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# A 10-year longitudinal study on the associations between changes in plant-based diet indices, anthropometric parameters and blood lipids in a Flemish adult population


## Abstract

**Aim**: Plant-based diets are recommended in the context of environmental sustainability and health. Since not all plant foods can be considered beneficial, a distinction needs to be made between healthful and unhealthful plant foods. The aim of this study was to investigate longitudinal associations between changes in an overall plant-based diet index, a healthful plant-based diet index and an unhealthful plant-based diet index, with changes in anthropometrics and blood lipids as indicators of morphological and metabolic fitness, respectively.

**Methods:** A 3-day dietary record was completed by 650 Flemish adults (420 men, 230 women) in 2002-2004 and 2012-2014. Three plant-based diet indices were calculated based on quintile scores regarding the intake of animal or plant-based food items. Associations between 10-year changes in diet indices and changes in anthropometrics and blood lipids were tested using multivariate linear regression.

**Results:** Plant-based diet indices did not differ over time. Using the unadjusted model, few significant associations were found between changes in diet indices and changes in anthropometrics and blood lipids. However, these relationships disappeared after adjusting for confounding. In women, a positive association was found between changes in overall plant-based diet index and changes in body mass index in the adjusted model.

**Conclusion:** Index values did not differ over time and few longitudinal associations were found.


**Key words**

Adults, blood cholesterol, body mass index, longitudinal change, plant-based diet index, waist circumference

**Introduction**

Tackling diet-related factors through preventive interventions is one of the leading priorities of our time.[1] Substantial evidence indicates that plant-based diets involve various health benefits[2] and are more sustainable compared to diets rich in animal products because of using fewer natural resources and being less taxing on the environment.[3,4] Hence, plant-based diets are recommended in more recent food-based dietary guidelines (e.g. in Belgium, the Netherlands and Brazil). However, a clear definition indicating the ratio of animal versus plant food components is currently lacking.

Diet indices have been developed and are more recently used to measure diet quality by scoring intake of specific components of foods, possibly in combination with multiple nutrients.[5] Some of these indices (e.g. the Mediterranean Diet Score, the Healthy Eating Index (HEI)) also positively weigh plant-based food components such as fruits, vegetables and whole grains.[6] The use of such indices as a measure of diet quality has emerged to be a more preferred approach to study the relationship between dietary habits and noncommunicable chronic diseases.[5,7]

Several studies showed that plant-based diets have beneficial effects on blood lipid levels. In their review, Ferdowsian et al.[8] demonstrated that individuals consuming more plant foods have lower total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) concentrations compared to those following diets that include more animal products. Furthermore, reviews by Wang et al.[9] and Yokoyama et al.[10] showed a lowering effect of vegetarian diets on TC, high-density lipoprotein cholesterol (HDL-C) and LDL-C. No remarkable effect was found on triglyceride concentrations.[9,10] Because the proportion of vegetarians is low in most cultures, Martinez-Gonzalez et al.[11] studied the association between a provegetarian food pattern (i.e. positively weighing vegetable-derived foods and negatively weighing animal-derived foods) and reduction in total mortality in 7216 participants at high cardiovascular risk. This prospective study demonstrated that preference for plant-derived foods was associated with reduced mortality from any cause compared with preferential selection of foods from animal sources.

Further elaboration of the plant-based diet index resulted in an overall plant based-diet index (PDI), a healthy plant-based diet index (hPDI) and an unhealthy plant-based diet index (uPDI)[12]. Using prospective data on health professionals (n>200.000), Satija et al.[12] demonstrated that PDI and hPDI were inversely associated with type 2 diabetes incidence whilst a positive association was reported for the uPDI. Using the same classification of plant-based diet indices, applied on a nationally representative sample of US adults, Kim et al.[13] found a nonlinear association between all-cause mortality and the PDI. Their sex-specific results showed that a hPDI above the median was associated with a lower risk in women. Using their own created plant-based diet index, applied on baseline food intake data of 9633 participants in the prospective Rotterdam Study, Chen et al.[14] reported that a diet higher in plant foods and lower in animal foods was associated with a lower adiposity status over time.



The abovementioned literature indicates the growing importance of indices that positively weigh plant foods and negatively weigh animal foods to characterise the food pattern. Outcomes in the abovementioned studies were mortality, incidence of type 2 diabetes and anthropometrics. To the best of our knowledge, no studies investigated associations between these diet indices and blood lipids. Moreover, as one's diet quality does not remain stable over time[15], there is a need for a dynamic research design that can determine whether changes in plant-based diet indices are associated with changes in health-related outcomes.[16]

Therefore, the aim of the present study was to apply an overall plant-based diet index (PDI), a healthful PDI (hPDI) and an unhealthful PDI (uPDI) in order to investigate the longitudinal associations between changes in these indices with changes in anthropometric parameters (i.e. body mass index (BMI) and waist circumference) and blood lipids (i.e. TC, HDL-C, LDL-C, ratio TC/HDL-C and triglycerides) in Flemish adults over a period of 10 years.

## Methods

Data for this study were collected as part of an overall research project supported by the Policy Research Centre Sport of the Flemish government aiming to investigate (evolution in) health-related behaviours, physical and mental health as well as physical fitness among the Flemish adult population (over time). In 2002, a random sample of adult women and men (aged 18 to 75 years) was selected being representative for geographic distribution, age, gender and educational level. A first test moment took place during the period 2002-2004, whereas a second test moment was held during the period 2012-2014. Of the original 1562 participants assessed at the first test moment, 650 participants (420 men and 230 women) could be assessed 10 years later. Before each test moment, all participants received information about the various assessments, which were exactly the same at both occasions, and signed a written informed consent. Ethical approval was granted by the ethical and medical committee of [removed for blind peer review].

Participants completed a 3-day dietary record booklet, in which they were asked to record all foods and drinks consumed during two weekdays and one weekend day. If possible, the amount of foods and drinks had to be provided in g and/or ml. Otherwise, participants were inquired to estimate the consumed amount by using standard household measures (e.g. tablespoons). Afterwards, dietary records were analysed by using the Becel Institute Nutrition Software (BINS) (Unilever Co.; Rotterdam, The Netherlands). Total energy intake (in kcal/day), consumption of food groups (in g/day), macronutrients (in g/day) and micronutrients (in mg/day or µg/day) were calculated.

The PDI, hPDI and uPDI were calculated based on methods proposed by Martinez-Gonzalez et al.[11] and Satija et al.[12]. The overall PDI is similar in composition to the "provegetarian food pattern" used by Martinez-Gonzalez et al.[11], whereas the three indices used in the present study are the same as those used by Satija et al.[12]. Accordingly, after collecting the 3-day dietary record booklets, all consumed foods were classified into 18 different food groups. A distinction was made between healthy plant foods (i.e. fruits, vegetables, nuts, whole grains, legumes, tea/coffee and vegetable oils), unhealthy plant foods (i.e. potatoes, fruit juices, sugar-sweetened beverages, refined grains, and sweets/desserts) and animal foods (i.e. eggs, fish, dairy, meat, animal fats and miscellaneous animal-based foods). Consumption for total energy intake was adjusted by using the residual method[11], transforming the consumption of each food group in energy-adjusted intakes per food group, from which sex-specific quintiles were computed according to consumption. Each quintile was assigned a score between 1 and 5. For the overall PDI, positive scores were given to plant foods and reverse scores to animal foods. On the one hand, participants received a score of 5 for each plant food group for which they had a consumption above the highest quintile, a score of 4 for each plant food group for which they had a consumption above the second highest quintile but below the highest quintile, and so on (i.e. positive scores). On the other hand, participants received a score of 5 for each animal food group for which they had a consumption below the lowest quintile, a score of 4 for each animal food group for which they had a consumption below the second lowest quintile but above the lowest quintile, and so on (i.e. reverse scores).

For the hPDI, positive scores were awarded to healthy plant food groups and reverse scores for less healthy plant food groups and animal food groups using the same quintile system. Lastly and likewise, positive scores were given to less healthy food groups and reverse scores to healthy plant food groups and animal food groups for the uPDI. To obtain the value of the indices, the scores of all 18 food groups were added together, resulting in a score ranging from 18 to 90. A high score on the overall PDI represents a diet high in plant-based foods and low in animal-based foods. For the hPDI, a high score represents a diet high in healthy plant-based foods and low in both unhealthy plant-based and animal-based foods. Lastly, a high score on the uPDI represents a diet high in unhealthy plant-based foods and low in both healthy plant-based foods and animal-based foods[12].

Anthropometric parameters were measured using the standardized techniques and equipment proposed by the International Society for the Advancement of Kinanthropometry (ISAK)[17]. A fasting blood sample was taken to determine TC, HDL-C, LDL-C and triglycerides. To account for the level of the cardiorespiratory fitness and smoking, a maximal exercise test was performed and the WHO Monica Smoking Questionnaire[18] was taken, respectively. The protocols of these measurements are described elsewhere.[6]

Statistical analyses were conducted using SPSS 25.0 (SPSS Inc. Chicago, IL) with the alpha significance level set at 0.05. To perform a drop-out analysis, independent samples t-tests were used. To check significant changes over time between the two test moments (i.e. from 2002-2004 to 2012-2014) for continuous variables of interest, a paired samples t-test was used. Cross tabulation and Chi-square analyses were performed to examine differences in number of actual smokers between both test moments. Independent samples t-tests were used to examine possible gender differences in the calculated index scores. Residual change scores of the diet indices (i.e. PDI, hPDI, uPDI), blood lipids (TC, HDL-C, LDL-C, ratio TC/HDL-C, triglycerides), anthropometric parameters (waist circumference and BMI) and $VO_{2peak}$ between the two test moments were calculated by regressing the follow-up measures onto their respective baseline measures. The residual change scores thus describe the amount of change between the first and second test moment, independent of baseline levels. Multivariate linear regression analyses were used to test the associations between changes in the three plant-based diet indices and changes in anthropometric parameters and blood lipids, respectively. These associations were tested in an unadjusted and an adjusted model, correcting for potential confounding factors (i.e. age, changes in smoking behaviour and $VO_{2peak}$ with the addition of waist circumference for examining the association with changes in blood lipids). All analyses were stratified by gender[13,19], and thus performed separately for men and women.

**Results**

Table 1 presents differences between the sample of participants who dropped out after being assessed at the first test moment (N=912) and the 10-year follow-up sample (N=650). More specifically, 55 percent of men and 64 percent of women dropped out of the present 10-year longitudinal study. In men, the follow-up sample scored significantly lower on ratio TC/HDL-C and triglycerides compared to men who dropped out from this study. In women, the follow-up sample scored significantly lower on BMI, waist circumference and ratio TC/HDL-C, and significantly higher on $VO_{2peak}$ and HDL-C than the women who dropped out.

The follow-up sample characteristics and scores on the three indices are represented in Table 2 for both test moments. In men, there was a significant increase over time in waist circumference, BMI and ratio TC/HDL-C and a significant decrease in $VO_{2peak}$, HDL-C, energy intake, intake of carbohydrates and the number of actual smokers. In women, waist circumference, BMI, fish intake, intake of polyunsaturated fat, TC, LDL-

C and ratio TC/HDL-C significantly increased over time, wheras $VO_{2peak}$, meat intake and the number of actual smokers significantly decreased. When compared to men, women had a significantly higher score on hPDI (p=0.011) and uPDI (p=0.028) in 2002 and also on hPDI (p=0.045) in 2012.

Table 3 presents the associations between changes in PDI, hPDI and uPDI and changes in anthropometric parameters as well as changes in blood lipids, both for the unadjusted model (model 1) and the adjusted model (model 2). Out of the 21 investigated longitudinal associations, only four were found to be significant. In men, a positive association was established between changes in uPDI and changes in waist circumference ($p<0.001$) as well as changes in BMI (p=0.007) based on the unadjusted model. In women, there was a positive association between changes in PDI and changes in BMI (p=0.046) in the adjusted model only, with an increase in PDI being associated with an increase in BMI. Furthermore, the unadjusted model indicated that an increase in uPDI was associated with an increase in TC (p=0.044).



## Discussion

The aim of this longitudinal study was to apply an overall plant-based diet index (PDI), a healthful PDI (hPDI) and an unhealthful PDI (hPDI) in order to investigate the longitudinal association between changes in these indices with changes in anthropometric parameters and blood lipids over a 10-year period.

Regardless of gender, no significant changes over time were found for mean scores on PDI, hPDI and uPDI between 2002-2004 and 2012-2014. This is in contrast with Mertens et al.[6], who found that the scores on the Diet Quality Index and HEI-2010 did significantly increase over time based on the same study sample. In addition, women showed a significantly higher score on hPDI at both test moments and on uPDI at the first test moment compared to men in the present study. Considering that, in general, women are more health conscious than men[20], the higher score on uPDI in women is remarkable.

Only few associations were found between changes in the plant-based diet indices and changes in anthropometrics. In men, an increase in uPDI was associated with an increase in BMI and waist circumference in the unadjusted model, but the relation disappeared after adjusting for confounding. Nevertheless, these positive associations are in line with the expectations. In women, an increased PDI was associated with an increase in BMI in the adjusted model only. Our results, concerning associations between the plant-based diet indices and anthropometrics, differ from the study of Chen et al.[14], demonstrating that a higher score on the plant-based diet index was associated with a lower BMI, waist circumference, fat mass index and body fat percentage. These conflicting results may be explained by the different methods used. The sample size in the Chen et al.[14] study was larger and only baseline measurement of dietary intake were available, whereas in the present study food intake was measured at both test moments.

Moreover, no longitudinal associations were found between the applied plant-based diet indices and blood lipids, except for a positive association between uPDI and total cholesterol in women in the unadjusted model. However, this significant relation disappeared after adjusting for confounding factors. This is in contrast with the literature review findings of Yokoyama et al.[10] and Wang et al.[9], who both demonstrated a lowering effect of vegetarian diets on total, LDL and HDL cholesterol. However, most studies included in the reviews were cross-sectional in nature, whereas the present paper used a methodologically stronger prospective cohort study design investigating changes over 10 years of time. Besides, the studies included in both literature reviews used specific categories (e.g. vegan, vegetarian, ovolactovegetarian), whereas in the present study indices were used as continuous measures. However, in Belgium, only a 1.7% of the population follows a vegetarian diet[21] and given that this study did not specifically recruited vegetarians, the proportion of vegetarians in the present sample was very small (i.e. 0.46% of all participants). This can cause limited variation in index scores. Consequently, this limited variation in score could possibly contribute to the explanation of the lack in associations between the diet indices and blood lipids. To the best of our knowledge, the present study was the first to investigate associations between plant-based diet indices and blood lipids. Hence, comparison with existing literature is difficult. Moreover, previous research on the relation between plant-based diet indices and more distal health outcomes such as type 2 diabetes and mortality delivered equivocal results. Satija et al.[12] studied the associations of plant-based diet indices with the incidence of type 2 diabetes and demonstrated a significant linear inverse association for PDI as well as hPDI. Besides, uPDI was positively associated with the incidence of type 2 diabetes. On the contrary, Kim et al.[13] who investigated the associations between all-cause mortality and PDI, hPDI as well as uPDI, found only very few significant associations. As stated by Kim et al.[13] it could be possible that the results may be overadjusted and underestimate the true associations.



The present study used specific plant-based diet indices to overcome some previous methodological shortcomings of other studies, such as using specific categories to divide the population into different diet groups (i.e. vegan, vegetarian, omnivorous).[8] However, the continuous indices used in this study also have some limitations. Because the calculation is based on quintiles, the individual score of a participant depends on the intakes of the total sample under investigation. Since the quintiles were calculated separately for the two test moments, the value of the quintiles may differ between 2002-2004 and 2012-2014. Furthermore, the division into healthy and less healthy plant foods, although based on scientific literature, can be discussed. For example, the indices used in the present study classified potatoes as less healthy plant foods, while in the Flemish dietary guidelines potatoes are considered as a recommended and adequate nutrient. This classification could thus depend on cultural differences, with some of them using potatoes as staple foods and other as vegetables.

Some other aspects in relation to the present study need to be taken into account. As in all longitudinal studies, a considerable number of participants dropped out, especially women in this case. Moreover, our drop-out analysis indicated a healthy volunteer effect. Therefore, the results of the present study are not entirely representative for the Flemish adult population. Besides, no specific exclusion criteria were used for implausible reporting of nutritional intake. However, mean energy intake values are very close to values of a recent National Food Survey after exclusion for under-reporters (2149 kcal/day) or to the plausible reporters of the initial sample (2782 ± 1916 kcal/day and 2171 ± 348 kcal/day for males and females, respectively) using the conservative exclusion criteria as proposed by McCrory et al.[22]. Another limitation is that food intake was self-reported, which implies that measurement errors are inevitable. Besides, food intake was assessed for only three days and even though these 3-day dietary records were collected throughout the year across participants, the influence of different seasons on the food consumption was not assessed. Although the use of 3-day dietary records has been validated against a 7-day dietary record[23], long-term conclusions based on this method should be interpreted with caution.

An important strength of the present study is the novelty of its particular research topic and the dynamic longitudinal design being used. To our knowledge, it is the first 10-year longitudinal study investigating the associations between changes in three plant-based diet indices and changes in anthropometric parameters and blood lipids among adults. Other strengths include the use of objective measures for anthropometric parameters and blood lipids, the use of residual change scores and the inclusion of some potential confounding factors in our analyses, conducted for men and women separately.

## Conclusions

It can be concluded that there were no differences in mean plant-based diet index scores over time. In addition, few significant associations were found between the changes in diet indices and the changes in the evaluated anthropometric and blood lipid parameters, for both the unadjusted and adjusted models. Only in women an increase in overall plant-based diet index was associated with an increase in BMI over the 10 years period and this for the adjusted model only.

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**Table 1** Drop-out analysis by means of independent samples t-test.

| 2002-2004 | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Drop-out (*N=501)* | Follow-up (*N=420)* | | Drop-out (*N=411)* | Follow-up (*N=230*) | |
| | Mean (SD) | Mean (SD) | *p* | Mean (SD) | Mean (SD) | *p* |
| Body mass index (kg/m²) | 26 (3.4) | 25 (2.8) | 0.148 | 25 (4.2) | 24 (3.2) | **<0.001** |
| Waist circumference (cm) | 90 (10) | 89 (8.8) | 0.595 | 78 (10) | 76 (7.6) | **0.001** |
| $VO_{2peak}$ (ml/kg/min) | 37 (9.0) | 37 (8.1) | 0.331 | 27 (6.3) | 29 (6.1) | **<0.001** |
| Total cholesterol (mg/dl) | 209 (41) | 206 (38) | 0.238 | 203 (36) | 205 (39) | 0.521 |
| HDL cholesterol (mg/dl) | 54 (12) | 55 (12) | 0.159 | 66 (15) | 70 (15) | **0.001** |
| LDL cholesterol (mg/dl) | 130 (37) | 128 (34) | 0.332 | 119 (32) | 116 (35) | 0.413 |
| Ratio Total/HDL cholesterol | 4.0 (1.1) | 3.9 (1.0) | **0.028** | 3.2 (0.8) | 3.1 (0.9) | **0.019** |
| Triglycerides (mg/dl) | 122 (84) | 112 (66) | **0.036** | 94 (43) | 93 (42) | 0.858 |

$VO_{2peak}$ = peak oxygen uptake; HDL = high-density lipoprotein; LDL = low-density lipoprotein
Significant results (*p<0.05)* are indicated in bold

**Table 2** Characteristics of the study participants (N=650) and their 10-year evolution based on paired samples t-tests.

| | Men (N=420) | | | Women (N=230) | | |
|---|---|---|---|---|---|---|
| | 2002-2004 | 2012-2014 | | 2002-2004 | 2012-2014 | |
| | Mean (SD) | Mean (SD) | *p* | Mean (SD) | Mean (SD) | *P* |
| Age (years) | 47 (10) | 58 (10) | **<0.001** | 45 (8.4) | 56 (8.4) | **<0.001** |
| Waist circumference (cm) | 89 (8.5) | 90 (8.8) | **0.001** | 76 (7.5) | 78 (8.5) | **<0.001** |
| Body Mass Index (kg/m²) | 25 (2.7) | 26 (3.0) | **<0.001** | 23 (3.1) | 24 (3.4) | **<0.001** |
| $VO_{2peak}$ relative (ml/kg/min) | 38 (8.0) | 37 (8.7) | **<0.001** | 30 (5.6) | 28 (5.6) | **<0.001** |
| Energy intake (kcal/day) | 2599 (679) | 2419 (625) | **<0.001** | 2033 (517) | 1966 (546) | 0.102 |
| Meat intake (g/day) | 162 (83) | 152 (82) | 0.050 | 116 (65) | 102 (62) | **0.009** |
| Fish intake (g/day) | 33 (45) | 39 (58) | 0.169 | 33 (45) | 56 (78) | **<0.001** |
| Vegetable intake (g/day) | 119 (86) | 123 (93) | 0.417 | 122 (93) | 130 (88) | 0.294 |
| Fruit intake (g/day) | 167 (149) | 181 (151) | 0.082 | 184 (136) | 212 (140) | **0.012** |
| Protein (percent of energy) | 16 (3.3) | 16 (3.7) | 0.154 | 16 (3.3) | 16 (3.7) | 0.410 |
| Carbohydrates (percent of energy) | 47 (7.6) | 46 (7.9) | **0.018** | 46 (6.8) | 45 (7.5) | 0.469 |
| Saturated fat (percent of energy) | 13 (3.1) | 13 (3.2) | 0.632 | 14 (3.1) | 13 (3.4) | 0.221 |
| Monounsaturated fat (percent of energy) | 13 (3.3) | 13 (3.3) | 0.633 | 13 (3.4) | 13 (3.3) | 0.569 |
| Polyunsaturated fat (percent of energy) | 5.7 (2.0) | 5.8 (1.9) | 0.369 | 5.7 (2.0) | 6.2 (2.2) | **0.014** |
| Cholesterol intake (mg/day) | 279 (115) | 275 (120) | 0.096 | 237 (104) | 230 (100) | 0.400 |
| Total cholesterol (mg/dl) | 207 (37) | 205 (38) | 0.579 | 208 (39) | 225 (37) | **<0.001** |

| | | | | | | |
|---|---|---|---|---|---|---|
| HDL cholesterol (mg/dl) | 56 (12) | 54 (12) | **<0.001** | 71 (16) | 70 (15) | 0.167 |
| LDL cholesterol (mg/dl) | 128 (34) | 130 (34) | 0.264 | 118 (35) | 136 (32) | **<0.001** |
| Ratio Total/HDL cholesterol | 3.9 (1.0) | 4.0 (1.2) | **0.029** | 3.0 (0.9) | 3.4 (0.8) | **<0.001** |
| Triglycerides (mg/dl) | 112 (65) | 108 (75) | 0.297 | 92 (37) | 96 (54) | 0.257 |
| Plant-based diet index (18-90 point range) | 53.7 (5.8) | 53.9 (5.9) | 0.521 | 53.7 (5.6) | 53.8 (5.6) | 0.818 |
| Unhealthful plant-based diet index (18-90 point range) | 53.9 (6.5) | 53.9 (6.7) | 0.923 | 55.4 (5.5) | 54.8 (5.8) | 0.204 |
| Healthful plant-based diet index (18-90 point range) | 53.2 (7.1) | 53.3 (7.0) | 0.764 | 55.2 (5.9) | 55.4 (6.2) | 0.630 |
| | % | % | *p chi²* | % | % | *p chi²* |
| Actual smokers (%) | 14.5 | 8.8 | **0.007** | 15.5 | 8.3 | **0.011** |

$VO_{2peak}$ = peak oxygen uptake; HDL = high-density lipoprotein; LDL = low-density lipoprotein
Significant results (*p<0.05*) are indicated in bold

**Table 3** Associations between 10-year changes in overall plant-based diet index (PDI), healthful plant-based diet index (hPDI) and unhealthful plant-based diet index (uPDI) and changes in anthropometric parameters (i.e. waist circumference (cm), body mass index (kg/m²)) as well as in blood lipids (i.e. total cholesterol (mg/dl), HDL cholesterol (mg/dl), LDL cholesterol (mg/dl), ratio total/HDL cholesterol, triglycerides (mg/dl)).

| | Men (*N = 420*) | | | | Women (*N = 230*) | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 | | Model 2 | | Model 1 | | Model 2 | |
| | β | Adj. $R^2$ | β | Adj. $R^2$ | β | Adj. $R^2$ | β | Adj. $R^2$ |
| PDI-Waist circumference | -0.052 | <0.001 | 0.075 | 0.062 | 0.119 | 0.009 | 0.116 | 0.230 |
| PDI-BMI | -0.028 | -0.002 | 0.034 | 0.017 | 0.142 | 0.015 | 0.135* | **0.219** |
| PDI-Total cholesterol | -0.012 | -0.003 | 0.077 | -0.051 | 0.043 | -0.004 | 0.047 | 0.167 |
| PDI-HDL cholesterol | 0.005 | -0.003 | 0.137 | 0.173 | -0.065 | -0.001 | -0.020 | 0.033 |
| PDI-LDL cholesterol | -0.012 | -0.003 | 0.085 | -0.037 | 0.056 | -0.002 | 0.057 | 0.165 |
| PDI-Ratio Total/HDL cholesterol | -0.022 | -0.002 | -0.059 | 0.130 | 0.087 | 0.002 | 0.038 | 0.209 |
| PDI-Triglycerides | 0.022 | -0.002 | -0.112 | 0.015 | 0.088 | 0.002 | 0.018 | 0.191 |
| hPDI-Waist circumference | -0.079 | 0.003 | -0.089 | 0.065 | 0.070 | <0.001 | 0.052 | 0.219 |
| hPDI-BMI | -0.023 | -0.002 | -0.004 | 0.015 | 0.070 | -0.001 | 0.052 | 0.202 |
| hPDI-Total cholesterol | 0.006 | -0.003 | 0.055 | -0.054 | -0.043 | -0.004 | 0.057 | 0.168 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| hPDI-HDL cholesterol | -0.063 | 0.001 | -0.079 | 0.160 | -0.039 | -0.004 | 0.023 | 0.033 |
| hPDI-LDL cholesterol | 0.027 | -0.002 | 0.110 | -0.032 | -0.025 | -0.005 | 0.057 | 0.165 |
| hPDI-Ratio Total/HDL cholesterol | 0.065 | 0.001 | 0.110 | 0.139 | -0.010 | -0.005 | 0.016 | 0.208 |
| hPDI-Triglycerides | 0.008 | -0.003 | -0.031 | 0.003 | -0.022 | -0.005 | -0.019 | 0.191 |
| uPDI-Waist circumference | 0.204*** | **0.039** | 0.153 | 0.080 | 0.011 | -0.005 | 0.000 | 0.217 |
| uPDI-BMI | 0.144** | **0.018** | -0.049 | 0.018 | 0.015 | -0.005 | -0.001 | 0.200 |
| uPDI-Total cholesterol | 0.036 | -0.002 | -0.185 | -0.023 | 0.148* | **0.016** | 0.042 | 0.166 |
| uPDI-HDL cholesterol | 0.049 | -0.001 | 0.012 | 0.154 | 0.034 | -0.004 | -0.018 | 0.033 |
| uPDI-LDL cholesterol | 0.010 | -0.003 | -0.216 | 0.002 | 0.130 | 0.012 | 0.053 | 0.164 |
| uPDI-Ratio Total/HDL cholesterol | -0.030 | -0.002 | -0.156 | 0.151 | 0.066 | -0.001 | 0.015 | 0.208 |
| uPDI-Triglycerides | 0.021 | -0.002 | -0.018 | 0.003 | 0.076 | 0.000 | 0.009 | 0.191 |

*p < 0.05, **p < 0.01, ***p < 0.001

Model 1: unadjusted

Model 2 (anthropometric parameters): adjusted for age and residual change scores for smoking and peak oxygen uptake

Model 2 (blood lipids): adjusted for age and residual change scores for smoking, peak oxygen uptake and waist circumference

HDL = high-density lipoprotein; LDL = low-density lipoprotein

Significant results (*p<0.05)* are indicated in bold

**eTable 1** Classification of food items into the 18 food groups

| | | PDI | hPDI | uPDI |
|---|---|---|---|---|
| **Plant food groups** | | | | |
| *Healthy* | | | | |
| Fruits | Orange, grapefruit, apple, kiwi, banana, grape, strawberry, plum, mandarin, pear, etc. | + | + | - |
| Vegetables | Asparagus, tomato, carrot, broccoli, cucumber, spinach, zucchini, lettuce, mushrooms, brussels sprouts, etc. | + | + | - |
| Nuts | Nuts, peanut butter | + | + | - |
| Whole grains | Dark bread, brown rice, muesli, oatmeal, whole-wheat pasta, etc. | + | + | - |
| Legumes | Beans, peas, lentils, soybeans, etc. | + | + | - |
| Tea / coffee | Tea, coffee, decaffeinated coffee | + | + | - |
| Vegetable oils | Vegetable oil for cooking | + | + | - |
| *Unhealthy* | | | | |
| Potatoes | Baked and boiled potatoes, French fries, potato croquette | + | - | + |
| Fruit juices | Orange juice, apple juice, pineapple juice, grape juice, etc. | + | - | + |
| Sugar-sweetened beverages | Carbonated beverages with sugar, noncarbonated fruit drinks with sugar | + | - | + |
| Refined grains | White bread, white rice, refined grain breakfast cereal, French bread roll, pasta, etc. | + | - | + |
| Sweets / desserts | Chocolate, candy, pie, cookies, etc. | + | - | + |
| **Animal food groups** | | | | |
| Eggs | Eggs | - | - | - |
| Fish | Trout, shrimp, herring, codfish, mackerel, tuna, salmon, etc. | - | - | - |
| Dairy | Milk, cheese, yogurt, ice cream, etc. | - | - | - |
| Meat | Pork, chicken, beef, veal, etc. | - | - | - |
| Animal fats | Butter | - | - | - |
| Miscellaneous animal-based foods | Pizza, bami goreng, chilli con carne, etc. | - | - | - |

+: positive scores
-: reverse scores