

Supplemental Table 1. The main component of rats' diet for three groups.

Ingredient	LZG (g/kg)	NZG and PZG (g/kg)
Cornstarch	465.7	465.7
Egg white	140	140
Sucrose	100	100
Maltodextrin	155	155
Soybean oil	40	40
Fiber	50	50
Mineral mix	35	35
Vitamin mix	10	10
L-Cystine	1.8	1.8
Choline bitartrate	2.5	2.5
Antioxidant	0.08	0.08
Total	1000.08	1000.08
Mineral mix		
Calcium carbonate	357	357
Potassium phosphate	250	250
Sodium chloride	74	74
Potassium sulfate	46.6	46.6
Potassium citrate	28	28
Magnesium oxide	24	24
Ferric citrate	6.06	6.06
Sodium Metasilicate	1.45	1.45
Zinc carbonate	0	1.1
Manganous carbonate	0.63	0.63
Cupric carbonate	0.3	0.3
Chromium potassium sulfate	0.28	0.28
Boric acid	0.08	0.08
Sodium fluoride	0.06	0.06
Nickel (II) Carbonate	0.03	0.03
Lithium Chloride, anhydrous	0.02	0.02
Sodium Selenate	0.01	0.01
1%Potassium iodate	0.01	0.01
Ammonium molybdate	0.01	0.01
Ammonium (meta)vanadate	0.01	0.01
Sucrose	Add to 1000	Add to 1000

LZG: Low-zinc diet group; NZG: Normal-zinc diet group; PZG: Pair-fed group.

Supplemental Table 2. Concentrations of 14 minerals in low-zinc and normal diets.

	Low-zinc diet	Normal zinc diet
Na (g/kg)	3.11±0.11	3.18±0.06
Mg (g/kg)	2.95±0.07	2.92±0.04
K (g/kg)	7.26±0.19	7.40±0.01
Ca (g/kg)	5.23±0.29	5.21±0.13
V (mg/kg)	0.17±0.03	0.16±0.04
Cr (mg/kg)	1.14±0.01	1.05±0.02
Mn (mg/kg)	79.52±0.77	80.04±0.85
Fe (g/kg)	0.11±0.01	0.11±0.01
Co (mg/kg)	0.023±0.003	0.02±0.005
Ni (mg/kg)	0.75±0.05	0.75±0.19
Cu (mg/kg)	11.66±0.14	11.43±0.05
Zn (mg/kg)	10.40±0.74	30.40±1.43
Se (mg/kg)	0.20±0.01	0.20±0.01
Mo (mg/kg)	0.23±0.01	0.22±0.03
As	No detected	No detected
Pb	No detected	No detected

Supplemental Table 3. Linear relationships and detection limits of 16 minerals.

Minerals	Internal Standards	Standard Curve Regression Equation	R ²	Range	Detection Limit
Na	45	$y=741735.4809*x + 91189.7338$	0.9999	1-50mg/L	0.0128 mg/L
Mg	45	$y=310667.3488*x + 2151.3709$	1.0000	0.2-10mg/L	0.0015 mg/L
K	45	$y=229688.1177*x + 8376.6681$	1.0000	1-50mg/L	0.0014 mg/L
Ca	45	$y=14370.9673*x + 827.4617$	0.9999	0.2-10mg/L	0.0012 mg/L
V	45	$y=4712.0963*x + 30.7505$	0.9998	0.5-10µg/L	0.0026 µg/L
Cr	45	$y=7038.5065*x + 2073.6387$	0.9984	0.5-50µg/L	0.0127 µg/L
Mn	45	$y=3720.6850*x + 205.8273$	0.9997	0.5-50µg/L	0.0234 µg/L
Fe	45	$y=158989.6388*x + 270.4420$	0.9998	0.05-10mg/L	0.0002 mg/L
Co	72	$y=11787.8954*x + 73.7023$	1.0000	0.5-10µg/L	0.0015 µg/L
Ni	72	$y=3015.7006*x + 1161.1928$	0.9994	0.5-10µg/L	0.0191 µg/L
Cu	72	$y=7758.3355*x + 1935.2720$	0.9997	5-500µg/L	0.0362 µg/L
Zn	72	$y=1190.4871*x + 1156.3873$	0.9995	5-500µg/L	0.0167 µg/L
As	72	$y=587.8430*x + 71.5504$	0.9998	0.5-10µg/L	0.2503 µg/L
Se	72	$y=48.7935*x + 2.2139$	0.9997	0.5-10µg/L	0.0668 µg/L
Mo	103	$y=5646.8281*x + 118.8650$	0.9998	0.5-10µg/L	0.0024 µg/L
Pb	209	$y=13814.8623*x + 875.8645$	0.9994	0.5-10µg/L	0.0083 µg/L

Supplemental Table 4. Analytical results of standard reference materials (Seronorm serum L-1 RUO, n=3).

	Certified value	Determined value (M±SD)
Na (mg/g)	3855±776	3366.98±42.02
Mg (mg/g)	19.3±3.9	18.02±0.32
K (mg/g)	148±30	133.26±2.06
Ca (mg/g)	97±20	86.41±1.38
V (µg/g)	0.23	0.28±0.02
Cr (µg/g)	1.50±0.30	1.7±0.09
Mn (µg/g)	9.4±1.9	10.78±0.19
Fe (mg/g)	1.40±0.28	1.38±0.04
Co (µg/g)	0.99±0.20	1.03±0.05
Ni (µg/g)	5.06±1.02	5.39±0.81
Cu (µg/g)	1128±227	1263.89±10.05
Zn (µg/g)	1.46±0.29	1.27±0.68
As (µg/g)	0.32	0.37±0.03
Se (µg/g)	95±19	89.52±3.65
Mo (µg/g)	0.41	0.47±0.06
Pb (µg/g)	0.75	0.82±0.07

Supplemental Table 5. Spiked recoveries of 16 minerals (n=6).

	Low concentration	Medium concentration	High concentration
Na	101.2%	101.5%	99.4%
Mg	104.2%	101.8%	98.7%
K	97.5%	96.8%	94.2%
Ca	99.5%	97.7%	93.8%
V	99.0%	98.0%	94.6%
Cr	108.4%	101.2%	96.0%
Mn	104.7%	102.2%	95.8%
Fe	94.2%	91.8%	85.7%
Co	108.6%	105.4%	97.3%
Ni	104.0%	100.5%	91.7%
Cu	110.4%	110.8%	102.4%
Zn	83.36%	96.07%	85.1%
As	82.1%	83.1%	81.9%
Se	86.2%	81.6%	78.4%
Mo	104.6%	103.1%	98.2%
Pb	79.8%	82.0%	79.5%

Low, medium, and high concentrations of K, Ca, Na, Mg, and Fe are 1mg/L, 5mg/L, 20mg/L; V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Mo, Pb are 10, 50, 200 µg/L.

Supplemental Table 6. Precision of 16 minerals (n=6).

	Low concentration	Medium concentration	High concentration
Na	1.67%	1.43%	1.07%
Mg	1.81%	1.42%	0.92%
K	1.67%	1.53%	0.88%
Ca	2.07%	1.38%	0.85%
V	1.42%	1.29%	0.87%
Cr	7.74%	1.31%	0.71%
Mn	1.40%	1.66%	0.95%
Fe	1.32%	1.50%	0.71%
Co	1.52%	1.42%	0.78%
Ni	1.66%	1.36%	1.01%
Cu	1.86%	1.39%	0.82%
Zn	6.55%	5.36%	2.35%
As	2.72%	1.33%	2.72%
Se	1.99%	1.76%	4.00%
Mo	1.90%	1.35%	1.04%
Pb	2.14%	0.95%	0.46%

Low, medium, and high concentrations of K, Ca, Na, Mg, and Fe are 1mg/L, 5mg/L, 20mg/L; V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Mo, Pb are 10, 50, 200 µg/L.

Supplemental Table 7. The concentrations of 16 minerals in the feces (n=32).

	LZG	NZG	PZG
Na (mg/g)	0.59±0.61	0.63±0.36	0.73±0.79
Mg (µg/g)	3582.47±587.98*	2928.6±504.56	3101.44±444.83
K (mg/g)	2.03±1.96	3.23±3.43	2.15±2.11
Ca (µg/g)	43055.34±6695.71*	51726.04±5046.91	53686.55±5986.25
V (ng/g)	1194.88±363.72*	1573.98±206.26	1620.16±410.66
Cr (ng/g)	14008.17±1476.48	13452.09±1208.27	14781.93±1124.03
Mn (ng/g)	132501.82±13770.07	124350.55±10806.92	129972.18±12322.28
Fe (µg/g)	643.86±101.64	602.92±51.16	728.47±214.72
Co (ng/g)	204.36±28.06*	275.03±58.32	267.93±36.17
Ni (ng/g)	4861.85±1261.14*	5829.47±666.86	6136.6±920.08
Cu (µg/g)	62.67±6.92	57.42±4.17	59.43±6.37
Zn (µg/g)	189.84±42.16*	322.97±21.06	327±33.9
As (µg/g)	0.85±0.39*	0.35±0.1	0.42±0.17
Se (µg/g)	1.46±0.14*	1.35±0.28	1.33±0.15
Mo (µg/g)	0.44±0.13	0.4±0.07	0.55±0.22
Pb (ng/g)	225.01±45.16	226.88±58.39	270.2±246.49

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 8. The concentrations of 16 minerals in the urine (n=32).

	LZG	NZG	PZG
Na (mg/ml)	0.42±0.35	0.48±0.34	0.46±0.32
Mg (µg/ml)	20.06±12.32	30.36±8.99	27.81±11.03
K (mg/ml)	5.89±2.13*	3.36±1.71	3.15±2.1
Ca (µg/ml)	93.72±33.15*	59.62±30.51	63.85±22.99
V (ng/ml)	13.3±8.8	6.69±2.65	9±4.37
Cr (ng/ml)	85.28±53.67*	191.06±138.32	293.22±170.06
Mn (ng/ml)	42.71±14.33	51.82±33.71	66.59±38.22
Fe (µg/ml)	0.72±0.32	1.09±1.12	0.82±0.41
Co (ng/ml)	4.39±0.77*	2.86±0.98	3.59±1.02
Ni (ng/ml)	23.17±6.82*	30.8±9.56	34.9±18.1
Cu (µg/ml)	0.29±0.16	0.28±0.2	0.33±0.19
Zn (µg/ml)	1.27±0.6*	1.94±0.47	2.02±0.91
As (µg/ml)	0.35±0.05*	0.41±0.06	0.42±0.09
Se (µg/ml)	0.31±0.07	0.28±0.07	0.3±0.08
Mo (µg/ml)	0.23±0.08*	0.35±0.12	0.38±0.15
Pb (ng/ml)	11.48±3.81	11.76±2.97	11.08±5.14

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 9. The concentrations of 16 minerals in the serum (n=29).

	LZG	NZG	PZG
Na (mg/ml)	3.2±0.12	3.18±0.09	3.13±0.08
Mg (µg/ml)	30.93±10.93*	20.11±2.52	21.01±6.03
K (mg/ml)	0.17±0.02	0.17±0.03	0.22±0.09
Ca (µg/ml)	116.53±15.21*	102.31±3.44	103.54±6.6
V (ng/ml)	7.28±4.35	6.47±2.85	5.54±1.58
Cr (ng/ml)	49.37±12.61*	66.55±19.51	63.43±13.78
Mn (ng/ml)	41.2±16.26	47.6±15.1	42.16±11.82
Fe (µg/ml)	2.96±1.48	3.84±1.39	3.53±1.85
Co(ng/ml)	1.59±0.52	1.56±0.28	1.41±0.26
Ni (ng/ml)	61.84±13.54	56.22±5.24	54.15±3.42
Cu (µg/ml)	2.08±0.46*	1.7±0.23	1.7±0.3
Zn (µg/ml)	1.29±0.28*	1.65±0.3	1.56±0.22
As (ng/ml)	41.53±21.14*	85.85±39.47	74.88±38.16
Se (ng/ml)	386.79±34.75	394.02±77.67	377.98±52.53
Mo (ng/ml)	13.1±3.77	13.75±4.55	13.87±2.76
Pb (ng/ml)	20.1±7.11	15.06±4.43	15.07±4.1

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 10. The concentrations of 16 minerals in the blood (n=25).

	LZG	NZG	PZG
Na (mg/ml)	2.71±0.34	2.83±0.34	2.76±0.27
Mg (µg/ml)	45.41±2.98	52.4±18.46	43.09±3
K (mg/ml)	3.32±0.31	3.14±0.34	3.18±0.4
Ca (µg/ml)	105.23±10.05	98.49±14.53	106.37±9.61
V (ng/ml)	6.83±1.87*	4.09±1.02	5±1.21
Cr (ng/ml)	366.99±161.21*	180.3±74.46	237.86±75.98
Mn (ng/ml)	62.24±13.93*	39.57±15.08	51.81±11.97
Fe (µg/ml)	565.88±102.51	548.08±72.92	520.05±106.03
Co(ng/ml)	2.27±1.06*	1.41±0.26	1.8±0.49
Ni (ng/ml)	75.12±3.95*	80.57±31.2	71.71±2.51
Cu (µg/ml)	1.92±0.54	1.95±0.53	1.86±0.51
Zn (µg/ml)	7.75±0.99	6.99±0.92	7.61±0.78
As (µg/ml)	22.61±9.18	27.84±5.93	23.47±2.44
Se (µg/ml)	0.62±0.06	0.61±0.1	0.6±0.08
Mo (µg/ml)	0.15±0.04*	0.08±0.04	0.13±0.04
Pb (ng/ml)	14.11±4.73	10.42±9.75	13.79±12.59

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 11. The concentrations of 16 minerals in the heart (n=37).

	LZG	NZG	PZG
Na (mg/g)	1.41±0.29	1.31±0.23	1.41±0.3
Mg (µg/g)	166.9±19.63	171.82±44.05	169.42±15.28
K (mg/g)	2.51±0.27	2.67±0.45	2.47±0.4
Ca (µg/g)	81.39±38.37*	50.06±9.06	49.08±13.05
V (ng/g)	42.59±6.66*	36.31±4.14	35.14±3.54
Cr (ng/g)	911.88±551.84*	514.02±248.86	468.24±290.93
Mn (ng/g)	550.61±214.52	451.99±34.23	451.41±50.36
Fe (µg/g)	84.89±21.12	87.2±11.93	76.11±8.61
Co (ng/g)	14.15±3.65	13.98±2.62	13.71±1.83
Ni (ng/g)	63.55±60.77*	24.06±12.29	20.72±6.85
Cu (µg/g)	4.58±0.81	4.54±0.52	4.43±0.32
Zn (µg/g)	16.11±2.31	15.46±1.29	14.77±1.09
As (µg/g)	1.57±1.01	1.81±0.71	0.95±0.39
Se (µg/g)	0.28±0.03	0.27±0.04	0.27±0.04
Mo (µg/g)	0.28±0.13	0.26±0.12	0.2±0.09
Pb (ng/g)	74.43±47.76*	44.04±24.33	40.02±30.74

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 12. The concentrations of 16 minerals in the spleen (n=43).

	LZG	NZG	PZG
Na (mg/g)	1.02±0.27	0.97±0.22	0.94±0.11
Mg (µg/g)	177.08±23.82*	190.08±29.26	200.45±13.26
K (mg/g)	3.79±0.58*	4.41±0.33	4.35±0.29
Ca (µg/g)	51.88±18.1	48.84±13.87	49.92±8.09
V (ng/g)	63.62±37.93*	35.08±13.8	31.19±12.59
Cr (ng/g)	72.21±9.58	76.24±14.08	74.47±8.05
Mn (ng/g)	268.7±35.71	256.55±38.91	280.48±50.67
Fe (µg/g)	1766.05±1181.95	1508.79±807.84	1377.54±1271.61
Co (ng/g)	4.34±1.14	3.9±0.97	4.71±1.41
Ni (ng/g)	11.11±8.83	6.79±3.46	6.87±4.87
Cu (µg/g)	1.71±0.5	1.56±0.21	1.74±0.37
Zn (µg/g)	16.72±1.59*	18.14±1.51	17.88±0.92
As (µg/g)	4.33±2.45	5.86±2.42	4.02±2.32
Se (µg/g)	0.38±0.06*	0.44±0.08	0.41±0.07
Mo (µg/g)	0.3±0.09	0.31±0.1	0.28±0.12
Pb (ng/g)	25.07±10.68	27.13±10.73	22.9±13.38

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 13. The concentrations of 16 minerals in the testis (n=41).

	LZG	NZG	PZG
Na (mg/g)	2.07±0.63*	1.49±0.19	1.44±0.3
Mg (µg/g)	110.04±49.01	118.67±14.16	119.48±14.78
K (mg/g)	1.97±0.91*	2.89±0.38	2.79±0.48
Ca (µg/g)	1027.05±1120.47*	104.51±100	100.33±84.85
V (ng/g)	47.14±18.3*	28.01±4.48	28.09±3.79
Cr (ng/g)	227.73±121.87	254.26±124.67	257.28±142.37
Mn (ng/g)	366.07±161.23	297.94±72.88	274.6±37.25
Fe (µg/g)	65.99±23.72	61.04±8.54	62.1±12.48
Co (ng/g)	5.5±3*	3.57±0.73	3.73±0.45
Ni (ng/g)	26.56±20.16	21.72±12.03	15.31±4.19
Cu (µg/g)	2.09±0.65*	1.67±0.16	1.63±0.24
Zn (µg/g)	14.97±6.69*	20.9±3.02	20.2±3.72
As (µg/g)	0.36±0.19	0.31±0.21	0.27±0.13
Se (µg/g)	0.49±0.23*	0.76±0.1	0.71±0.15
Mo (µg/g)	0.15±0.07	0.13±0.04	0.14±0.03
Pb (ng/g)	15.69±9.81	13.75±13.13	11.75±10.46

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 14. The concentrations of 16 minerals in the cecal contents (n=34).

	LZG	NZG	PZG
Na (mg/g)	1.99±0.51	2.11±0.45	1.97±0.51
Mg (µg/g)	666.65±331.72	745.56±453.3	579.63±259.68
K (mg/g)	1.64±0.76	1.43±0.49	1.43±0.53
Ca (µg/g)	11780.11±2178.66*	9779.9±2039.35	9552.58±2344.84
V (ng/g)	357.38±105.48*	272.8±75.57	250.98±72.57
Cr (ng/g)	3237.86±1035.69	3336.3±664.94	3554.07±615.86
Mn (ng/g)	26923.39±7186.08	29007.02±8967.61	23597.44±6541.77
Fe (µg/g)	179.75±107.18	195.52±108.98	162.4±102.42
Co (ng/g)	52.22±11.82*	40.88±8.64	41.48±8.19
Ni (ng/g)	1367.81±408.08*	989.49±235.28	1050.85±295.33
Cu (µg/g)	14.14±4.1	12±1.61	11.52±2.33
Zn (µg/g)	60.16±17.81*	79.5±19.06	77.73±11.99
As (µg/g)	0.15±0.08	0.11±0.06	0.28±0.34
Se (µg/g)	0.36±0.13	0.34±0.05	0.31±0.13
Mo (µg/g)	0.27±0.12	0.32±0.17	0.33±0.11
Pb (ng/g)	48.19±20.79	44.59±22.44	45.59±26.93

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 15. The concentrations of 16 minerals in the kidney (n=43).

	LZG	NZG	PZG
Na (mg/g)	2.13±0.36	1.9±0.32	2.05±0.34
Mg (µg/g)	188.44±31.01*	213.04±27.54	212.13±22.64
K (mg/g)	3.12±0.44*	3.49±0.46	3.24±0.47
Ca (µg/g)	143.7±43.92*	114.39±22.95	115.85±20.72
V (ng/g)	53.88±14.91*	35.07±8.85	29.38±6.73
Cr (ng/g)	157.43±21.21	181.96±90.61	168.98±26.43
Mn (ng/g)	784.04±130.4*	904.91±180.78	928.48±171.46
Fe (µg/g)	197.97±88.5	197.91±72.69	181.3±147.49
Co (ng/g)	90.46±27.81*	51.07±26.37	81.35±43.27
Ni (ng/g)	32.49±4.29	37.09±9.85	34.3±12.54
Cu (µg/g)	5.12±1.57*	6.2±1.09	6.54±1.51
Zn (µg/g)	20.96±3.52*	24.48±4.29	23.95±4.07
As (µg/g)	2.41±1.44	2.49±1.06	2.17±1.79
Se (µg/g)	1.97±0.36	2.1±0.53	2.17±0.41
Mo (µg/g)	0.41±0.1	0.42±0.1	0.45±0.09
Pb (ng/g)	15.21±6.65	20.62±8.28	17.56±11.81

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 16. The concentrations of 16 minerals in the femur (n=41).

	LZG	NZG	PZG
Na (mg/g)	5.49±0.62	5.4±0.99	5.29±0.73
Mg (µg/g)	3850.97±281.95	3674.03±805.15	3738.9±365.78
K (mg/g)	1.06±0.38	1.27±0.36	1.21±0.42
Ca (µg/g)	228434.54±21873.28*	211628.05±43803.1	208154.29±27239.41
V (ng/g)	80.45±11.37	83.13±11	76.85±14.5
Cr (ng/g)	310.42±38.86	349.6±121.17	300.26±41.86
Mn (ng/g)	629.38±104.09	669.97±114.73	597.02±70.61
Fe (µg/g)	78.21±9.57	84.84±12.75	76.45±16.45
Co (ng/g)	46.32±3.72	44.85±11.51	44.07±3.6
Ni (ng/g)	1531.65±140.31	1363.62±417.5	1501.84±134.63
Cu (µg/g)	0.87±0.4	1.11±0.81	0.9±0.47
Zn (µg/g)	171±37.67	167.57±38.96	183.54±24.09
As (µg/g)	0.15±0.09*	0.25±0.14	0.24±0.11
Se (µg/g)	0.06±0.02*	0.1±0.04	0.09±0.03
Mo (µg/g)	0.27±0.09	0.23±0.07	0.23±0.08
Pb (ng/g)	172.72±81.38	213.6±127.17	170.35±94.48

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 17. The concentrations of 16 minerals in the liver (n=43).

	LZG	NZG	PZG
Na (mg/g)	1.14±0.41	1.11±0.43	0.98±0.32
Mg (µg/g)	171.95±24.56*	195.01±34.9	207.15±39.94
K (mg/g)	2.86±0.47	2.75±0.6	3.15±0.42
Ca (µg/g)	61.54±17.66	56.47±17.48	91.05±86.89
V (ng/g)	21.43±8.2*	15.66±4.15	14.85±4.04
Cr (ng/g)	182.67±38.89	194.28±53.85	201.84±65.38
Mn (ng/g)	1463.82±452.59	1614.93±626.48	1650.29±468.31
Fe (µg/g)	301.21±175.95	293.53±97.27	258.23±161.89
Co (ng/g)	11.85±6.6	9.58±3.89	18.71±16.12
Ni (ng/g)	24.23±10.75	20.74±7.52	25.7±9.21
Cu (µg/g)	4.08±1.23	3.93±1.16	5.26±3.51
Zn (µg/g)	22.16±4.62	21.52±6.75	23.38±4.76
As (µg/g)	2.94±2.24	3.38±2.66	2.11±1.53
Se (µg/g)	0.7±0.19	0.76±0.21	0.81±0.23
Mo (µg/g)	0.59±0.19	0.61±0.2	0.62±0.18
Pb (ng/g)	20.67±14.68	23.98±16.24	20.47±11.67

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 18. The concentrations of 16 minerals in the lung (n=41).

	LZG	NZG	PZG
Na (mg/g)	1.81±0.2	1.79±0.25	1.73±0.27
Mg (µg/g)	197.96±19.14	192.52±12.34	193.66±17.48
K (mg/g)	2.58±0.4	2.49±0.32	2.57±0.54
Ca (µg/g)	179.55±112.16	164.04±57.15	158.79±33.84
V (ng/g)	18.88±3.51*	16.86±2.77	15.14±1.8
Cr (ng/g)	254.08±129.45	241.38±77.5	199.42±65.69
Mn (ng/g)	245.67±122.08	206.73±39.41	188.45±43.41
Fe (µg/g)	152±62.57	167.06±74.17	140.46±68.56
Co (ng/g)	7.3±1.76	6.25±1.01	6.51±1.78
Ni (ng/g)	12±0.87	11.9±0.97	12.29±2.75
Cu (µg/g)	1.72±0.25	1.6±0.18	1.65±0.21
Zn (µg/g)	12.53±2.14*	14.72±2.28	14.78±2.62
As (µg/g)	4.75±3.66	6.35±3.58	4.16±3.31
Se (µg/g)	0.34±0.06	0.38±0.08	0.37±0.08
Mo (µg/g)	0.17±0.07	0.16±0.07	0.16±0.06
Pb (ng/g)	25.04±15.88	19.18±11.83	26.29±23.27

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 19. The concentrations of 16 minerals in the skeletal muscle (n=44).

	LZG	NZG	PZG
Na (mg/g)	0.77±0.17	0.8±0.19	0.82±0.17
Mg (µg/g)	246.75±21.05	248.24±26.08	245.72±34.27
K (mg/g)	3.6±0.34	3.57±0.48	3.53±0.47
Ca (µg/g)	70.17±16.9	66.37±12.87	67.01±11.95
V (ng/g)	14.81±3.28	13.51±2.96	13.29±2.32
Cr (ng/g)	184.38±36.79	174.66±28.46	179.99±28.2
Mn (ng/g)	282.62±153.48	207.4±100.8	270.3±148.75
Fe (µg/g)	37.74±8.31	33.09±7.97	36.88±13.3
Co (ng/g)	5.1±2.17	3.82±1.44	4.85±1.99
Ni (ng/g)	45.11±26.17	42.72±20.59	57.61±43.29
Cu (µg/g)	1.11±0.21	1±0.35	1.13±0.26
Zn (µg/g)	11.48±1.81*	14.28±4.16	14.33±5.16
As (µg/g)	0.22±0.12	0.21±0.1	0.21±0.16
Se (µg/g)	0.15±0.02	0.15±0.03	0.16±0.03
Mo (µg/g)	0.14±0.07	0.13±0.07	0.16±0.07
Pb (ng/g)	18.25±8.28	17.94±6.17	18.68±12.73

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 20. The concentrations of 16 minerals in the subcutaneous fat (n=44).

	LZG	NZG	PZG
Na (mg/g)	0.47±0.22	0.51±0.37	0.42±0.16
Mg (µg/g)	16.41±15.73	17.36±17.62	18.32±10.31
K (mg/g)	0.28±0.23	0.29±0.28	0.23±0.11
Ca (µg/g)	33.56±10.12	33.61±17.22	40.08±18.55
V (ng/g)	18.66±11.49	15.25±6.82	13.51±2.63
Cr (ng/g)	205.28±86.87	184.62±36.12	183.08±33.95
Mn (ng/g)	141.27±97.7	117.12±40.13	130.03±85.69
Fe (µg/g)	18.27±8.04	21.53±13.83	15.08±5.75
Co (ng/g)	3.02±2.63	1.87±0.73	2.33±1.39
Ni (ng/g)	36.02±21.68	35.43±19.34	36.76±17.68
Cu (µg/g)	0.28±0.07	0.29±0.11	0.28±0.11
Zn (µg/g)	2.45±0.66*	3.16±1.06	3.44±1.69
As (µg/g)	0.22±0.12	0.24±0.07	0.2±0.08
Se (µg/g)	0.08±0.03	0.08±0.04	0.07±0.02
Mo (µg/g)	0.16±0.07	0.18±0.09	0.14±0.07
Pb (ng/g)	10.01±5.38	12.96±10.46	13.31±10.16

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 21. The concentrations of 16 minerals in the prostate (n=38).

	LZG	NZG	PZG
Na (mg/g)	1.96±0.46	1.83±0.25	2.03±0.51
Mg (µg/g)	357.85±81.52	330.06±104.94	327.82±89.82
K (mg/g)	4.32±1.25	4.44±1.3	4.01±1.17
Ca (µg/g)	420.67±297.93	441.02±360.99	596.29±474.18
V (ng/g)	103.32±15.05	105.83±22.23	95.85±11.85
Cr (ng/g)	1995.85±680.03	2308.19±802.41	1544.99±649.64
Mn (ng/g)	722.15±318.79	831.68±423.71	900.03±349.41
Fe (µg/g)	77.63±40.42	66.85±18.98	67.94±20.06
Co (ng/g)	9.2±4.16	7.86±2.79	9.23±3.07
Ni (ng/g)	77.46±43.04	76.12±42.75	97.44±58.63
Cu (µg/g)	2.19±0.57*	3.44±2.01	3.29±1.56
Zn (µg/g)	387.77±95.2*	550.78±161.88	529.94±185.97
As (µg/g)	0.51±0.25	0.67±0.26	0.55±0.48
Se (µg/g)	0.59±0.25	0.52±0.29	0.59±0.18
Mo (µg/g)	0.53±0.19	0.55±0.21	0.42±0.19
Pb (ng/g)	277.34±146.61	351.52±246.27	338.79±287.67

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 22. The concentrations of 16 minerals in the pancreas (n=26).

	LZG	NZG	PZG
Na (mg/g)	1.38±0.22	1.41±0.21	1.5±0.22
Mg (µg/g)	352.23±20.94	344.01±25.8	361.81±17.66
K (mg/g)	3.05±0.51	2.87±0.19	2.98±0.49
Ca (µg/g)	86.19±35.05	76.5±13.71	72.52±28.23
V (ng/g)	37.76±10.44*	30.49±6.99	28.31±4.84
Cr (ng/g)	2365.05±322.86	2291.43±355.24	2235.92±198.32
Mn (ng/g)	2020.92±465.82*	1546.25±332.91	1701.71±384.9
Fe (µg/g)	122.4±59.18	84.4±23.28	115.75±88.62
Co (ng/g)	11.15±0.44	10.64±0.73	11.15±0.67
Ni (ng/g)	164.7±10.78	161.38±14.08	165.73±9.54
Cu (µg/g)	1.65±0.11	1.61±0.14	1.66±0.1
Zn (µg/g)	20.91±3.69*	25.65±3.51	25.85±4.17
As (µg/g)	0.46±0.26	0.57±0.11	0.63±0.53
Se (µg/g)	0.23±0.04	0.25±0.03	0.27±0.03
Mo (µg/g)	0.45±0.17	0.39±0.1	0.42±0.15
Pb (ng/g)	36.03±12.3	34.6±14.34	31.67±11.58

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 23. The concentrations of 16 minerals in the brain (n=33).

	LZG	NZG	PZG
Na (mg/g)	1.3±0.16	1.26±0.11	1.23±0.14
Mg (µg/g)	258.14±90.3	228.2±11.77	233.19±13.72
K (mg/g)	3.68±0.35	3.54±0.26	3.68±0.33
Ca (µg/g)	98.35±50.23	104.81±59.76	116.08±83.28
V (ng/g)	16.01±2.2	17.38±3.45	16.96±2.78
Cr (ng/g)	699.21±451.57	599.27±179.74	867.15±782.22
Mn (ng/g)	418.13±67.12	373.32±36.47	433.03±72.35
Fe (µg/g)	22.6±3.49	20.63±3.12	21.67±4.22
Co (ng/g)	10.85±8.03	5.96±0.48	9.07±7.78
Ni (ng/g)	13.74±2.35	13.12±1.12	13.53±1.43
Cu (µg/g)	3.91±0.81*	3.19±0.54	3.84±0.84
Zn (µg/g)	14.21±1.03	14.83±2.64	14.14±1.17
As (µg/g)	0.33±0.19	0.3±0.1	0.28±0.15
Se (µg/g)	0.13±0.02	0.12±0.01	0.13±0.01
Mo (µg/g)	0.16±0.06	0.17±0.07	0.19±0.07
Pb (ng/g)	11.5±9.27	8.56±7.4	14.93±14.51

*: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 24. The concentrations of 16 minerals in the duodenum (n=40).

	LZG	NZG	PZG
Na (mg/g)	1.46±0.34	1.27±0.13	1.24±0.29
Mg (µg/g)	174.34±24.74	181.14±20.87	171.01±18.24
K (mg/g)	2.86±0.78	3.1±0.37	2.83±0.63
Ca (µg/g)	149.17±85.72	103.32±38.75	136.86±85.8
V (ng/g)	26.03±2.24	24.44±3.33	25.8±5.88
Cr (ng/g)	361.11±141.53	342.91±258.65	452.63±165.5
Mn (ng/g)	764.18±314.64	707.05±193.39	910.49±602.36
Fe (µg/g)	38.82±13.36	43.51±13.58	33.99±11.76
Co (ng/g)	5.62±2.07	5.51±2.49	5.57±2.93
Ni (ng/g)	35±32.22	30.4±14.51	33.12±18.4
Cu (µg/g)	1.62±0.39	1.69±0.35	1.39±0.22
Zn (µg/g)	20.85±3.45	22.78±0.96	20.39±2.96
As (µg/g)	0.5±0.32	0.5±0.37	0.41±0.28
Se (µg/g)	0.3±0.05	0.3±0.04	0.28±0.03
Mo (µg/g)	0.21±0.09	0.22±0.06	0.29±0.09
Pb (ng/g)	18.68±12.45	21.45±16.83	17.21±12.24

Supplemental Table 25. The concentrations of 16 minerals in the colon (n=41).

	LZG	NZG	PZG
Na (mg/g)	1.38±0.29	1.17±0.27	1.25±0.3
Mg (µg/g)	148.14±33.06	133.3±43.72	143.56±41.97
K (mg/g)	2.41±0.33	2.21±0.41	2.29±0.53
Ca (µg/g)	208.65±142.12	228.15±184.17	196.17±83.91
V (ng/g)	24.48±4.72	26.92±4.5	24.08±3.72
Cr (ng/g)	348.22±309.29	485.08±313.57	446.1±229.46
Mn (ng/g)	914.17±353.82	1060.85±305.6	982.47±339.7
Fe (µg/g)	23.65±7.57	29.01±11.21	20.75±9.55
Co (ng/g)	5.22±2.39	4.72±1.44	5.38±1.29
Ni (ng/g)	22.38±20.89	41.87±31.03	29.57±20.85
Cu (µg/g)	1.67±0.73	1.51±0.36	1.36±0.14
Zn (µg/g)	21.37±2.55	19.59±4.45	19.83±2.12
As (µg/g)	0.33±0.18	0.52±0.41	0.3±0.19
Se (µg/g)	0.23±0.03	0.24±0.03	0.22±0.02
Mo (µg/g)	0.13±0.05	0.15±0.07	0.16±0.07
Pb (ng/g)	29.01±21.5	31.51±19.27	21.9±11.93

Supplemental Table 26. Dietary and mineral intake before urine and feces collection.

	LZG	NZG	PZG
48h-Food intake (g)	46.98 ±4.11	45.55 ±5.72	46.03 ±1.42
Mineral intake			
Na (mg)	146.1±12.77	144.85±18.2	146.38±4.51
Mg (mg)	138.58±12.11	133.01±16.71	134.41±4.14
K (mg)	341.05±29.81	337.07±42.35	340.62±10.49
Ca (mg)	245.69±21.47	237.15±29.79	239.64±7.38
V (µg)	7.99±0.7	7.29±0.92	7.36±0.23
Cr (µg)	53.55±4.68	47.8±6	48.3±1.49
Mn (µg)	3735.6±326.5	3645.82±458.02	3684.24±113.45
Fe (mg)	5.17±0.45	5.01±0.63	5.06±0.16
Co (µg)	1.08±0.09	1.06±0.13	1.07±0.03
Ni (µg)	35.23±3.08	33.99±4.27	34.35±1.06
Cu (µg)	547.75±47.88	520.64±65.41	526.12±16.2
Zn (µg)	488.56±42.7*#	1384.72±173.96	1399.31±43.09
Se (µg)	9.4±0.82	9.11±1.14	9.21±0.28
Mo (µg)	10.8±0.94	10.02±1.26	10.13±0.31

*: P<0.05 (One-Way ANOVA, LZG vs NZG). #: P<0.05 (One-Way ANOVA, LZG vs PZG).

Supplemental Table 27. 48h total excretion of 16 minerals in rats.

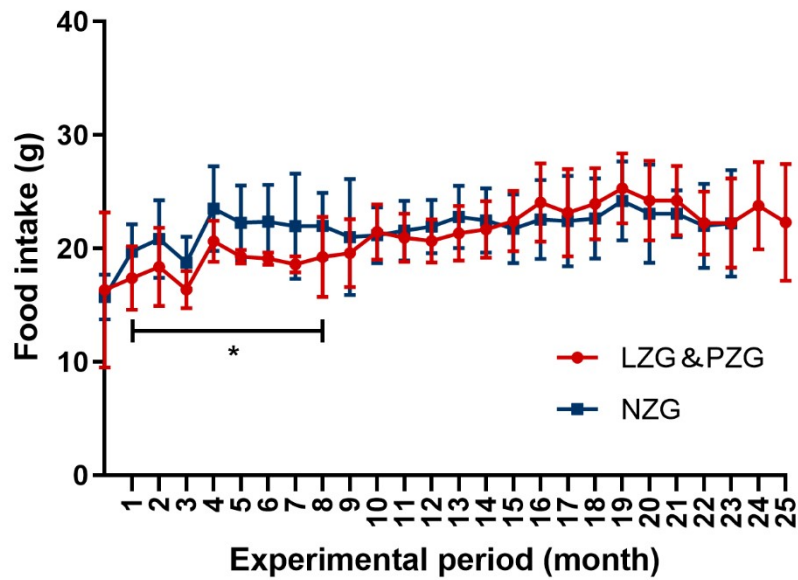
	LZG	NZG	PZG
Na (mg)	6.33±4.07	6.41±3.81	6.17±3.37
Mg (µg)	6790.71±1281.59*	5358.05±1269.25	5438.15±728.16
K (mg)	75.84±23.26*	43.34±18.74	37.16±22.27
Ca (µg)	79059.91±9695.7*	87780.79±6940.67	89561.43±11028.04
V (ng)	2286.75±483.06*	2726.23±355.3	2755.32±482.02
Cr (ng)	26736.84±4569.71	24965.59±5099.93	27849.24±4084.68
Mn (ng)	243122.76±41068.88	213489.62±45918.61	216647.99±30159.6
Fe (µg)	1183.14±232.5	1040.18±196.67	1201.97±267.88
Co (ng)	427.06±55.72*	487.86±35.29	483.34±64.03
Ni (ng)	9012.79±1804.12*	10296.15±1926.26	10534.32±1658.88
Cu (µg)	118.19±18.52	101.13±17.62	103.22±18.98
Zn (µg)	361.06±75.74*	571.65±81.71	564.43±66.5
As (µg)	5.91±0.56*	5.23±0.81	5.23±0.93
Se (µg)	6.55±0.91*	5.43±1.03	5.49±0.96
Mo (µg)	3.68±0.88*	4.58±1.07	5.04±1.6
Pb (ng)	555.57±116.03	523.69±97.9	577.91±513.16

Total mineral excretion = (mineral concentration in urine × urine volume) + (mineral concentration in feces × fecal output).. *: P<0.05 (One-Way ANOVA, LZG vs NZG and PZG).

Supplemental Table 28. Apparent absorption rates of 14 minerals.

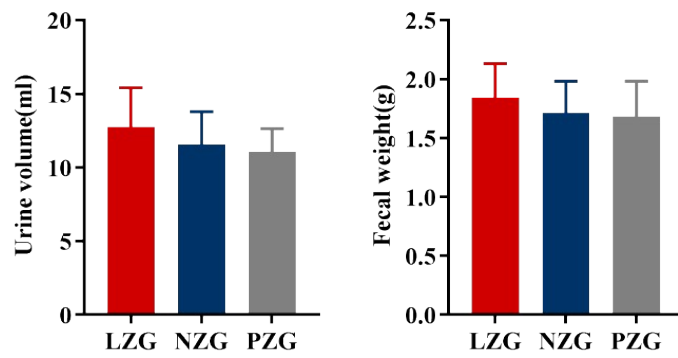
%	LZG	NZG	PZG
Zn	28.79±11.03* [#]	58.4±6.13	59.01±3.88
K	77.89±6.31* [#]	87.06±5.12	88.2±6.19
Mg	95.06±1.06* [#]	95.99±0.68	95.94±0.61
Se	30.18±7.74 [#]	38.78±16.32	40.67±10.64
Ca	67.55±5.23* [#]	62.53±5.02	62.34±4.41
Co	60.32±5.44* [#]	53.09±7.72	53.84±4.95
V	71.05±7.28* [#]	62.06±6.91	61.99±6.49
Ni	74.47±4.54* [#]	69.64±5.05	69.14±4.86
Mo	65.89±7.79* [#]	53.59±12.59	47.31±12.87
Na	95.67±2.91	95.3±3.12	95.7±2.42
Mn	93.45±1.2	94.11±1.24	94.07±0.81
Fe	77.03±4.37	79.12±3.77	75.49±4.43
Cu	78.33±3.57	80.53±2.81	79.82±2.99
Cr	49.72±9.87	47.41±10.42	42.05±8.61

Apparent absorption rate (%) = (Mineral intake (48 h) – Total mineral excretion) / Mineral intake × 100, using values from Table S26 and Table S27. *: P<0.05 (One-Way ANOVA, LZG vs NZG). #: P<0.05 (One-Way ANOVA, LZG vs PZG).



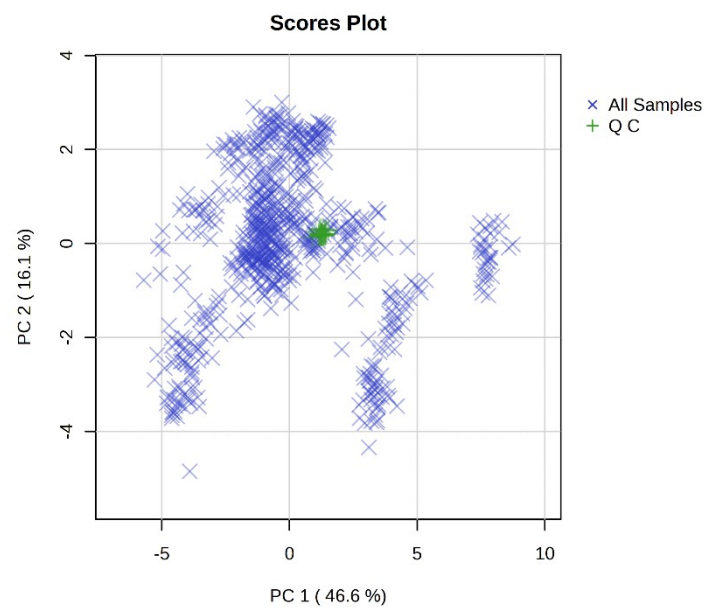
Supplemental Figure 1. Food intake of all three rat groups.

LZG: Low-zinc diet group; NZG: Normal-zinc diet group; PZG: Pair-fed group. The LZG was fed a low-zinc diet, while the NZG received a normal-zinc diet. The daily food consumption of the LZG was recorded, and an equivalent amount was subsequently provided to the PZG the following day. Any remaining or wasted food was measured and accounted for on a daily basis, thereby maintaining consistent intake between the two groups under pair-fed conditions.



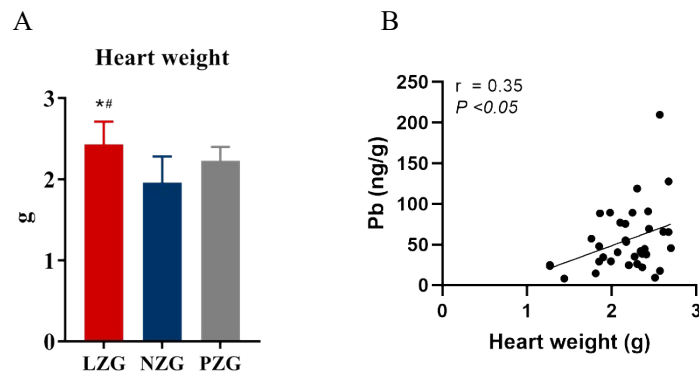
Supplemental Figure 2. The urine volume and fecal weight of rats within 48 hours.

LZG: Low-zinc diet group; NZG: Normal-zinc diet group; PZG: Pair-fed group. Urine and feces samples were collected at regular 4-week intervals. When approximately 50% mortality was reached, 48-hour samples were obtained from the surviving rats prior to euthanasia. For rats that died before this endpoint, data from their last available sample collection were utilized.



Supplemental Figure 3. Principal Component Analysis of samples and QC.

All biological samples ($n = 707$) are shown in blue, and QC samples ($n = 27$) are shown in green. Each symbol represents a single sample. The distinct clustering of QC samples demonstrates the stability and reproducibility of the analytical method.



Supplemental Figure 4. Heart weight and its correlation with Pb concentration in rats.

(A) Heart weight in each group. *: $P < 0.05$ (LZG vs. NZG); #: $P < 0.05$ (LZG vs. PZG). LZG: Low-zinc diet group; NZG: Normal-zinc diet group; PZG: Pair-fed group. (B) Scatter plot showing the relationship between heart weight and lead (Pb) concentration in individual rats. Each point represents a single rat. The correlation was assessed using the Pearson correlation coefficient.