	**NEGATIVE**	3. White, unprocessed meat
4. Legumes & Nuts		4. Cheese
5. Fish	1. Red & Processed meat	5. Savory & Ready products
6. Oils & Soft margarines	2. Butter & Hard margarines	6. Sugary products
7. Unsweetened dairy	3. Sugar-sweetened beverages	7. Soups
8. Coffee		8. Sweetened dairy
9. Tea		9. Artificially sweetened products

Table 1: Baseline data of the adult LifeLines population (N=129 369), collected between
2006 and 2013.

	Male			Female		
	18-39 years *(N=17360)*	40-59 years *(N=27369)*	≥ 60 years *(N=8923)*	18-39 years *(N=26196)*	40-59 years *(N=39039)*	≥ 60 years *(N=10482)*
DEMOGRAPHICS						
Age (years) (mean ± SD)	30.9 ± 5.8	47.9 ± 5.2	66.3 ± 5.2	30.2 ± 6.2	47.9 ± 5.2	65.8 ± 5.0
White, East/West European Ethnicity (%)	97.8	98.4	98.9	97.2	98.0	98.7
Education* (%)						
Low	18.2	31.2	44.5	13.8	31.1	64.7
Moderate	46.3	37.8	25.3	47.1	42.5	18.5
High	35.5	30.9	30.3	39.1	26.4	16.8
DIET						
Energy intake (kcal/day) (mean ± SD)	2511 ± 682	2395 ± 646	2093 ± 536	1863 ± 485	1851 ± 477	1718 ± 422
Percentage energy from[§]: (mean ± SD)						
Carbohydrates	48.0 ± 5.3	46.9 ± 5.4	46.4 ± 5.6	48.4 ± 5.5	46.5 ± 5.7	46.9 ± 5.8
Protein	14.9 ± 2.2	15.3 ± 2.2	15.9 ± 2.3	15.2 ± 2.4	16.1 ± 2.5	16.7 ± 2.5
Fat	37.1 ± 5.1	37.8 ± 5.1	37.7 ± 5.1	36.4 ± 5.0	37.4 ± 5.2	36.4 ± 5.2
LIFESTYLE						
Body Mass Index (kg/m²) (mean ± SD)	25.3 ± 3.7	26.8 ± 3.6	27.0 ± 3.3	24.8 ± 4.6	26.1 ± 4.7	27.0 ± 4.3
Obesity[#] (%)	9.9	16.5	16.5	12.5	17.5	20.9
Alcohol						
User percentage (%)	92.1	90.6	89.0	78.5	77.0	74.3
Median consumption† (g/day)	8.8 [3.8 – 16.1]	8.6 [3.4 – 16.5]	9.0 [3.5 – 17.3]	3.2 [1.6 – 6.8]	5.3 [1.7 – 9.9]	6.1 [1.7 – 11.4]
Smoking (%)						
Current Smoker	29.6	21.9	12.2	23.7	19.5	8.8
Former Smoker	18.0	34.2	63.6	18.8	37.0	47.2
Never Smoker	52.4	43.9	24.2	57.6	43.5	44.0

* Low education = primary school, vocational and lower general secondary education. Moderate education = higher secondary education and intermediate vocational training. High education = higher vocational education and university education.

[#] Body mass index ≥ 30 kg/m²

†Median + IQR among alcohol users. One standard drink contains 10g alcohol.

[§] Energy from carbohydrates, protein and fat, relative to the sum of energy from the three macronutrients.

Table 2: Median [p25-p75] consumption of the 22 food groups in the adult LifeLines

population (N=129 369) in grams per 1000 kcal, presented stratified by age and gender.

	Male			Female		
	18-39 years	40-59 years	≥ 60 years	18-39 years	40-59 years	≥ 60 years
Positive food groups						
Vegetables	35	39	48	49	56	63
	[22 - 52]	[25 - 57]	[32 - 66]	[32 - 71]	[38 - 79]	[44 - 86]
Fruit	32	40	73	54	67	120
	[11 - 65]	[16 - 80]	[37 - 117]	[24 - 102]	[31 - 119]	[70 - 166]
Whole grain products	58	58	57	51	51	55
	[41 - 76]	[41 - 75]	[42 - 72]	[34 - 67]	[35 - 66]	[40 - 69]
Legumes & Nuts	8	10	10	7	8	9
	[4 - 14]	[5 - 16]	[5 - 17]	[3 - 12]	[4 - 15]	[4 - 15]
Fish	4	5	6	5	6	7
	[1 - 6]	[2 - 7]	[3 - 10]	[1 - 8]	[2 - 9]	[4 - 12]
Oils & soft margarines	9	9	6	8	7	4
	[3 - 16]	[3 - 16]	[1 - 14]	[3 - 14]	[2 - 14]	[1 - 12]
Unsweetened dairy	57	66	83	66	83	102
	[22 - 110]	[28 - 119]	[41 - 136]	[23 - 127]	[35 - 147]	[50 - 164]
Coffee	167	230	226	98	228	244
	[77 - 253]	[156 - 318]	[161 - 304]	[0 - 213]	[141 - 325]	[170 - 327]
Tea	29	40	88	135	131	163
	[5 - 84]	[5 – 102]	[19 - 162]	[53 – 253]	[48 – 243]	[73 – 269]
Neutral food groups						
Eggs	4	5	7	4	5	7
	[2 - 8]	[3 - 8]	[3 - 10]	[3 - 8]	[3 - 9]	[4 - 11]
Negative food groups						
Red & processed meats	32	32	33	33	33	31
	[24 - 42]	[24 - 42]	[23 - 43]	[23 - 43]	[23 - 43]	[20 - 42]
Butter & hard margarines	9	12	16	8	10	14
	[3 - 16]	[6 - 19]	[9 - 24]	[3 - 15]	[5 - 18]	[7 - 21]
Sugar-sweetened beverages	82	49	27	65	32	16
	[38 - 146]	[17 - 96]	[6 - 66]	[22 - 15]	[8 - 81]	[0 - 56]
Unknown food groups						
Potatoes	27	32	42	27	30	38
	[13 - 43]	[19 - 49]	[26 - 60]	[13 - 43]	[17 - 46]	[23 - 55]
Refined grain products	34	34	27	37	36	27
	[22 – 52]	[22 - 50]	[17 – 41]	[25 – 53]	[25 – 51]	[18 – 40]

White, unprocessed meat	4 [3 - 7]	4 [2 - 6]	4 [2 - 6]	6 [3 - 9]	5 [3 - 8]	5 [2 - 8]
Cheese	9 [4 - 16]	12 [6 - 19]	15 [9 - 23]	10 [5 - 17]	14 [8 - 22]	17 [11 - 26]
Savory & Ready products	52 [37 - 71]	42 [28 - 58]	24 [14 - 38]	52 [37 - 70]	41 [27 - 57]	22 [13 - 36]
Sugary products	32 [22 - 44]	35 [23 - 48]	37 [25 - 51]	38 [26 - 51]	37 [24 - 50]	38 [26 - 52]
Soups	15 [8 - 28]	17 [10 - 33]	19 [11 - 37]	16 [10 - 27]	18 [11 - 32]	19 [12 - 35]
Sweetened dairy products	38 [19 - 62]	39 [20 - 60]	46 [23 - 70]	44 [21 - 72]	43 [20 - 69]	52 [25 - 80]
Artificially sweetened products	11 [0 - 49]	8 [0 - 43]	3 [0 - 27]	21 [0 - 75]	12 [0 - 69]	3 [0 - 31]

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444 **Table 3:** Median [p25-p75] consumption of the 12 components included in the LifeLines Diet

445 Score in grams per 1000 kcal, per quintile of the LLDS for men and women separately.

|	Quintiles of LLDS					
	Males			**Females**		
	1	**3**	**5**	**1**	**3**	**5**
	(N=13.137)	(N=10.336)	(N=6.233)	(N = 11.098)	(N = 14.108)	(18.038)
LLDS-score*	16 [1 - 18]	24 [23 – 25]	32 [30 – 46]	16 [3 – 18]	24 [23 – 25]	32 [30 – 46]
Energy intake (kcal) #	2597 ± 719	2350 ± 617	2064 ± 521	2023 ± 531	1872 ± 461	1659 ± 397
Positive components						
Vegetables	29 [18 – 41]	42 [28 – 58]	60 [43 – 81]	36 [23 – 51]	52 [36 – 71]	76 [56 – 99]
Fruit	17 [6 – 39]	48 [23 – 86]	93 [56 – 133]	25 [9 – 49]	62 [33 – 107]	123 [80 – 165]
Whole grain products	47 [11 – 63]	61 [45 – 76]	71 [55 – 86]	40 [27 – 55]	51 [36 – 65]	61 [44 – 76]
Legumes & Nuts	6 [2 – 10]	10 [5 – 16]	15 [9 – 22]	4 [2 – 8]	7 [4 – 13]	12 [6 – 19]
Fish	3 [0 – 5]	5 [2 – 7]	8 [5 – 12]	2 [0 – 5]	5 [2 – 8]	9 [6 – 13]
Oils & soft margarines	5 [2 – 11]	10 [3 – 17]	13 [6 – 18]	5 [2 – 10]	7 [2 – 13]	10 [3 – 16]
Unsweetened dairy	38 [13 – 77]	73 [35 – 123]	109 [64 – 164]	36 [11 – 80]	77 [33 – 135]	119 [66 – 182]
Coffee	164 [87 – 246]	221 [147 – 308]	257 [185 – 343]	117 [0 – 218]	189 [83 – 283]	254 [165 – 347]
Tea	13 [0 – 56]	46 [8 – 109]	113 [44 – 194]	60 [12 – 143]	129 [51 – 230]	213 [121 – 325]
Negative components						
Red & processed meat	37 [28 – 46]	32 [24 – 41]	25 [17 – 34]	37 [28 – 47]	34 [24 – 44]	26 [16 – 36]
Butter, hard margarines	16 [9 – 23]	11 [5 – 17]	5 [1 – 11]	16 [9 – 22]	11 [5 – 18]	5 [1 – 11]
Sugar-sweetened beverages	104 [54– 170]	46 [17 – 87]	18 [4 – 45]	120 [62 – 196]	44 [13 – 91]	13 [0 – 36]

* Median score + Full Range

Mean + SD

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448 **Figure 2:** Mean Lifelines Diet Score, stratified by age category and educational level.

Males

Females
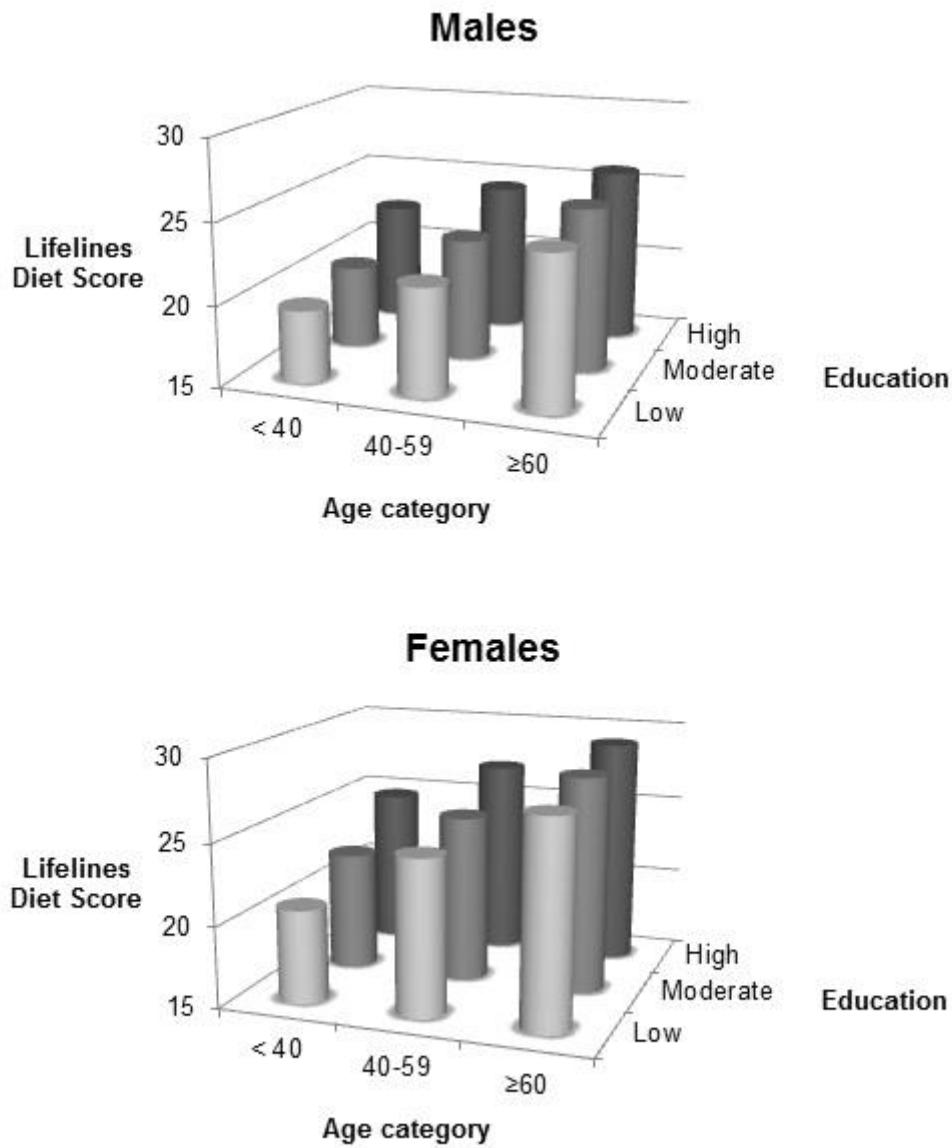
449
450 * Low education = primary school, vocational and lower general secondary education.
451 Moderate education = higher secondary education and intermediate vocational training.
452 High education = higher vocational education and university education.

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Supplementary Tables

Table S1: Classification of FFQ items in the 22 established food groups, including comments regarding the choices that have been made.

Group	Examples of food group items	LL FFQ items	Comments
Positive food groups			
Vegetables	All boiled, stir-fried and raw vegetables (fresh, canned or frozen)	Boiled vegetables with butter, boiled vegetables without butter, stir-fried vegetables (including vegetables in mixed dishes)	Vegetables prepared with butter or cream are also included in this group since there is no evidence that these additions abolish the positive effects of vegetable consumption. However, the consumption of vegetables without cream or butter is recommended.
Fruit	All whole fruits (fresh or frozen)	Fresh fruit	Fruit juices are included in sugar-sweetened beverages. Canned fruit in syrup and apple sauce are included in the group sugary products due to high amounts of added sugars.
Whole grain products	Whole grain crackers/biscuits, bread rolls, slices of bread, breakfast cereals, pasta and brown rice. Products should contain at least 25% wholegrain flour	Slices of bread	The LifeLines FFQ does not distinguish between whole grain and refined products. In the Netherlands, whole meal and brown bread account for approximately 70% of bread consumption. Also, with an estimated mean intake of 95 grams per day, whole meal and brown bread are the largest contributors to the total whole grain consumption in the Netherlands. Therefore, bread was used as a proxy for whole grain consumption.

Legumes & Nuts	Plant-based, protein rich products including nuts, legumes and seeds	Legumes, nuts or seeds with a meal, nuts as snack, peanut butter	Salted nuts and salt-containing peanut butter are also included in this group since there is no evidence that this addition abolishes the positive effects of nut consumption. Peanut butter is included because peanuts are the main ingredient.

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Fish	All types of fish	Herring, fried fish, lean fish, fatty fish, other kinds of fish	All types of fish are included in this group since there is no evidence that frying or adding salt to fish abolishes the positive effects of fish consumption. Furthermore, lean types of fish are included since total fish consumption also has beneficial effects.
Oils & Soft margarines	Plant-based oils, spreads, soft margarines and other soft/liquid baking fats	Margarine spread for bread, salad dressing, mayonnaise	Salad dressing and mayonnaise are included in this group since plant-based oils are the main ingredient of these items.
Unsweetened dairy	All unsweetened milk and yoghurt products	Semi-skimmed milk, low-fat milk, buttermilk, low-fat yoghurt, full-fat yoghurt, milk in coffee	No distinction is made between low and high fat dairy, since there is evidence for health benefits of total dairy consumption. Due to high sugar content of sweetened dairy products, the Health Council advised to avoid sweetened dairy.
Coffee	Coffee	Coffee	Both coffee consumed with and without sugar are included in this group, since health benefits for coffee are found for total consumption and not for coffee consumption without sugar alone. However, the consumption of coffee without sugar is recommended.
Tea	Green or black tea	Tea	Both tea consumed with and without sugar are included in this

			group, since health benefits for tea are found for total consumption and not consumption for tea without sugar alone. However, the consumption of tea without sugar is recommended.
Neutral food groups			
Eggs	Boiled or fried eggs, omelets	Boiled eggs, fried eggs	Eggs used in combination dishes (hot meals, baked goods) are not included in this group.
Negative food groups			
Red & Processed meat	Red and processed meat, including deli meat	Deli meat, several types of beef and pork, both processed and unprocessed	Red and processed meat are both included in this group, since health effects described in literature usually concern both the consumption of red and processed meat.
Butter & Hard margarines	All types of butter and hard margarines	Butter/Margarine on bread, other spreads on bread, gravy	Butter and hard margarines used for cooking as well as on sandwiches are included in this group. Gravy is included in this group as butter and hard margarines are usually the main component.
Sugar-sweetened beverages	All types of sugar containing drinks	Breakfast drinks, soda or lemonade with sugar, fruit-drinks, fruit juice, alcohol-free beers	Fruit juice are included in this group because effects of fruit in liquid form are assumed equal to those of other sugary drinks. Sugar-containing light fruit-drinks are also included in this group, but sugar-free artificially sweetened drinks are not.
Unknown food groups			
Potatoes	Boiled and mashed potatoes	Boiled potatoes, mashed potatoes	French fries, fried potatoes and potato chips are included in savory, ready products because of their high fat and salt content.
Refined cereal products	Crackers/biscuits, bread rolls, slices of bread, breakfast	Crackers/biscuits, croissants & other bread rolls, breakfast	Refined cereal products are a less healthy choice compared with whole grain products. The health

	cereals, pasta and rice that contain less than 25% whole grain flour	cereals, pasta and rice	effects of refined cereal products are unclear. In the Netherlands, the majority of breakfast cereals, crisp breads & rusks, rice and pasta consumed concern refined grain variants (approximately 55%, 60%, 85% and 95%, respectively). These items are included in this group, as the LifeLines FFQ does not distinguish between refined and whole grain variants of the items.
White, unprocessed meat	Chicken filets, turkey filets	chicken without skin, chicken with skin	This group does not include fried chicken, which is included in savory, ready products because of the high fat and salt content.
Cheese	All cheeses, low and high fat	20/30% fat cheese, 40% fat cheese, 48% fat cheese, cream cheese	Both low and high fat cheeses are included in this group. The contribution of low-fat cheese to total cheese consumption is marginal.
Savory & Ready products	All ready products, including both snacks and ready meals	Asian ready meals, fast food, pizza, warm sauces, warm fried snacks, potato chips, French fries	This group mainly consists of products that are high in (satiated) fat and salt. The composition of the products is usually unknown and varying. The health effects of this group are unclear.
Sugary products	Sandwich spreads, candy, biscuits, cakes or chocolates	Chocolate sandwich spread, other sweet sandwich spreads, sugar or syrup in coffee/tea, small biscuits, cake or large cookies, pies, candy bars, chocolate, candy, applesauce	This group mainly consists of products that are high in sugar and/or (satiated) fat. The composition of the products is often unknown and strongly varying and the health effects of this group as a whole are unclear.
Soups	All soups	Soups with legumes, soups without legumes	The composition of soups consumed is usually unknown. Although usually high in salt, vegetables could be a main ingredient, especially of home-made soups.

Sweetened dairy	Sweetened yoghurts, ice-cream, custard, sweetened dairy drinks	Fruit yoghurts, custard, ice-cream with dairy, whipped cream, vanilla yoghurt, chocolate milk, sweetened yoghurt drinks	It is unknown whether the added sugar abolishes the effects of the nutrient rich dairy.
Artificially sweetened products	Light soda's, artificially sweetened dairy products	Light soda, light lemonade, artificially sweetened yoghurt drinks	There is yet no consensus on the health effects of artificially sweetened products, both drinks and solid foods.

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	Coronary heart disease	Stroke	T2DM	Colon cancer	Lung cancer	Systolic blood pressure	LDL-cholesterol	Body weight
Vegetables	[green]	[green]	[green] *green leafy vegetables	[green]	[green] *green leafy vegetables	[green]		
Fruit	[green]	[green]	[green]	[green]	[green]	[green]		
Whole grain products	[green]		[green]	[green]			[green] *oats	
Legumes & Nuts	[green] *nuts						[green]	
Fish	[green]	[green]						
Oils & soft margarines	[green] *MUFA						[green]	
Unsweetened dairy			[green] *yoghurt	[green] *milk, total dairy				[red] *extra ad libitum dairy
Coffee	[green]	[green]					[red] *unfiltered coffee	
Tea		[green]	[green]			[green]	[green] *green tea	
Red & processed meat		[red]	[red]	[red]	[red] *red meat			
Butter & Hard margarines	[red] *SFA						[red] *butter	
Sugar-sweetened beverages			[red]					[red]

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