

Maternal intake of lutein and zeaxanthin during pregnancy is positively associated with offspring verbal intelligence and behavior regulation in mid-childhood in the Project Viva cohort

Hiya A Mahmassani – Online Supplementary Material

Supplemental Table 1 – Associations of maternal intake of lutein and zeaxanthin (L/Z) during pregnancy with child cognitive and behavioral outcomes (subtest scores only)

Child outcome Trimester Model ^b	Quartiles of maternal L/Z intake ^a			
	Quartile 1 (Ref)	Quartile 2 β (95%CI) ^c	Quartile 3 β (95%CI)	Quartile 4 β (95%CI)
Early Childhood				
WRAVMA Pegboard				
T1 (n=1232)				
Model 0	0	0.54 (-1.23, 2.32)	-0.29 (-2.05, 1.46)	-1.06 (-2.79, 0.67)
Model 1	0	0.34 (-1.44, 2.13)	-0.78 (-2.57, 1.01)	-1.48 (-3.27, 0.31)
Model 2	0	0.20 (-1.59, 1.99)	-0.88 (-2.70, 0.94)	-1.64 (-3.52, 0.24)
T2 (n=1201)				
Model 0	0	-0.90 (-2.74, 0.95)	-0.87 (-2.70, 0.97)	-1.32 (-3.13, 0.49)
Model 1	0	-1.06 (-2.93, 0.80)	-1.37 (-3.23, 0.50)	-1.83 (-3.71, 0.05)
Model 2	0	-1.06 (-2.95, 0.83)	-1.29 (-3.22, 0.63)	-1.66 (-3.69, 0.37)
WRAVMA Drawing				
T1 (n=1235)				
Model 0	0	0.18 (-1.67, 2.03)	-0.48 (-2.30, 1.34)	0.28 (-1.51, 2.07)
Model 1	0	-0.07 (-1.93, 1.79)	-1.04 (-2.89, 0.82)	-0.44 (-2.29, 1.41)
Model 2	0	-0.14 (-2.02, 1.74)	-1.19 (-3.08, 0.70)	-0.72 (-2.68, 1.23)
T2 (n=1203)				
Model 0	0	0.67 (-1.15, 2.50)	1.70 (-0.13, 3.53)	2.64 (0.83, 4.45)
Model 1	0	0.40 (-1.44, 2.25)	1.14 (-0.73, 3.00)	1.99 (0.11, 3.87)
Model 2	0	0.42 (-1.45, 2.29)	1.12 (-0.80, 3.03)	1.91 (-0.11, 3.93)
WRAVMA Matching				
T1 (n=1189)				
Model 0	0	1.13 (-1.11, 3.37)	1.10 (-1.13, 3.33)	1.18 (-1.04, 3.40)
Model 1	0	0.33 (-1.84, 2.51)	-0.37 (-2.56, 1.83)	-0.19 (-2.40, 2.02)
Model 2	0	0.16 (-2.03, 2.36)	-0.51 (-2.75, 1.72)	-0.41 (-2.74, 1.92)
T2 (n=1158)				
Model 0	0	0.55 (-1.75, 2.86)	1.15 (-1.15, 3.44)	1.46 (-0.81, 3.72)
Model 1	0	-0.31 (-2.57, 1.94)	-0.44 (-2.73, 1.85)	0.12 (-2.18, 2.42)
Model 2	0	-0.19 (-2.48, 2.09)	-0.24 (-2.59, 2.11)	0.46 (-2.00, 2.91)
Mid-childhood				
WRAML design memory				
T1 (n=1098)				
Model 0	0	0.78 (0.29, 1.28)	0.81 (0.32, 1.30)	0.59 (0.11, 1.07)
Model 1	0	0.73 (0.23, 1.23)	0.70 (0.20, 1.20)	0.47 (-0.03, 0.97)
Model 2	0	0.64 (0.13, 1.14)	0.62 (0.11, 1.13)	0.30 (-0.23, 0.83)

T2 (n=1056)				
Model 0	0	0.40 (-0.11, 0.91)	0.57 (0.06, 1.08)	0.40 (-0.10, 0.89)
Model 1	0	0.32 (-0.20, 0.83)	0.42 (-0.11, 0.95)	0.19 (-0.33, 0.72)
Model 2	0	0.32 (-0.20, 0.85)	0.43 (-0.11, 0.97)	0.20 (-0.36, 0.76)
WRAML picture memory				
T1 (n=1101)				
Model 0	0	0.04 (-0.49, 0.58)	-0.08 (-0.62, 0.46)	0.00 (-0.52, 0.53)
Model 1	0	0.01 (-0.54, 0.55)	-0.15 (-0.71, 0.41)	-0.07 (-0.62, 0.48)
Model 2	0	-0.04 (-0.59, 0.52)	-0.20 (-0.77, 0.37)	-0.17 (-0.75, 0.42)
T2 (n=1059)				
Model 0	0	-0.02 (-0.57, 0.54)	0.15 (-0.40, 0.71)	-0.29 (-0.83, 0.25)
Model 1	0	-0.16 (-0.73, 0.40)	0.02 (-0.55, 0.60)	-0.45 (-1.03, 0.13)
Model 2	0	-0.12 (-0.70, 0.45)	0.06 (-0.53, 0.66)	-0.43 (-1.05, 0.18)
BRIEF BRI				
T1 (n=1181)				
Model 0	0	-1.51 (-3.00, -0.01)	-2.27 (-3.76, -0.78)	-2.07 (-3.55, -0.59)
Model 1	0	-1.21 (-2.72, 0.29)	-1.75 (-3.27, -0.23)	-1.67 (-3.20, -0.14)
Model 2	0	-1.19 (-2.70, 0.31)	-1.66 (-3.19, -0.14)	-1.63 (-3.22, -0.04)
T2 (n=1139)				
Model 0	0	-0.94 (-2.51, 0.63)	-1.53 (-3.09, 0.02)	-2.51 (-4.03, -0.99)
Model 1	0	-0.65 (-2.23, 0.94)	-1.07 (-2.68, 0.53)	-2.20 (-3.79, -0.60)
Model 2	0	-0.45 (-2.04, 1.15)	-0.80 (-2.44, 0.84)	-1.89 (-3.58, -0.21)
BRIEF MI				
T1 (n=1174)				
Model 0	0	-0.18 (-1.67, 1.30)	-1.64 (-3.13, -0.15)	-1.36 (-2.83, 0.10)
Model 1	0	-0.08 (-1.57, 1.42)	-1.36 (-2.87, 0.16)	-1.21 (-2.73, 0.30)
Model 2	0	-0.09 (-1.59, 1.41)	-1.27 (-2.81, 0.26)	-1.23 (-2.81, 0.35)
T2 (n=1132)				
Model 0	0	-0.34 (-1.92, 1.25)	-0.74 (-2.30, 0.82)	-1.25 (-2.77, 0.27)
Model 1	0	-0.14 (-1.75, 1.47)	-0.40 (-2.01, 1.20)	-1.33 (-2.93, 0.26)
Model 2	0	0.06 (-1.54, 1.65)	-0.04 (-1.67, 1.59)	-0.91 (-2.57, 0.76)
SDQ Prosocial				
T1 (n=1191)				
Model 0	0	0.08 (-0.21, 0.36)	0.15 (-0.13, 0.43)	0.31 (0.04, 0.59)
Model 1	0	0.09 (-0.20, 0.38)	0.17 (-0.11, 0.46)	0.37 (0.09, 0.66)
Model 2	0	0.06 (-0.23, 0.35)	0.14 (-0.15, 0.43)	0.29 (-0.01, 0.59)
T2 (n=1148)				
Model 0	0	0.33 (0.04, 0.63)	0.09 (-0.20, 0.38)	0.20 (-0.08, 0.49)
Model 1	0	0.37 (0.07, 0.67)	0.12 (-0.18, 0.42)	0.31 (0.01, 0.61)
Model 2	0	0.35 (0.05, 0.65)	0.09 (-0.22, 0.40)	0.25 (-0.06, 0.57)

^aMedian maternal L/Z intake (range), in mg/day, for each quartile

T1: Q1=0.97 (0.09 - 1.433); Q2=1.78 (1.434 - 2.200); Q3=2.64 (2.201 - 3.251); Q4= 4.51 (3.253 - 16.307)

T2: Q1=0.98 (0.05 - 1.426); Q2=1.82 (1.427 - 2.209); Q3=2.59 (2.210 - 3.187); Q4=4.48 (3.194 - 15.205)

Nutrient values were adjusted for total energy intake using the residual model.

^bModel 0 (crude): Adjusted for child age and sex

Model 1 (multivariable): Model 0 adjusted for maternal socio-demographic characteristics (age, race/ethnicity, marital status, parity, education, income, smoking history, pre-pregnancy BMI).

Model 2 (multivariable): Model 1 additionally adjusted for trimester-specific intake of total energy, DHA, folate, choline, vitamin B12, alcohol.

^c β (95%CI) represent the difference in mean cognitive scores compared to the lowest quartile of maternal L/Z intake (Referent).

BRIEF BRI, Behavioral Rating Inventory of Executive Function Behavioral Regulation Index;

BRIEF MI, Behavioral Rating Inventory of Executive Function Metacognition Index; SDQ, Strengths and Difficulties Questionnaire; T1, first trimester of pregnancy; T2, second trimester of pregnancy; WRAML, Wide Range Assessment of Memory and Learning, Second Edition; WRAVMA, Wide Range Assessment of Visual Motor Abilities.

Supplemental Table 2 – Associations of maternal intake of lutein and zeaxanthin-rich (L/Z-rich) foods^a during pregnancy with child cognitive and behavioral outcomes (subtest scores only)

Child outcome Trimester Model ^c	Quartiles of maternal L/Z-rich foods intake ^b			
	Quartile 1 (Ref)	Quartile 2	Quartile 3	Quartile 4
		β (95%CI) ^d	β (95%CI)	β (95%CI)
Early Childhood				
WRAVMA Pegboard				
T1 (n=1232)				
Model 0	0	-0.66 (-2.41, 1.09)	-0.76 (-2.52, 1.00)	-1.09 (-2.83, 0.65)
Model 1	0	-0.93 (-2.67, 0.81)	-0.99 (-2.74, 0.77)	-1.22 (-2.95, 0.52)
Model 2	0	-0.77 (-2.54, 0.99)	-0.69 (-2.55, 1.17)	-0.65 (-2.68, 1.37)
T2 (n=1201)				
Model 0	0	-0.33 (-2.11, 1.45)	-0.12 (-1.90, 1.67)	-0.84 (-2.63, 0.94)
Model 1	0	-0.31 (-2.10, 1.49)	-0.41 (-2.20, 1.39)	-0.97 (-2.76, 0.83)
Model 2	0	0.14 (-1.69, 1.97)	0.35 (-1.55, 2.25)	0.45 (-1.66, 2.56)
WRAVMA Drawing				
T1 (n=1235)				
Model 0	0	-0.77 (-2.58, 1.05)	-1.40 (-3.21, 0.40)	-0.35 (-2.14, 1.45)
Model 1	0	-1.10 (-2.90, 0.71)	-1.60 (-3.41, 0.21)	-0.54 (-2.34, 1.25)
Model 2	0	-1.08 (-2.93, 0.77)	-1.57 (-3.50, 0.36)	-0.43 (-2.54, 1.69)
T2 (n=1203)				
Model 0	0	-0.37 (-2.21, 1.47)	0.74 (-1.09, 2.57)	0.73 (-1.11, 2.56)
Model 1	0	-0.57 (-2.41, 1.28)	0.29 (-1.55, 2.12)	0.47 (-1.37, 2.31)
Model 2	0	-0.42 (-2.30, 1.47)	0.47 (-1.47, 2.41)	0.95 (-1.22, 3.12)
WRAVMA Matching				
T1 (n=1189)				
Model 0	0	0.69 (-1.54, 2.91)	-1.64 (-3.85, 0.57)	0.26 (-1.94, 2.45)
Model 1	0	0.00 (-2.13, 2.13)	-2.31 (-4.44, -0.18)	-0.30 (-2.41, 1.82)
Model 2	0	0.22 (-1.95, 2.40)	-1.99 (-4.28, 0.29)	0.51 (-1.98, 2.99)
T2 (n=1158)				
Model 0	0	-0.73 (-3.05, 1.59)	0.54 (-1.74, 2.82)	-0.68 (-2.95, 1.59)
Model 1	0	-1.01 (-3.26, 1.24)	-0.21 (-2.45, 2.02)	-1.26 (-3.49, 0.97)
Model 2	0	-0.61 (-2.90, 1.69)	0.51 (-1.84, 2.86)	-0.03 (-2.64, 2.57)
Mid-childhood				
WRAML design memory				
T1 (n=1098)				
Model 0	0	0.17 (-0.33, 0.66)	0.22 (-0.27, 0.70)	0.53 (0.05, 1.00)
Model 1	0	0.17 (-0.33, 0.66)	0.17 (-0.32, 0.65)	0.48 (0.00, 0.95)
Model 2	0	0.12 (-0.38, 0.63)	0.10 (-0.42, 0.62)	0.42 (-0.14, 0.98)
T2 (n=1056)				
Model 0	0	0.10 (-0.40, 0.60)	-0.12 (-0.63, 0.38)	0.44 (-0.06, 0.93)
Model 1	0	0.06 (-0.44, 0.56)	-0.23 (-0.73, 0.28)	0.34 (-0.16, 0.85)
Model 2	0	0.09 (-0.42, 0.61)	-0.18 (-0.72, 0.36)	0.45 (-0.15, 1.06)

WRAML picture memory				
T1 (n=1101)				
Model 0	0	-0.35 (-0.89, 0.18)	-0.11 (-0.64, 0.41)	-0.17 (-0.70, 0.35)
Model 1	0	-0.32 (-0.86, 0.22)	-0.13 (-0.65, 0.40)	-0.20 (-0.73, 0.33)
Model 2	0	-0.40 (-0.95, 0.16)	-0.27 (-0.83, 0.30)	-0.42 (-1.04, 0.20)
T2 (n=1059)				
Model 0	0	-0.27 (-0.83, 0.30)	-0.39 (-0.94, 0.15)	-0.24 (-0.79, 0.31)
Model 1	0	-0.30 (-0.87, 0.26)	-0.47 (-1.01, 0.08)	-0.30 (-0.86, 0.25)
Model 2	0	-0.27 (-0.84, 0.31)	-0.48 (-1.07, 0.10)	-0.33 (-0.99, 0.34)
BRIEF BRI				
T1 (n=1181)				
Model 0	0	-0.36 (-1.84, 1.13)	-0.39 (-1.89, 1.11)	-0.89 (-2.35, 0.57)
Model 1	0	-0.07 (-1.54, 1.41)	-0.05 (-1.53, 1.44)	-0.58 (-2.03, 0.87)
Model 2	0	-0.42 (-1.91, 1.07)	-0.54 (-2.10, 1.01)	-1.76 (-3.45, -0.08)
T2 (n=1139)				
Model 0	0	1.23 (-0.33, 2.79)	-0.24 (-1.76, 1.29)	0.03 (-1.52, 1.58)
Model 1	0	1.54 (-0.02, 3.09)	0.08 (-1.45, 1.60)	0.43 (-1.12, 1.97)
Model 2	0	1.35 (-0.22, 2.91)	-0.51 (-2.12, 1.10)	-0.55 (-2.35, 1.24)
BRIEF MI				
T1 (n=1174)				
Model 0	0	0.15 (-1.33, 1.62)	0.39 (-1.11, 1.90)	0.28 (-1.17, 1.73)
Model 1	0	0.34 (-1.13, 1.81)	0.54 (-0.95, 2.03)	0.47 (-0.98, 1.92)
Model 2	0	-0.15 (-1.64, 1.34)	-0.13 (-1.70, 1.44)	-0.98 (-2.66, 0.69)
T2 (n=1132)				
Model 0	0	1.19 (-0.39, 2.77)	-0.10 (-1.65, 1.45)	0.61 (-0.96, 2.19)
Model 1	0	1.46 (-0.11, 3.03)	0.09 (-1.44, 1.63)	0.82 (-0.74, 2.39)
Model 2	0	1.37 (-0.20, 2.94)	-0.38 (-1.99, 1.23)	0.16 (-1.65, 1.97)
SDQ Prosocial				
T1 (n=1191)				
Model 0	0	0.29 (0.01, 0.56)	0.21 (-0.07, 0.48)	0.46 (0.19, 0.73)
Model 1	0	0.26 (-0.02, 0.54)	0.19 (-0.08, 0.47)	0.46 (0.19, 0.73)
Model 2	0	0.23 (-0.05, 0.51)	0.12 (-0.18, 0.41)	0.37 (0.05, 0.69)
T2 (n=1148)				
Model 0	0	0.02 (-0.28, 0.31)	0.13 (-0.15, 0.42)	0.18 (-0.11, 0.47)
Model 1	0	0.00 (-0.30, 0.29)	0.12 (-0.17, 0.41)	0.20 (-0.09, 0.49)
Model 2	0	-0.03 (-0.33, 0.27)	0.08 (-0.23, 0.39)	0.11 (-0.23, 0.44)

^aL/Z-rich foods: top 10 contributors to total maternal L/Z intake in eligible sample (cooked spinach, raw spinach, romaine or leaf lettuce, kale, broccoli, peas or lima beans, orange juice with Ca, corn, eggplant or zucchini, mixed vegetables) and any food with L/Z ≥ 1 mg per 100g (Brussels sprouts, dark squash, popcorn, eggs).

^bMedian maternal L/Z-rich foods intake (range), in servings/day, for each quartile

T1: Q1=0.77 (0.07 \leq – \leq 1.06), Q2=1.35 (1.06 $<$ – \leq 1.63), Q3=1.93 (1.63 $<$ – $<$ 2.35), Q4=3.06 (2.35 \leq – \leq 9.58)

T2: Q1=0.84 (0.00 \leq – \leq 1.13), Q2=1.42 (1.13 $<$ – \leq 1.70), Q3=1.99 (1.70 $<$ – \leq 2.42), Q4=3.21 (2.42 $<$ – \leq 10.44)

^cModel 0 (crude): Adjusted for child age and sex

Model 1 (multivariable): Model 0 adjusted for maternal socio-demographic characteristics (age, race/ethnicity, marital status, parity, education, income, smoking history, pre-pregnancy BMI).

Model 2 (multivariable): Model 1 additionally adjusted for trimester-specific intake of total energy, DHA, folate, choline, vitamin B12, alcohol.

^d β (95%CI) represent the difference in mean cognitive scores compared to the lowest quartile of maternal L/Z-rich foods intake (Referent).

BRIEF BRI, Behavioral Rating Inventory of Executive Function Behavioral Regulation Index;
BRIEF MI, Behavioral Rating Inventory of Executive Function Metacognition Index; SDQ, Strengths and Difficulties Questionnaire; T1, first trimester of pregnancy; T2, second trimester of pregnancy; WRAML, Wide Range Assessment of Memory and Learning, Second Edition; WRAVMA, Wide Range Assessment of Visual Motor Abilities.
