# Supplementary material 1

**Table 1.** Age-adjusted serum carotenoid concentrations (µmol/L) across ethnic groups in men

|  |  |  |
| --- | --- | --- |
|  | **Geometric mean (95% CI)**\* |  |
|  | **Dutch** | **South Asian Surinamese** | **African Surinamese** | **Turkish** | **Moroccan** | **P value** |
| **Total carotenoids** | 2.07 (1.90, 2.26) | 1.71 (1.57, 1.87) | 1.91 (1.74, 2.09) | 2.26 (2.06, 2.47) | 1.71 (1.56, 1.89) | 0.001 |
| **α-carotene** | 0.10 (0.09, 0.11) | 0.08 (0.07, 0.09) | 0.10 (0.08, 0.11) | 0.08 (0.07, 0.09) | 0.11 (0.10, 0.12) | 0.001 |
| **β-carotene** | 0.61 (0.54, 0.69) | 0.37 (0.33, 0.42) | 0.52 (0.45, 0.59) | 0.60 (0.53, 0.68) | 0.52 (0.45, 0.59) | 0.018 |
| **β-cryptoxanthin** | 0.30 (0.26, 0.34) | 0.21 (0.18, 0.25) | 0.24 (0.21, 0.28) | 0.33 (0.28, 0.38) | 0.21 (0.18, 0.25) | <0.001 |
| **Lutein** | 0.29 (0.26, 0.31) | 0.28 (0.26, 0.30) | 0.30 (0.27, 0.33) | 0.28 (0.26, 0.31) | 0.26 (0.23, 0.28) | <0.001 |
| **Lycopene**† | 0.63 (0.57, 0.69) | 0.66 (0.60, 0.72) | 0.63 (0.57, 0.69) | 0.84 (0.78, 0.91) | 0.53 (0.46, 0.59) | 0.006 |
| **Zeaxanthin** | 0.08 (0.07, 0.08) | 0.06 (0.05, 0.07) | 0.06 (0.06, 0.07) | 0.07 (0.06, 0.07) | 0.04 (0.04, 0.04) | 0.004 |

\*Estimated geometric mean of log10 transformed serum carotenoid concentration at age: 46.96 obtained by using ANCOVA

†Mean

**Table 2.** Age-adjusted serum carotenoid concentrations (µmol/L) across ethnic groups in women

|  |  |  |
| --- | --- | --- |
|  | **Geometric mean (95% CI)**\* |  |
|  | **Dutch** | **South Asian Surinamese** | **African Surinamese** | **Turkish** | **Moroccan** | **P value** |
| **Total carotenoids** | 2.47 (2.27, 2.70) | 1.94 (1.79, 2.11) | 2.04 (1.87, 2.22) | 2.50 (2.29, 2.73) | 1.95 (1.78, 2.13) | 0.012 |
| **α-carotene** | 0.13 (0.11, 0.14) | 0.10 (0.09, 0.12) | 0.12 (0.11, 0.14) | 0.10 (0.09, 0.12) | 0.13 (0.12, 0.15) | 0.019 |
| **β-carotene** | 0.73 (0.65, 0.83) | 0.51 (0.45, 0.57) | 0.61 (0.54, 0.69) | 0.68 (0.61, 0.77) | 0.64 (0.57, 0.73) | <0.001 |
| **β-cryptoxanthin** | 0.36 (0.31, 0.42) | 0.30 (0.26, 0.34) | 0.27 (0.23, 0.31) | 0.35 (0.31, 0.41) | 0.26 (0.23, 0.30) | 0.002 |
| **Lutein** | 0.37 (0.34, 0.40) | 0.27 (0.25, 0.29) | 0.33 (0.30, 0.35) | 0.35 (0.32, 0.38) | 0.27 (0.25, 0.30) | <0.001 |
| **Lycopene**† | 0.62 (0.56, 0.68) | 0.67 (0.61, 0.73) | 0.55 (0.49, 0.61) | 0.89 (0.83, 0.95) | 0.57 (0.51, 0.63) | 0.399 |
| **Zeaxanthin** | 0.10 (0.09, 0.11) | 0.06 (0.06, 0.07) | 0.07 (3.4, 4.1) | 0.06 (0.06, 0.07) | 0.04 (0.04, 0.05) | <0.001 |

\*Estimated geometric mean of log10 transformed serum carotenoid concentration at age: 43.92 obtained by using ANCOVA

†Mean

**Supplementary material 2**

**Table 1.** Extra analyses of the association of carotenoid concentrations with type 2 diabetes in the study population

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **N** | **Cases** | **PR**\* | **95% CI** |
| **Total carotenoids** |
| Model 1† | 1002 | 133 | 0.67 | 0.54, 0.84 |
| Model 2‡ | 999 | 133 | 0.81 | 0.63, 1.02 |
| Model 3§ | 1002 | 133 | 0.67 | 0.54, 0.84 |
| **α-carotene** |
| Model 1 | 1002 | 133 | 0.57 | 0.42, 0.77 |
| Model 2 | 999 | 133 | 0.67 | 0.50, 0.91 |
| Model 3 | 1002 | 133 | 0.57 | 0.42, 0.78 |
| **β-carotene** |
| Model 1 | 1002 | 133 | 0.45 | 0.32, 0.63 |
| Model 2 | 999 | 133 | 0.54 | 0.38, 0.76 |
| Model 3 | 1002 | 133 | 0.45 | 0.32, 0.63 |
| **β-cryptoxanthin** |
| Model 1 | 1002 | 133 | 0.73 | 0.58, 0.92 |
| Model 2 | 999 | 133 | 0.84 | 0.67, 1.06 |
| Model 3 | 1002 | 133 | 0.73 | 0.58, 0.91 |
| **Lutein** |
| Model 1 | 1002 | 133 | 0.97 | 0.79, 1.18 |
| Model 2 | 999 | 133 | 1.08 | 0.88, 1.32 |
| Model 3 | 1002 | 133 | 0.98 | 0.80, 1.20 |
| **Lycopene** |
| Model 1 | 1002 | 133 | 0.98 | 0.81, 1.18 |
| Model 2 | 999 | 133 | 1.14 | 0.93, 1.38 |
| Model 3 | 1002 | 133 | 0.97 | 0.80, 1.17 |
| **Zeaxanthin** |
| Model 1 | 1002 | 133 | 0.89 | 0.71, 1.10 |
| Model 2 | 999 | 133 | 1.08 | 0.86, 1.37 |
| Model 3 | 1002 | 133 | 0.89 | 0.71, 1.11 |

\*PR=prevalence ratio; calculated using multivariate Cox regression analysis with a constant time at risk of one year; PR given per 1SD increase in serum carotenoid concentration

†Model 1: adjusted for age, sex, ethnicity, highest education level achieved (low, middle, high), smoking status (current, former, never), alcohol intake (abstinent, low intake, moderate intake, high intake), physical activity (adherent to the Dutch Healthy Physical Activity Guideline or not) and BMI (kg/m2)

‡Model 2: model 1 additionally adjusted for total cholesterol (mmol/L)

§Model 3: model 1 additionally adjusted for season of blood collection (winter, spring, summer, fall)

# Supplementary material 3

**Table 1.** Association of carotenoid concentrations with type 2 diabetes in study population stratified by sex

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Men** | **Women** |  |
|  | **N** | **Cases** | **PR (95% CI)**\* | **N** | **Cases** | **PR (95% CI)** | **P value**† |
| **Total carotenoids**  |  |  |  |  |  |  |  |
| Model 1‡ | 494 | 80 | 0.62 (0.47, 0.83) | 520 | 56 | 0.60 (0.43, 0.82) | 0.637 |
| Model 2§ | 485 | 79 | 0.63 (0.47, 0.86) | 517 | 54 | 0.62 (0.45, 0.87) | 0.734 |
| Model 3|| | 485 | 79 | 0.70 (0.52, 0.94) | 517 | 54 | 0.63 (0.44, 0.90) | 0.819 |
| Model 4¶ | 485 | 79 | 0.69 (0.51, 0.93) | 515 | 54 | 0.62 (0.43, 0.89) | 0.797 |
| **α-carotene** |  |  |  |  |  |  |  |
| Model 1 | 494 | 80 | 0.56 (0.38, 0.82) | 520 | 56 | 0.42 (0.26, 0.66) | 0.352 |
| Model 2 | 485 | 79 | 0.58 (0.39, 0.86) | 517 | 54 | 0.46 (0.28, 0.74) | 0.516 |
| Model 3 | 485 | 79 | 0.67 (0.45, 0.96) | 517 | 54 | 0.46 (0.28, 0.76) | 0.538 |
| Model 4 | 485 | 79 | 0.65 (0.45, 0.96) | 515 | 54 | 0.46 (0.28, 0.76) | 0.555 |
| **β-carotene** |  |  |  |  |  |  |  |
| Model 1 | 494 | 80 | 0.41 (0.26, 0.63) | 520 | 56 | 0.40 (0.25, 0.64) | 0.722 |
| Model 2 | 485 | 79 | 0.40 (0.26, 0.63) | 517 | 54 | 0.42 (0.26, 0.69) | 0.932 |
| Model 3 | 485 | 79 | 0.47 (0.30, 0.73) | 517 | 54 | 0.41 (0.25, 0.69) | 0.949 |
| Model 4 | 485 | 79 | 0.47 (0.30, 0.72) | 515 | 54 | 0.41 (0.25, 0.69) | 0.958 |
| **β-cryptoxanthin** |  |  |  |  |  |  |  |
| Model 1 | 494 | 80 | 0.62 (0.45, 0.85) | 520 | 56 | 0.70 (0.50, 0.97) | 0.795 |
| Model 2 | 485 | 79 | 0.62 (0.45, 0.87) | 517 | 54 | 0.77 (0.55, 1.07) | 0.610 |
| Model 3 | 485 | 79 | 0.68 (0.49, 0.94) | 517 | 54 | 0.80 (0.57, 1.12) | 0.543 |
| Model 4 | 485 | 79 | 0.68 (0.49, 0.94) | 515 | 54 | 0.78 (0.55, 1.09) | 0.575 |
| **Lutein** |  |  |  |  |  |  |  |
| Model 1 | 494 | 80 | 0.99 (0.77, 1.27) | 520 | 56 | 0.64 (0.45, 0.90) | 0.034 |
| Model 2 | 485 | 79 | 1.09 (0.84, 1.41) | 517 | 54 | 0.71 (0.50, 1.01) | 0.038 |
| Model 3 | 485 | 79 | 1.17 (0.91, 1.52) | 517 | 54 | 0.74 (0.52, 1.06) | 0.061 |
| Model 4 | 485 | 79 | 1.18 (0.91, 1.53) | 515 | 54 | 0.72 (0.50, 1.05) | 0.059 |
| **Lycopene** |  |  |  |  |  |  |  |
| Model 1 | 494 | 80 | 0.98 (0.77, 1.25) | 520 | 56 | 0.94 (0.71, 1.24) | 0.721 |
| Model 2 | 485 | 79 | 0.99 (0.78, 1.26) | 517 | 54 | 0.93 (0.69, 1.24) | 0.576 |
| Model 3 | 485 | 79 | 0.98 (0.77, 1.25) | 517 | 54 | 0.95 (0.70, 1.28) | 0.710 |
| Model 4 | 485 | 79 | 0.98 (0.77, 1.26) | 515 | 54 | 0.95 (0.70, 1.28) | 0.693 |
| **Zeaxanthin** |  |  |  |  |  |  |  |
| Model 1 | 494 | 80 | 0.79 (0.60, 1.05) | 520 | 56 | 0.74 (0.53, 1.04) | 0.656 |
| Model 2 | 485 | 79 | 0.83 (0.62, 1.10) | 517 | 54 | 0.84 (0.60, 1.19) | 0.766 |
| Model 3 | 485 | 79 | 0.89 (0.67, 1.18) | 517 | 54 | 0.88 (0.62, 1.26) | 0.926 |
| Model 4 | 485 | 79 | 0.89 (0.67, 1.18) | 515 | 54 | 0.88 (0.61, 1.26) | 0.926 |

\*PR=prevalence ratio; estimated using multivariate Cox regression with a constant time at risk of one year; reported per 1SD increase in the concentration of serum carotenoid

†Interaction between serum carotenoid concentration and sex (serum carotenoid concentration\*sex) in model; p value <0.05 considered significant

‡Model 1: adjusted for age and ethnicity

§Model 2: model 1 additionally adjusted for highest education level achieved (low, middle, high), smoking status (current, former, never), alcohol intake (abstinent, low intake, moderate intake, high intake) and physical activity (adherent to the Dutch Healthy Physical Activity Guideline or not)

||Model 3: model 2 additionally adjusted for BMI (kg/m2)

¶Model 4: model 3 additionally adjusted for average energy intake (kcal/d; low, moderate and high average energy intake)

# Supplementary material 4

**Table 1.** Association of carotenoid concentrations with type 2 diabetes in study population stratified by ethnic group

|  |  |  |
| --- | --- | --- |
|  | **PR (95% CI)**\* |  |
|  | **Dutch (N=203)** | **South-Asian Surinamese (N=200)** | **African Surinamese (N=200)** | **Turkish (N=200)** | **Moroccan (N=197)** | **P value****(serum carotenoid\*ethnicity)** |
| **Cases** | 10 | 46 | 26 | 22 | 29 |  |
| **Total carotenoids** |  |
| Model 3† | 0.36 (0.12, 1.11) | 0.80 (0.55, 1.16) | 0.66 (0.41, 1.07) | 0.71 (0.40, 1.24) | 0.49 (0.27, 0.90) | 0.481 |
| Model 4‡ | 0.34 (0.11, 1.07) | 0.80 (0.56, 1.16) | 0.67 (0.41, 1.08) | 0.70 (0.40, 1.24) | 0.50 (0.27, 0.93) | 0.471 |
| **α-carotene** |  |
| Model 3 | 0.22 (0.04, 1.22) | 0.50 (0.27, 0.92) | 0.58 (0.33, 1.02) | 0.52 (0.19, 1.40) | 0.68 (0.41, 1.14) | 0.753 |
| Model 4 | 0.16 (0.03, 1.08) | 0.50 (0.27, 0.90) | 0.58 (0.33, 1.01) | 0.52 (0.19, 1.41) | 0.69 (0.41, 1.17) | 0.719 |
| **β-carotene** |  |
| Model 3 | 0.13 (0.02, 0.77) | 0.45 (0.24, 0.86) | 0.45 (0.23, 0.89) | 0.61 (0.30, 1.26) | 0.40 (0.20, 0.83) | 0.529 |
| Model 4 | 0.11 (0.02, 0.69) | 0.46 (0.24, 0.86) | 0.45 (0.23, 0.90) | 0.61 (0.29, 1.27) | 0.41 (0.20, 0.85) | 0.516 |
| **β-cryptoxanthin** |  |
| Model 3 | 0.19 (0.04, 0.89) | 0.95 (0.70, 1.29) | 0.87 (0.56, 1.36) | 0.42 (0.20, 0.89) | 0.36 (0.14, 0.97) | 0.064 |
| Model 4 | 0.18 (0.04, 0.88) | 0.94 (0.69, 1.28) | 0.88 (0.56, 1.40) | 0.42 (0.20, 0.88) | 0.38 (0.14, 1.03) | 0.062 |
| **Lutein** |  |
| Model 3 | 0.56 (0.19, 1.61) | 1.18 (0.85, 1.63) | 0.92 (0.58, 1.47) | 0.80 (0.44, 1.47) | 0.90 (0.57, 1.41) | 0.485 |
| Model 4 | 0.54 (0.18, 1.62) | 1.19 (0.86, 1.64) | 0.93 (0.58, 1.49) | 0.77 (0.41, 1.44) | 0.95 (0.59, 1.53) | 0.463 |
| **Lycopene** |  |
| Model 3 | 1.20 (0.59, 2.41) | 1.01 (0.73, 1.39) | 1.00 (0.66, 1.52) | 1.09 (0.69, 1.72) | 0.64 (0.35, 1.18) | 0.468 |
| Model 4 | 1.19 (0.58, 2.47) | 1.02 (0.74, 1.41) | 1.00 (0.66, 1.50) | 1.10 (0.69, 1.73) | 0.66 (0.35, 1.24) | 0.491 |
| **Zeaxanthin** |  |
| Model 3 | 0.51 (0.19, 1.36) | 1.16 (0.80, 1.65) | 0.84 (0.56, 1.26) | 0.74 (0.37, 1.47) | 0.69 (0.29, 1.67) | 0.318 |
| Model 4 | 0.49 (0.18, 1.34) | 1.16 (0.80, 1.66) | 0.85 (0.56, 1.28) | 0.75 (0.37, 1.53) | 0.75 (0.31, 1.84) | 0.306 |

\*PR=prevalence ratio; estimated using multivariate Cox regression with a constant time at risk of one year; reported per 1SD increase in the concentration of serum carotenoid

†Model 3: adjusted for age, sex, highest education level achieved (low, middle, high), smoking status (current, former, never), alcohol intake (abstinent, low intake, moderate intake, high intake), physical activity (adherent to the Dutch Healthy Physical Activity Guideline or not), and BMI (kg/m2)

‡Model 4: model 3 additionally adjusted for average energy intake (kcal/d; low, moderate and high average energy intake)

# Supplementary material 5

**Table 1.** Ethnic differences in type 2 diabetes adjusted for known risk factors and serum concentration of carotenoids in men and women

|  |  |
| --- | --- |
|  | **PR (95% CI)**\* |
| ***Men* (n=485, cases=79)** | **Dutch** | **South Asian Surinamese** | **African Surinamese** | **Turkish** | **Moroccan** |
| **Fully adjusted model**† | 1.00 | 4.01 (1.65, 9.71) | 1.61 (0.62, 4.14) | 2.80 (1.02, 7.68) | 3.05 (1.07, 8.69) |
| **+ Total carotenoids** | 1.00 | 4.09 (1.69, 9.93) | 1.86 (0.72, 4.80) | 3.51 (1.26, 9.80) | 2.98 (1.05, 8.46) |
| **+ α-carotene** | 1.00 | 4.25 (1.74, 10.40) | 2.07 (0.78, 5.46) | 3.01 (1.09, 8.35) | 3.71 (1.28, 10.79) |
| **+ β-carotene** | 1.00 | 3.43 (1.40, 8.42) | 1.87 (0.73, 4.84) | 3.26 (1.18, 9.04) | 2.80 (0.98, 7.95) |
| **+ β-cryptoxanthin** | 1.00 | 4.10 (1.70, 9.91) | 1.71 (0.67, 4.38) | 3.27 (1.17, 9.12) | 2.74 (0.96, 7.80) |
| **+ Lutein** | 1.00 | 3.81 (1.57, 9.27) | 1.50 (0.57, 3.90) | 2.67 (0.97, 7.36) | 2.90 (1.01, 8.34) |
| **+ Lycopene** | 1.00 | 4.02 (1.66, 9.76) | 1.62 (0.63, 4.17) | 2.86 (1.01, 8.06) | 3.04 (1.07, 8.68) |
| **+ Zeaxanthin** | 1.00 | 3.98 (1.65, 9.63) | 1.62 (0.63, 4.16) | 2.80 (1.03, 7.67) | 2.84 (0.99, 8.16) |
| ***Women* (n=515, cases=54)** | **Dutch** | **South Asian Surinamese** | **African Surinamese** | **Turkish** | **Moroccan** |
| **Fully adjusted model**† | 1.00 | 6.86 (1.72, 27.31) | 3.40 (0.83, 13.96) | 2.61 (0.51, 13.29) | 5.19 (1.06, 25.28) |
| **+ Total carotenoids** | 1.00 | 6.82 (1.75, 26.57) | 3.91 (0.95, 16.11) | 4.03 (0.78, 20.92) | 5.33 (1.11, 25.67) |
| **+ α-carotene** | 1.00 | 7.51 (1.92, 29.40) | 4.65 (1.11, 19.39) | 3.41 (0.67, 17.42) | 7.31 (1.50, 35.71) |
| **+ β-carotene** | 1.00 | 6.70 (1.71, 26.20) | 4.33 (1.04, 18.06) | 4.31 (0.84, 22.19) | 6.57 (1.35, 32.03) |
| **+ β-cryptoxanthin** | 1.00 | 6.53 (1.66, 25.69) | 3.31 (0.81, 13.52) | 2.71 (0.54, 13.77) | 4.53 (0.93, 21.97) |
| **+ Lutein** | 1.00 | 6.63 (1.68, 26.18) | 3.91 (0.95, 16.17) | 3.30 (0.64, 17.07) | 5.21 (1.07, 25.39) |
| **+ Lycopene** | 1.00 | 7.00 (1.76, 27.93) | 3.44 (0.84, 14.13) | 2.83 (0.53, 15.30) | 5.20 (1.07, 25.29) |
| **+ Zeaxanthin** | 1.00 | 6.40 (1.60, 25.55) | 3.31 (0.81, 13.58) | 2.50 (0.49, 12.66) | 4.55 (0.91, 22.83) |

\*PR=prevalence ratio; calculated using multivariate Cox regression analysis with a constant time at risk of one year; PR given per 1SD increase in serum carotenoid concentration

†Adjusted for age, highest education level achieved (low, middle, high), smoking status (current, former, never), alcohol intake (abstinent, low intake, moderate intake, high intake), physical activity (adherent to the Dutch Healthy Physical Activity Guideline or not), BMI (kg/m2) and average energy intake (kcal/d; low, moderate, and high average energy intake)