Cross-Sectional Association of Blood Selenium with Glycemic Biomarkers among U.S. Adults with Normoglycemia in the National Health and Nutrition Examination Survey 2013–2016

Supplemental material

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Table S1. Collinearity analysis (variance inflation factor, VIFs) and the lower limit of detections (LLOD)

	VIFs				LLODs
	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)	
Cadmium (Cd)	1.06	1.05	1.04	1.06	0.1 μg/L
Manganese (Mn)	1.01	1.01	1.01	1.01	0.99 μg/L
Mercury (Hg)	1.04	1.05	1.03	1.04	0.28 μg/L
Selenium (Se)	1.02	1.03	1.02	1.02	24.48 μg/L
Lead (Pb)	1.08	1.06	1.05	1.08	0.07 ug/dL

Table S2. Regression coefficients (β) for the association between blood selenium and glycaemic biomarkers stratified by sex

	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)
Men				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.20 (0.09, 0.32)	-0.09 (-0.51, 0.33)	0.04 (-0.02, 0.09)	2.14 (-0.16, 4.44)
Q3	0.23 (0.12, 0.35)	0.08 (-0.33, 0.49)	0.05 (0.00, 0.10)	3.59 (1.33, 5.86)
Q4	0.15 (0.04, 0.26)	0.25 (-0.17, 0.66)	0.03 (-0.02, 0.08)	2.56 (0.30, 4.83)
P for trend	0.02	0.16	0.23	0.02
Log_{10} Se	1.08 (0.31, 1.85)	1.49 (-1.31, 4.30)	0.20 (-0.15, 0.55)	16.33 (1.07, 31.60)
Women				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.01 (-0.10, 0.12)	0.45 (0.11, 0.80)	0.00 (-0.05, 0.05)	0.61 (-1.17, 2.39)
Q3	0.01 (-0.11, 0.13)	0.46 (0.07, 0.84)	-0.01 (-0.06, 0.05)	1.19 (-0.73, 3.12)
Q4	0.10 (-0.01, 0.22)	0.36 (-0.01, 0.73)	0.04 (-0.01, 0.09)	2.43 (0.53, 4.33)
P for trend	0.11	0.06	0.20	0.01
Log_{10} Se	0.26 (-0.54, 1.05)	2.04 (-0.51, 4.58)	0.29 (-0.07, 0.64)	12.53 (-0.61, 25.67)
P interaction	0.78	0.57	0.94	0.88

Model was adjusted for age, race, education level, ratio of family income to poverty, smoking status, alcohol drinking status, body mass index, dietary energy, hypertension history, the levels of blood lead, cadmium, manganese and mercury. Q1, <180; Q2, 180 – 194; Q3, 194 – 208; Q4, ⩾208.

Table S3. Regression coefficients (β) for the association between blood selenium and glycaemic biomarkers stratified by hypertension history

	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)
Without hypertension				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.05 (-0.04, 0.14)	0.20 (-0.12, 0.52)	0.01 (-0.03, 0.05)	1.41 (-0.31, 3.14)
Q3	0.16 (0.07, 0.26)	0.21 (-0.13, 0.55)	0.02 (-0.03, 0.06)	3.39 (1.57, 5.22)
Q4	0.14 (0.05, 0.23)	0.23 (-0.10, 0.56)	0.01 (-0.03, 0.06)	3.15 (1.38, 4.92)
P for trend	<0.01	0.18	0.46	<0.01
Log_{10} Se	0.99 (0.34, 1.64)	1.60 (-0.78, 3.97)	0.14 (-0.14, 0.43)	21.70 (9.19, 34.21)
With hypertension				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.17 (0.01, 0.33)	0.12 (-0.4, 0.63)	0.04 (-0.03, 0.11)	1.17 (-1.38, 3.72)
Q3	0.05 (-0.11, 0.21)	0.14 (-0.38, 0.66)	0.04 (-0.03, 0.11)	1.15 (-1.38, 3.69)
Q4	0.07 (-0.1, 0.23)	0.36 (-0.17, 0.89)	0.07 (0.00, 0.14)	0.68 (-1.95, 3.31)
P for trend	0.73	0.19	0.05	0.66
Log_{10} Se	0.22 (-0.83, 1.27)	1.14 (-2.13, 4.41)	0.43 (-0.04, 0.90)	3.63 (-13.22, 20.48)
P interaction	0.09	0.66	0.06	0.11

Model was adjusted for sex, age, race, education level, ratio of family income to poverty, smoking status, alcohol drinking status, body mass index, dietary energy, and the levels of blood lead, cadmium, manganese and mercury. Q1, <180; Q2, 180 – 194; Q3, 194 – 208; Q4, ⩾208.

Table S4. Regression coefficients (β) for the association between blood selenium and glycaemic biomarkers stratified by BMI category

	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)
⩽25 kg/m^2				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.09 (-0.04, 0.23)	0.29 (-0.18, 0.76)	0.04 (-0.01, 0.10)	0.01 (-1.65, 1.66)
Q3	0.09 (-0.05, 0.23)	-0.02 (-0.53, 0.48)	0.01 (-0.05, 0.07)	0.61 (-1.15, 2.38)
Q4	0.16 (0.03, 0.29)	0.27 (-0.20, 0.75)	0.04 (-0.02, 0.10)	1.14 (-0.51, 2.78)
P for trend	0.02	0.41	0.33	0.14
Log_{10} Se	0.51 (-0.33, 1.35)	0.96 (-2.00, 3.92)	0.16 (-0.23, 0.54)	5.75 (-4.88, 16.39)
25.1-29.9 kg/m^2				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.12 (-0.03, 0.27)	0.19 (-0.33, 0.72)	0.02 (-0.04, 0.08)	1.83 (-0.49, 4.14)
Q3	0.11 (-0.05, 0.26)	0.37 (-0.17, 0.90)	0.01 (-0.06, 0.07)	2.98 (0.63, 5.32)
Q4	0.07 (-0.08, 0.22)	0.63 (0.10, 1.15)	0.01 (-0.05, 0.08)	1.75 (-0.60, 4.10)
P for trend	0.47	0.01	0.86	0.12
Log_{10} Se	0.83 (-0.20, 1.85)	4.14 (0.50, 7.77)	0.30 (-0.14, 0.73)	16.70 (1.06, 32.35)
⩾ 30 kg/m^2				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.06 (-0.07, 0.19)	0.29 (-0.14, 0.71)	-0.01 (-0.07, 0.05)	2.96 (-0.14, 6.06)
Q3	0.17 (0.03, 0.31)	0.53 (0.08, 0.97)	0.05 (-0.01, 0.11)	5.25 (2.01, 8.50)
Q4	0.14 (0.00, 0.28)	0.19 (-0.27, 0.65)	0.05 (-0.02, 0.12)	4.99 (1.61, 8.36)
P for trend	0.02	0.25	0.06	<0.01
Log_{10} Se	0.95 (-0.10, 2.00)	1.46 (-2.02, 4.94)	0.31 (-0.15, 0.77)	31.53 (6.07, 56.98)
P interaction	0.90	0.62	0.51	0.02

Model was adjusted for sex, age, race, education level, ratio of family income to poverty, smoking status, alcohol drinking status, dietary energy, hypertension history, the levels of blood lead, cadmium, manganese and mercury. Q1, <180; Q2, 180 – 194; Q3, 194 – 208; Q4, ⩾208.

Table S5. Regression coefficients (β) for the association between blood selenium and glycaemic biomarkers stratified by age

	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)
18-39 years				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.09 (-0.03, 0.21)	0.54 (0.12, 0.96)	0.01 (-0.04, 0.07)	1.74 (-0.81, 4.28)
Q3	0.20 (0.07, 0.32)	0.58 (0.14, 1.02)	0.03 (-0.03, 0.08)	3.64 (0.98, 6.31)
Q4	0.18 (0.06, 0.30)	0.67 (0.24, 1.09)	0.01 (-0.04, 0.07)	2.57 (0.00, 5.14)
P for trend	<0.01	<0.01	0.57	0.03
Log_{10} Se	1.58 (0.68, 2.48)	4.61 (1.40, 7.82)	0.06 (-0.34, 0.46)	19.60 (0.50, 38.71)
40-59 years				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.21 (0.07, 0.34)	0.02 (-0.42, 0.46)	0.06 (0.00, 0.12)	1.39 (-0.66, 3.43)
Q3	0.15 (0.01, 0.30)	-0.13 (-0.56, 0.34)	0.04 (-0.02, 0.10)	2.86 (0.71, 5.02)
Q4	0.16 (0.02, 0.30)	0.13 (-0.32, 0.59)	0.07 (0.01, 0.14)	4.22 (2.12, 6.32)
P for trend	0.05	0.68	0.03	<0.01
Log_{10} Se	0.54 (-0.41, 1.48)	0.48 (-2.63, 3.58)	0.56 (0.16, 0.97)	23.12 (8.80, 37.44)
⩾ 60 years				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	-0.05 (-0.24, 0.13)	-0.43 (-1.11, 0.25)	-0.03 (-0.12, 0.05)	1.74 (-1.35, 4.82)
Q3	-0.06 (-0.25, 0.12)	-0.15 (-0.83, 0.53)	0.00 (-0.08, 0.08)	1.57 (-1.49, 4.63)
Q4	0.00 (-0.20, 0.20)	-0.05 (-0.77, 0.67)	0.04 (-0.04, 0.13)	2.24 (-1.04, 5.53)
P for trend	0.90	0.95	0.25	0.20
Log_{10} Se	-0.03 (-1.20, 1.15)	-0.17 (-4.36, 4.02)	0.16 (-0.38, 0.70)	13.01 (-6.53, 32.55)
P interaction	0.07	0.04	0.30	0.84

Model was adjusted for sex, race, education level, ratio of family income to poverty, smoking status, alcohol drinking status, body mass index, dietary energy, hypertension history, the levels of blood lead, cadmium, manganese and mercury. Q1, <180; Q2, 180 – 194; Q3, 194 – 208; Q4, ⩾208.

Table S6. Regression coefficients (β) for the association between blood selenium and glycaemic biomarkers stratified by smoking status

	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)
Never smoker				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.08 (-0.03, 0.19)	0.41 (0.05, 0.76)	0.01 (-0.04, 0.06)	1.91 (-0.17, 3.98)
Q3	0.10 (0.00, 0.21)	0.27 (-0.10, 0.63)	0.01 (-0.04, 0.06)	2.22 (0.13, 4.31)
Q4	0.07 (-0.05, 0.18)	0.35 (-0.02, 0.72)	0.06 (0.01, 0.11)	2.49 (0.33, 4.65)
P for trend	0.23	0.12	0.02	0.03
Log_{10} Se	0.01 (-0.72, 0.75)	1.39 (-1.08, 3.85)	0.36 (0.02, 0.69)	13.03 (-1.21, 27.27)
Former smoker				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	-0.09 (-0.25, 0.08)	-0.18 (-0.82, 0.46)	0.01 (-0.07, 0.09)	1.81 (-1.44, 5.06)
Q3	0.02 (-0.15, 0.20)	0.26 (-0.40, 0.91)	0.00 (-0.08, 0.08)	3.98 (0.62, 7.34)
Q4	0.02 (-0.15, 0.19)	-0.12 (-0.76, 0.51)	-0.02 (-0.1, 0.06)	3.59 (0.33, 6.85)
P for trend	0.58	0.92	0.50	0.02
Log_{10} Se	0.73 (-0.47, 1.92)	0.35 (-4.20, 4.90)	-0.14 (-0.67, 0.39)	20.59 (-2.72, 43.90)
Current smoker				
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.23 (0.07, 0.39)	-0.12 (-0.68, 0.45)	0.04 (-0.03, 0.12)	0.47 (-1.95, 2.90)
Q3	0.23 (0.05, 0.40)	-0.06 (-0.69, 0.57)	0.11 (0.03, 0.19)	3.22 (0.51, 5.94)
Q4	0.35 (0.18, 0.52)	0.50 (-0.10, 1.10)	0.03 (-0.05, 0.10)	0.56 (-1.99, 3.11)
P for trend	0.00	0.13	0.28	0.35
Log_{10} Se	2.69 (1.49, 3.89)	2.43 (-1.80, 6.66)	0.39 (-0.14, 0.92)	11.57 (-6.57, 29.70)
P interaction	0.01	0.46	0.76	0.82

Model was adjusted for sex, age, race, education level, ratio of family income to poverty, alcohol drinking status, body mass index, dietary energy, hypertension history, the levels of blood lead, cadmium, manganese and mercury. Q1, <180; Q2, 180 – 194; Q3, 194 – 208; Q4, ⩾208.

Table S7. Sensitivity analysis on the association between blood selenium and glycaemic biomarkers by including people with and without type 2 diabetes (total n= 3,226)

	FPG (mmol/L)	OGTT (mmol/L)	HbA1c (%)	Insulin (uU/ml)
Blood Se (μg/L)				
Q1	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
Q2	0.03 (-0.24, 0.30)	0.22 (-0.20, 0.64)	-0.01 (-0.10, 0.09)	0.90 (-1.12, 2.92)
Q3	0.09 (-0.19, 0.37)	0.36 (-0.08, 0.79)	0.07 (-0.02, 0.16)	1.93 (-0.12, 3.98)
Q4	0.29 (0.02, 0.57)	0.61 (0.18, 1.03)	0.08 (-0.01, 0.17)	1.88 (-0.13, 3.90)
P for trend	0.03	<0.01	0.04	0.05
Log_{10} Se	2.20 (0.33, 4.06)	4.05 (1.12, 6.97)	0.91 (0.27, 1.54)	12.14 (-1.66, 25.95)

Model was adjusted for sex, age, race, education level, ratio of family income to poverty, smoking status, alcohol drinking status, body mass index, dietary energy, hypertension history, the levels of blood lead, cadmium, manganese and mercury. Q1, <180; Q2, 180 – 194; Q3, 194 – 209; Q4, ⩾209.

Table S8. The values of the lowest (Q1) to the highest (Q4) quartiles for blood Se

Blood selenium (µg/L)	Q1	Q2	Q4	Q4	Overall
Overall					
Mean (SD)	169 (10.5)	188 (3.88)	202 (3.95)	227 (20.7)	196 (24.1)
Median [Min, Max]	171 [105, 181]	188 [181, 195]	201 [195, 209]	221 [209, 388]	195 [105, 388]
Men					
Mean (SD)	168 (10.8)	188 (3.74)	202 (3.91)	226 (17.8)	198 (23.3)
Median [Min, Max]	171 [110, 181]	188 [181, 195]	201 [195, 209]	221 [209, 356]	197 [110, 356]
Women					
Mean (SD)	169 (10.3)	188 (4.02)	202 (4.01)	228 (24.2)	194 (24.8)
Median [Min, Max]	171 [105, 181]	188 [181, 195]	201 [195, 209]	221 [209, 388]	192 [105, 388]
18-39 yrs					
Mean (SD)	169 (9.19)	188 (3.76)	202 (4.12)	225 (14.6)	196 (21.7)
Median [Min, Max]	171 [129, 181]	188 [181, 195]	201 [195, 209]	221 [209, 318]	195 [129, 318]
40-59 yrs					
Mean (SD)	169 (11.3)	188 (3.98)	202 (3.80)	229 (24.7)	196 (26.4)
Median [Min, Max]	171 [105, 181]	188 [181, 195]	202 [195, 209]	222 [209, 388]	194 [105, 388]
>= 60 yrs					
Mean (SD)	168 (11.3)	188 (3.98)	202 (3.84)	228 (24.1)	195 (25.1)
Median [Min, Max]	171 [120, 181]	189 [181, 195]	201 [196, 209]	220 [209, 356]	195 [120, 356]
<=25, kg/m^2					
Mean (SD)	168 (11.3)	188 (3.88)	202 (3.88)	228 (24.8)	195 (26.0)
Median [Min, Max]	171 [110, 181]	188 [181, 195]	201 [195, 209]	221 [209, 377]	194 [110, 377]
25.1-29.9, kg/m^2					
Mean (SD)	169 (10.5)	188 (3.87)	202 (3.97)	227 (20.6)	198 (23.7)
Median [Min, Max]	172 [105, 181]	189 [181, 195]	201 [195, 209]	220 [209, 388]	197 [105, 388]
>=30, kg/m^2					
Mean (SD)	170 (9.67)	188 (3.90)	202 (4.02)	226 (16.3)	195 (22.6)
Median [Min, Max]	172 [131, 181]	188 [181, 195]	202 [195, 209]	221 [209, 318]	194 [131, 318]
HYP					
Mean (SD)	169 (11.1)	188 (4.03)	201 (3.94)	228 (22.0)	197 (25.1)
Median [Min, Max]	172 [110, 181]	188 [181, 195]	201 [195, 209]	222 [209, 377]	196 [110, 377]
Non-HYP					
Mean (SD)	169 (10.2)	188 (3.81)	202 (3.95)	226 (19.9)	196 (23.5)
Median [Min, Max]	171 [105, 181]	188 [181, 195]	202 [195, 209]	221 [209, 388]	194 [105, 388]
Never smoker					
Mean (SD)	168 (10.2)	188 (3.80)	202 (3.99)	228 (22.0)	196 (24.4)
Median [Min, Max]	170 [105, 181]	188 [181, 195]	202 [195, 209]	221 [209, 388]	195 [105, 388]
Former smoker					
Mean (SD)	171 (9.25)	189 (3.81)	202 (3.72)	228 (23.5)	198 (23.9)
Median [Min, Max]	173 [129, 181]	189 [182, 195]	201 [195, 209]	221 [209, 356]	197 [129, 356]
Current smoker					
Mean (SD)	168 (11.8)	188 (4.09)	201 (4.09)	224 (13.1)	193 (23.3)
Median [Min, Max]	172 [110, 181]	188 [181, 195]	201 [195, 209]	221 [209, 288]	191 [110, 288]