Table S1. Components of carbohydrate quality index and macronutrient quality index

Components	Index range (points)	Criteria for minimum index	Criteria for maximum index
Carbohydrate quality index (range)	**4 - 20**		
Total dietary fiber intake (g/d)	1 - 5	Minimum value (quintile 1)	Maximum value (quintile 5)
Glycemic index	1 - 5	Maximum value (quintile 5)	Minimum value (quintile 1)
Solid carbohydrate/total carbohydrate [a]	1 - 5	Minimum value (quintile 1)	Maximum value (quintile 5)
Whole-grain carbohydrate/total-grain carbohydrate [b]	1 - 5	Minimum value (quintile 1)	Maximum value (quintile 5)
Macronutrient quality index (range)	**3 - 15**		
Carbohydrate quality index	1 - 5	Minimum value (quintile 1)	Maximum value (quintile 5)
Fat quality index	1 - 5	Minimum value (quintile 1)	Maximum value (quintile 5)
Protein quality index	1 - 5	Minimum value (quintile 1)	Maximum value (quintile 5)

[a] Total carbohydrate included solid carbohydrate and liquid carbohydrate.

[b] Total-grain carbohydrate was from whole grains, refined grains or their products.

Table S2. Associations (OR and 95% CI) of macronutrient quality index and its sub-indices with asthenozoospermia risk via subgroup analysis [a]

Macronutrient quality	No. of cases/ controls	Tertile 1	Tertile 3	*P* for trend [b]	$P_{\text{multiplicative interaction}}$ [c]
Macronutrient quality index	552/585	≤ 7.00	> 11.00		
Age (year)					0.25
≤ 32.00	276/337	1.00 (ref)	1.41 (0.89, 2.24)	0.14	
> 32.00	276/248	1.00 (ref)	1.03 (0.63, 1.70)	0.89	
BMI					0.79
≤ 25.95	264/296	1.00 (ref)	1.53 (0.94, 2.51)	0.07	
> 25.95	288/289	1.00 (ref)	1.00 (0.63, 1.59)	0.98	
Physical activity (MET/hours/week)					0.06
≤ 128.05	256/293	1.00 (ref)	1.19 (0.73, 1.94)	0.49	
> 128.05	296/292	1.00 (ref)	1.30 (0.81, 2.08)	0.24	
Smoking					0.49
No	286/276	1.00 (ref)	1.27 (0.78, 2.06)	0.32	
Yes	266/309	1.00 (ref)	1.26 (0.78, 2.04)	0.35	
Drinking					0.36
No	353/332	1.00 (ref)	1.30 (0.84, 2.01)	0.22	
Yes	199/253	1.00 (ref)	1.21 (0.70, 2.09)	0.50	
Education					0.47
Junior secondary or below	122/142	1.00 (ref)	1.16 (0.56, 2.39)	0.69	

Senior high school/technical secondary school	79/83	1.00 (ref)	1.86 (0.70, 5.12)	0.25	
Junior college/university or above	351/360	1.00 (ref)	1.20 (0.79, 1.83)	0.38	
Carbohydrate quality index	552/585	≤ 10.00	> 13.00		
Age (year)					0.33
≤ 32.00	276/337	1.00 (ref)	1.51 (0.90, 2.54)	0.12	
> 32.00	276/248	1.00 (ref)	1.16 (0.66, 2.04)	0.61	
BMI					0.66
≤ 25.95	264/296	1.00 (ref)	1.45 (0.83, 2.52)	0.18	
> 25.95	288/289	1.00 (ref)	1.31 (0.77, 2.24)	0.28	
Physical activity (MET/hours/week)					0.15
≤ 128.05	256/293	1.00 (ref)	1.56 (0.90, 2.73)	0.11	
> 128.05	296/292	1.00 (ref)	1.20 (0.70, 2.04)	0.48	
Smoking					0.36
No	286/276	1.00 (ref)	1.53 (0.89, 2.64)	0.09	
Yes	266/309	1.00 (ref)	1.14 (0.64, 2.02)	0.60	
Drinking					0.85
No	353/332	1.00 (ref)	1.63 (0.99, 2.67)	**< 0.05**	
Yes	199/253	1.00 (ref)	1.10 (0.59, 2.05)	0.77	
Education					**< 0.05**
Junior secondary or below	122/142	1.00 (ref)	0.86 (0.36, 2.03)	0.73	

Senior high school/technical secondary school	79/83	1.00 (ref)	0.69 (0.23, 2.07)	0.55	
Junior college/university or above	351/360	1.00 (ref)	**1.82 (1.13, 2.94)**	**< 0.05**	
Fat quality index	552/585	≤ 1.37	> 1.56		
Age (year)					0.23
≤ 32.00	276/337	1.00 (ref)	1.34 (0.89, 2.02)	0.16	
> 32.00	276/248	1.00 (ref)	0.91 (0.57, 1.44)	0.72	
BMI					0.98
≤ 25.95	264/296	1.00 (ref)	1.26 (0.81, 1.95)	0.29	
> 25.95	288/289	1.00 (ref)	1.02 (0.67, 1.57)	0.87	
Physical activity (MET/hours/week)					0.21
≤ 128.05	256/293	1.00 (ref)	1.30 (0.83, 2.03)	0.23	
> 128.05	296/292	1.00 (ref)	1.01 (0.67, 1.54)	0.90	
Smoking					0.70
No	286/276	1.00 (ref)	1.10 (0.71, 1.70)	0.68	
Yes	266/309	1.00 (ref)	1.10 (0.72, 1.70)	0.54	
Drinking					0.94
No	353/332	1.00 (ref)	1.21 (0.81, 1.80)	0.34	
Yes	199/253	1.00 (ref)	1.00 (0.62, 1.63)	0.89	
Education					0.85
Junior secondary or below	122/142	1.00 (ref)	1.17 (0.62, 2.22)	0.40	

Senior high school/technical secondary school	79/83	1.00 (ref)	1.01 (0.43, 2.38)	0.99	
Junior college/university or above	351/360	1.00 (ref)	1.12 (0.76, 1.65)	0.57	
Protein quality index	552/585	≤ 0.54	> 0.85		
Age (year)					0.30
≤ 32.00	276/337	1.00 (ref)	1.40 (0.89, 2.21)	0.14	
> 32.00	276/248	1.00 (ref)	1.05 (0.64, 1.72)	0.79	
BMI					0.70
≤ 25.95	264/296	1.00 (ref)	1.43 (0.90, 2.29)	0.13	
> 25.95	288/289	1.00 (ref)	1.11 (0.69, 1.78)	0.63	
Physical activity (MET/hours/week)					0.08
≤ 128.05	256/293	1.00 (ref)	1.17 (0.73, 1.87)	0.51	
> 128.05	296/292	1.00 (ref)	1.38 (0.87, 2.21)	0.16	
Smoking					0.69
No	286/276	1.00 (ref)	1.32 (0.81, 2.16)	0.27	
Yes	266/309	1.00 (ref)	1.34 (0.85, 2.12)	0.20	
Drinking					0.30
No	353/332	1.00 (ref)	1.41 (0.91, 2.19)	0.11	
Yes	199/253	1.00 (ref)	1.13 (0.67, 1.91)	0.71	
Education					0.44
Junior secondary or below	122/142	1.00 (ref)	1.48 (0.74, 2.97)	0.26	

Senior high school/technical secondary school	79/83	1.00 (ref)	0.99 (0.39, 2.50)	0.92
Junior college/university or above	351/360	1.00 (ref)	1.31 (0.86, 2.00)	0.18

CI, confidence interval; MET, metabolic equivalent; OR, odds ratio; Ref, reference.

[a] The binary logistic regression model was used to calculate OR and 95% CI and adjusted by age (continuous, year), body mass index (continuous, kg/m^2), total energy intake (continuous, kcal/day), physical activity (continuous, MET/hours/week), annual family income (continuous, RMB, ten thousand yuan), education (junior secondary or below, senior high school/technical secondary school, or junior college/university or above), smoking (yes or no), drinking (yes or no), and abstinence time (continuous, day). Additionally, the logistic regression model was further adjusted by fat intake (continuous, g/day) and protein intake (continuous, g/day) for carbohydrate quality index, by carbohydrate intake (continuous, g/day) and protein intake (continuous, g/day) for fat quality index, and by carbohydrate intake (continuous, g/day) and fat intake (continuous, g/day) for protein quality index, unless a certain variable was the basis of the stratification.

[b] *P* for trend was calculated by the binary logistic regression model, according to continuous variables containing the median value for each tertile.

[c] Multiplicative interaction was evaluated using the binary logistic regression model by including the product term between macronutrient quality (tertiles) and potential confounding factors [dichotomous, except education (tripartite)].

The bold values indicated statistical significance.

Table S3. Additive interactions between macronutrient quality (MQI, CQI, FQI, and PQI) and potential confounding factors on asthenozoospermia risk [a]

Variables	Additive interaction (Tertile 3 vs. Tertile 1)		
	RERI (95% CI)	AP (95% CI)	S (95% CI)
MQI (> 11.00 vs. ≤ 7.00)			
Age (> 32.00 vs. ≤ 32.00, year)	-0.10 (-0.79, 0.58)	-0.07 (-0.52, 0.38)	0.84 (0.28, 2.53)
Body mass index (> 25.95 vs. ≤ 25.95, kg/m^2)	0.08 (-0.45, 0.60)	0.06 (-0.38, 0.51)	1.66 (0.01, 274.14)
Physical activity (≤ 128.05 vs. > 128.05, MET/hours/week)	0.07 (-0.37, 0.52)	0.09 (-0.45, 0.62)	0.66 (0.09, 4.81)
Smoking (yes vs. no)	-0.24 (-0.84, 0.35)	-0.23 (-0.77, 0.31)	0.16 (0.00, 248.94)
Drinking (yes vs. no)	-0.38 (-1.08, 0.32)	-0.43 (-1.27, 0.40)	-0.50 (---, ---)
Education [b]	0.18 (-0.28, 0.64)	0.18 (-0.31, 0.66)	-0.08 (---, ---)
CQI (> 13.00 vs. ≤ 10.00)			
Age (> 32.00 vs. ≤ 32.00, year)	-0.13 (-0.82, 0.57)	-0.08 (-0.51, 0.36)	0.83 (0.32, 2.16)
Body mass index (> 25.95 vs. ≤ 25.95, kg/m^2)	-0.47 (-1.19, 0.25)	-0.34 (-0.85, 0.17)	0.44 (0.16, 1.21)
Physical activity (≤ 128.05 vs. > 128.05, MET/hours/week)	0.21 (-0.20, 0.62)	0.24 (-0.25, 0.73)	0.36 (0.05, 2.63)
Smoking (yes vs. no)	-0.09 (-0.66, 0.48)	-0.08 (-0.59, 0.43)	0.49 (0.02, 15.66)
Drinking (yes vs. no)	-0.70 (-1.57, 0.17)	-0.74 (-1.71, 0.23)	-0.08 (---, ---)
Education [b]	0.41 (0.01, 0.81)	0.40 (-0.04, 0.84)	-0.07 (---, ---)
FQI (> 1.56 vs. ≤ 1.37)			
Age (> 32.00 vs. ≤ 32.00, year)	-0.14 (-0.82, 0.55)	-0.09 (-0.57, 0.38)	0.77 (0.23, 2.54)
Body mass index (> 25.95 vs. ≤ 25.95, kg/m^2)	-0.37 (-1.03, 0.30)	-0.30 (-0.83, 0.23)	0.37 (0.08, 1.64)
Physical activity (≤ 128.05 vs. > 128.05, MET/hours/week)	0.16 (-0.25, 0.57)	0.20 (-0.33, 0.72)	0.55 (0.16, 1.85)

Smoking (yes vs. no)	-0.03 (-0.53, 0.47)	-0.03 (-0.55, 0.49)	5.01 (---, ---)
Drinking (yes vs. no)	-0.15 (-0.74, 0.43)	-0.18 (-0.88, 0.52)	-11.97 (---, ---)
Education [b]	0.13 (-0.35, 0.61)	0.14 (-0.37, 0.64)	0.09 (---, ---)
	PQI (> 0.85 vs. ≤ 0.54)		
Age (> 32.00 vs. ≤ 32.00, year)	-0.14 (-0.86, 0.57)	-0.09 (-0.53, 0.35)	0.82 (0.32, 2.07)
Body mass index (> 25.95 vs. ≤ 25.95, kg/m^2)	-0.13 (-0.74, 0.48)	-0.10 (-0.56, 0.36)	0.70 (0.17, 2.84)
Physical activity (≤ 128.05 vs. > 128.05, MET/hours/week)	-0.04 (-0.54, 0.45)	-0.05 (-0.57, 0.48)	2.75 (---, ---)
Smoking (yes vs. no)	< 0.01 (-0.52, 0.53)	< 0.01 (-0.47, 0.48)	1.05 (< 0.01, 282.32)
Drinking (yes vs. no)	-0.38 (-1.08, 0.31)	-0.39 (-1.14, 0.35)	-0.08 (---, ---)
Education [b]	0.08 (-0.44, 0.60)	0.07 (-0.39, 0.54)	2.50 (---, ---)

AP, the attributable proportion due to interaction; CI, confidence intervals; CQI, carbohydrate quality index; FQI, fat quality index; MET, metabolic equivalent; MQI, macronutrient quality index; PQI, protein quality index; RERI, the relative excess risk due to interaction; S, the synergy index.

[a] Additive interaction was evaluated using RERI, AP, and S, and adjusted by age (continuous, year), body mass index (continuous, kg/m^2), total energy intake (continuous, kcal/day), physical activity (continuous, MET/hours/week), annual family income (continuous, RMB, ten thousand yuan), education (junior secondary or below, senior high school/technical secondary school, or junior college/university or above), smoking (yes or no), drinking (yes or no), and abstinence time (continuous, day). Additionally, the additive interaction was further adjusted by fat intake (continuous, g/day) and protein intake (continuous, g/day) for CQI, by carbohydrate intake (continuous, g/day) and protein intake (continuous, g/day) for FQI, and by carbohydrate intake (continuous, g/day) and fat intake (continuous, g/day) for PQI, unless a certain variable was the basis of the interaction.

[b] Education: junior college/university or above vs. senior high school/technical secondary school or below.

The bold values indicated statistical significance.

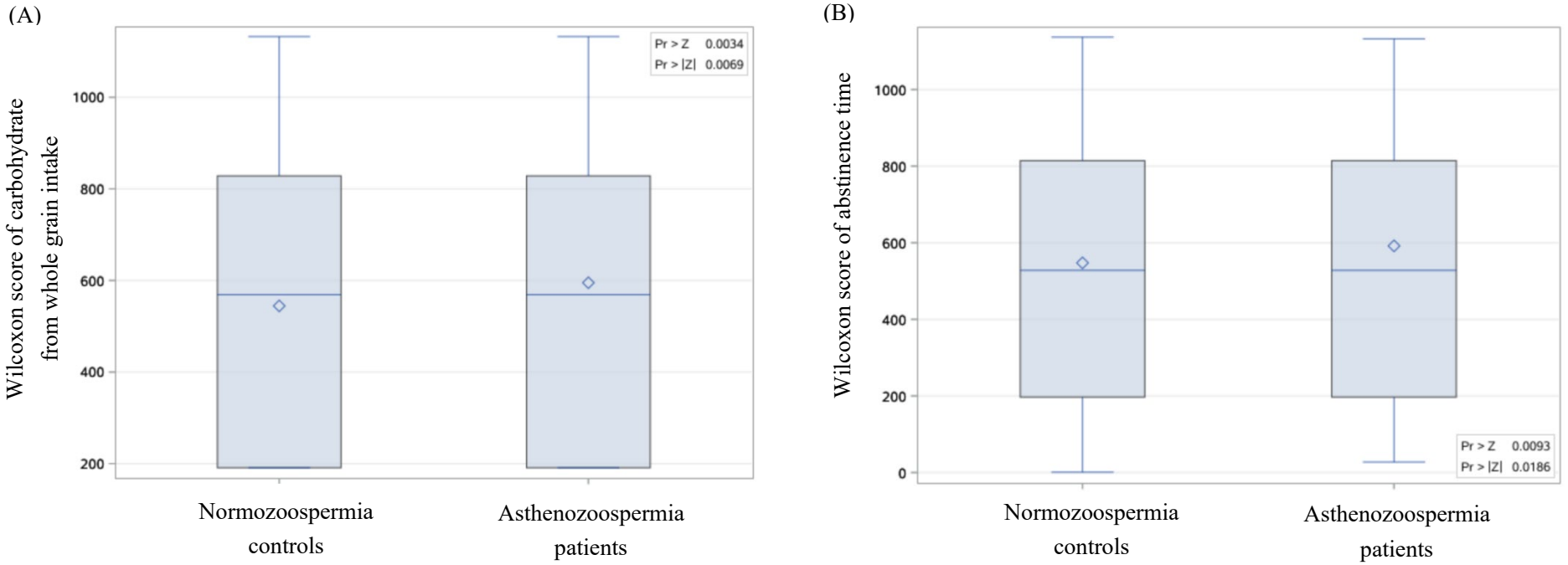
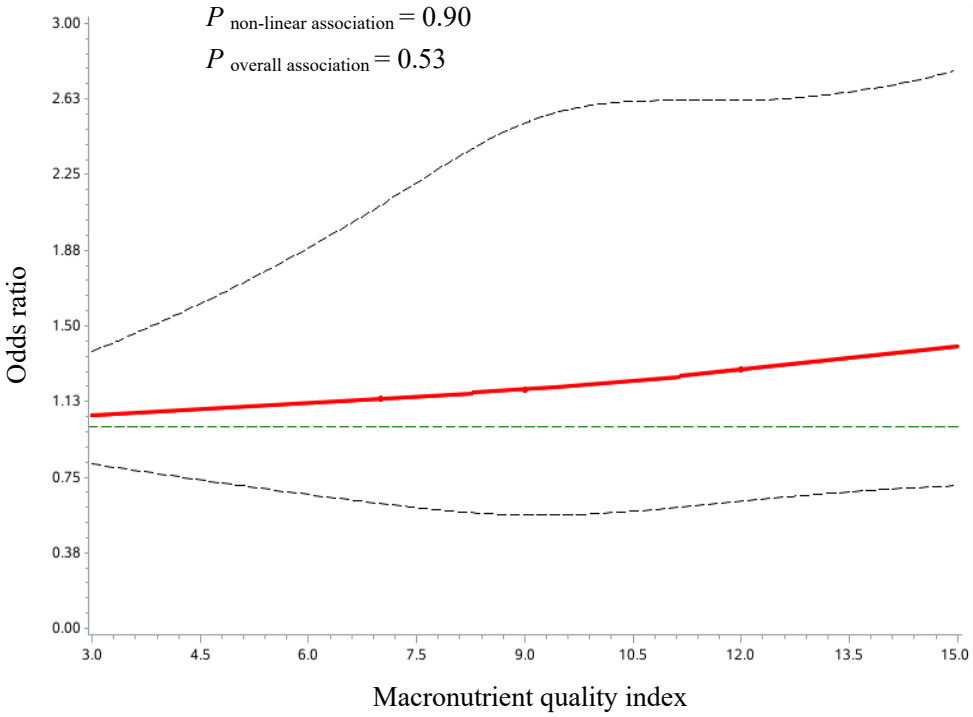


Figure S1. Box plots of the Wilcoxon rank-sum test.

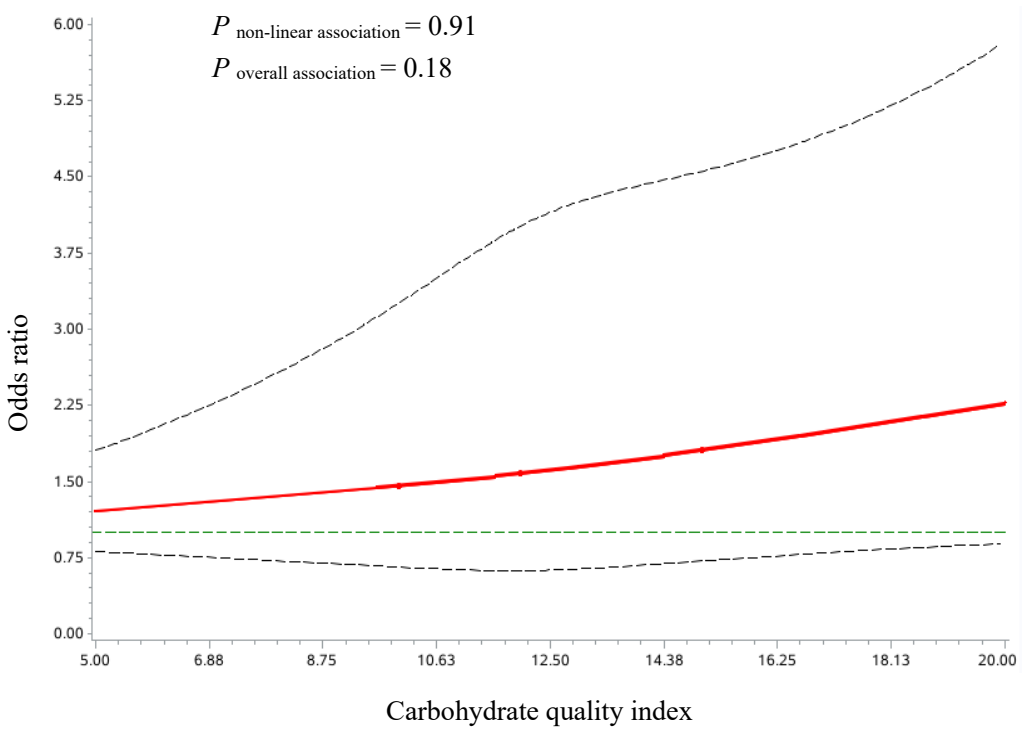
(A) Box plots of the Wilcoxon rank-sum test for carbohydrate from whole grain intake; (B) Box plots of the Wilcoxon rank-sum test for abstinence time.

The diamonds represented the mean Wilcoxon score, i.e., the mean rank sum.

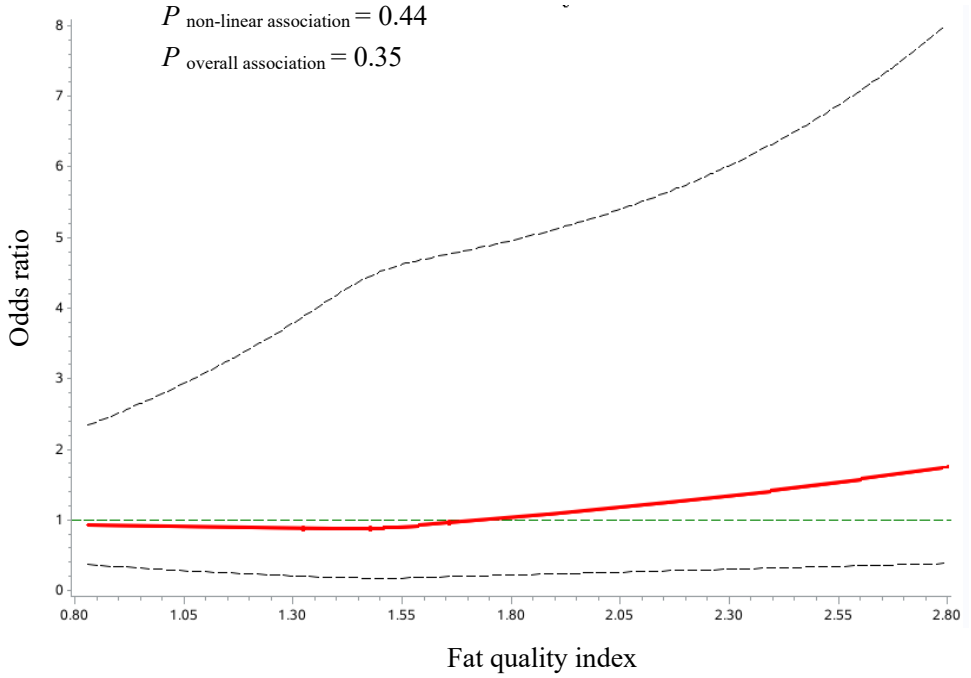
(A)


P non-linear association = 0.90
P overall association = 0.53
Odds ratio
3.00
2.63
2.25
1.88
1.50
1.13
0.75
0.38
0.00
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
Macronutrient quality index

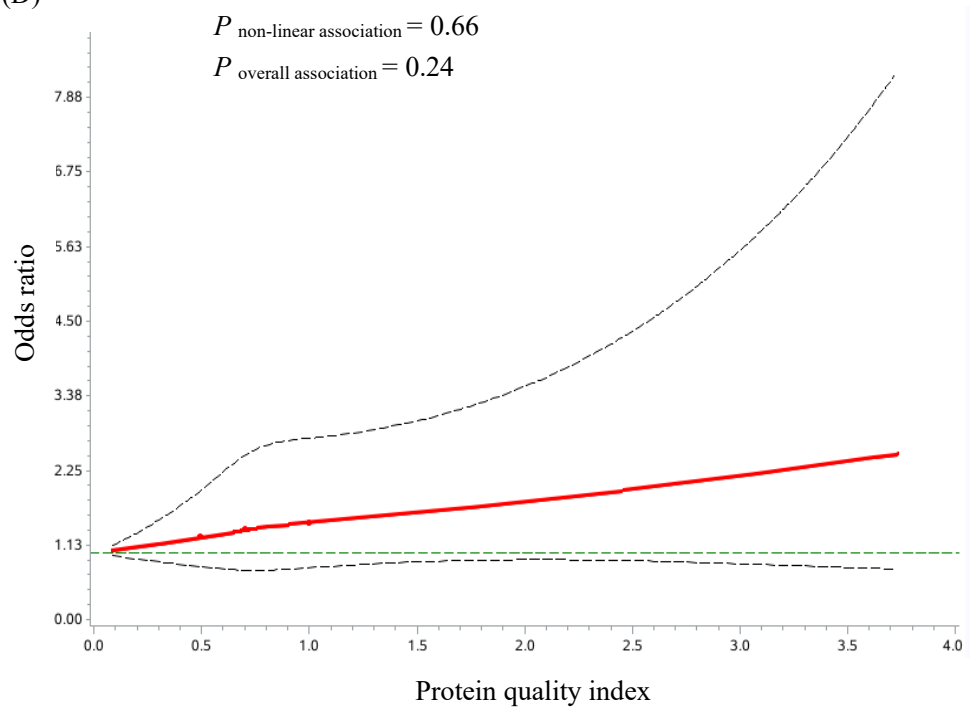
(B)


P non-linear association = 0.91
P overall association = 0.18
Odds ratio
6.00
5.25
4.50
3.75
3.00
2.25
1.50
0.75
0.00
5.00
6.88
8.75
10.63
12.50
14.38
16.25
18.13
20.00
Carbohydrate quality index

(C)


P non-linear association = 0.44
P overall association = 0.35
Odds ratio
0
1
2
3
4
5
6
7
8
0.80
1.05
1.30
1.55
1.80
2.05
2.30
2.55
2.80
Fat quality index

(D)


P non-linear association = 0.66
P overall association = 0.24
Odds ratio
0.00
1.13
2.25
3.38
4.50
5.63
6.75
7.88
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Protein quality index


Estimation
Lower_CL
Upper_CL
Knots

Figure S2. Dose–response relationships of macronutrient quality index and its sub-indices with asthenozoospermia risk using restricted cubic splines [a]

(A) The restricted cubic spline curve for relationships between macronutrient quality index and asthenozoospermia risk; (B) The restricted cubic spline curve for relationships between carbohydrate quality index and asthenozoospermia risk; (C) The restricted cubic spline curve for relationships between fat quality index and asthenozoospermia risk; (D) The restricted cubic spline curve for relationships between protein quality index and asthenozoospermia risk.

CL, confidence limit.

[a] The restricted cubic spline model was adjusted by age (continuous, year), body mass index (continuous, kg/m^2), total energy intake (continuous, kcal/day), physical activity (continuous, MET/hours/week), annual family income (continuous, RMB, ten thousand yuan), education (junior secondary or below, senior high school/technical secondary school, or junior college/university or above), smoking (yes or no), drinking (yes or no), and abstinence time (continuous, day). Additionally, the restricted cubic spline model was further adjusted by fat intake (continuous, day) and protein intake (continuous, day) for carbohydrate quality index, by carbohydrate intake (continuous, day) and protein intake (continuous, day) for fat quality index, and by carbohydrate intake (continuous, day) and fat intake (continuous, day) for protein quality index.

Macronutrient quality	No. of cases/ controls	Tertile 3 vs. Tertile 1		*P* for trend [b]
		Forest map	OR (95% CI) [a]	
Macronutrient quality index				
Main analysis	552/585		1.24 (0.88, 1.73)	0.20
Sensitivity analysis				
Excluding participants with dietary change	424/469		1.22 (0.84, 1.79)	0.29
Using the macronutrient quality index with the HPPQI	552/585		1.16 (0.85, 1.58)	0.34
Carbohydrate quality index				
Main analysis	552/585		1.35 (0.92, 1.97)	0.12
Sensitivity analysis				
Excluding participants with dietary change	424/469		1.32 (0.86, 2.04)	0.22
Fat quality index				
Main analysis	552/585		1.13 (0.84, 1.53)	0.38
Sensitivity analysis				
Excluding participants with dietary change	424/469		1.21 (0.85, 1.71)	0.25
Protein quality index				
Main analysis	552/585		1.28 (0.92, 1.78)	0.13
Sensitivity analysis				
Excluding participants with dietary change	424/469		1.37 (0.95, 1.98)	0.09

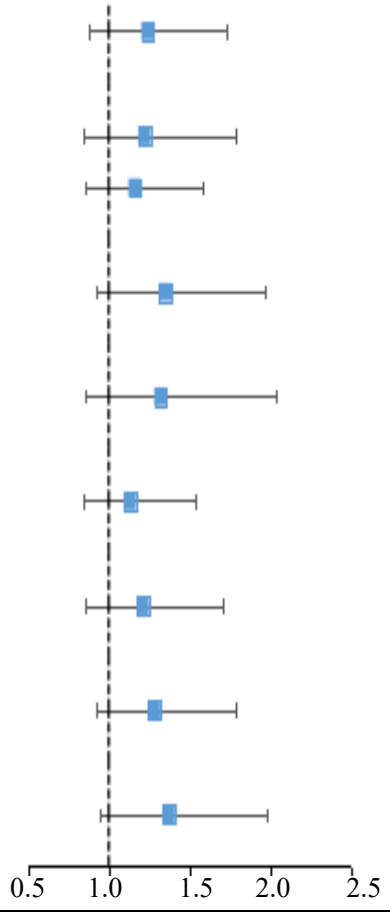


Figure S3. Sensitivity analysis of associations (OR and 95% CI) of macronutrient quality index and its sub-indices with asthenozoospermia risk

CI, confidence interval; HPPQI, the healthy plate protein source quality index; OR, odds ratio; Ref, reference.

[a] The binary logistic regression model was used to evaluate OR and 95% CI and adjusted by age (continuous, year), body mass index (continuous, kg/m^2), total energy intake (continuous, kcal/day), physical activity (continuous, MET/hours/week), annual family income (continuous, RMB, ten thousand yuan), education (junior secondary or below, senior high school/technical secondary school, or junior college/university or above), smoking (yes or no), drinking (yes or no), and abstinence time (continuous, day). Additionally, the binary logistic regression model was further adjusted by fat intake (continuous, g/day) and protein intake (continuous, g/day) for carbohydrate quality index, by carbohydrate intake (continuous, g/day) and protein intake (continuous, g/day) for fat quality index, and by carbohydrate intake (continuous, g/day) and fat intake (continuous, g/day) for protein quality index.

[b] *P* for trend was calculated by the binary logistic regression model, according to continuous variables containing the median value for each tertile.