

脐血锰浓度和1岁婴儿体重的关系： 基于山东莱州湾出生队列研究

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摘要：

[背景] 大量研究表明锰可以对人体的生长发育产生影响。婴幼儿阶段是生长发育的关键期，更易受锰暴露的毒性影响。

[目的] 探讨脐血锰浓度与1岁婴儿体重的关系。

[方法] 基于山东莱州湾出生队列，将183例同时完成问卷调查及脐带血检测的母子对纳入研究。通过问卷调查一般人口学特征和1岁婴儿膳食信息，测量其身高、体重，并测定脐血锰、铅、砷和铁的质量浓度（后称浓度）。按锰暴露水平对数值的四分位数将研究对象分为四组（Q1~Q4），描述不同组间的一般人口学特征。采用单因素回归分析研究1岁婴儿体重的影响因素。在校正孕前体质量指数（BMI）、家庭月收入、产次、出生体重、婴儿性别、1岁婴儿主食摄入频次及脐血铅、铁和砷元素后，采用广义线性模型分析脐血锰浓度对1岁婴儿体重的影响，并进一步研究了不同性别间该影响的差异。

[结果] 183例孕妇年龄为（27.90±4.61）岁，孕前BMI为（21.72±3.04）kg·m⁻²。其中132例为初产妇（72.1%），136例孕妇无主动或被动吸烟情况（74.3%）。大多数1岁婴儿经常摄入主食（83.6%）。1岁婴儿体重为（10.55±1.15）kg，身高为（76.97±2.71）cm。孕妇人口学特征在脐血锰浓度Q1~Q4组间差异均无统计学意义（ $P>0.05$ ），1岁婴儿体重和身高在脐血锰浓度Q1~Q4组间差异具有统计学意义（ $F=4.111$ ， $P=0.008$ ； $F=2.717$ ， $P=0.046$ ）。锰、铅、铁和砷在脐血的检出率分别为82.5%（151/183）、85.8%（157/183）、99.5%（182/183）和79.8%（146/183）。脐血锰、脐血铅、脐血铁和脐血砷中位数浓度分别为106.1 μg·L⁻¹、36.3 μg·L⁻¹、462.7 mg·L⁻¹、6.4 μg·L⁻¹。1岁婴儿体重与脐血锰浓度（ $P=0.005$ ）、脐血铅浓度（ $P=0.030$ ）、1岁婴儿主食摄入频次（ $P<0.05$ ）以及婴儿性别（ $P<0.001$ ）的关联具有统计学意义。脐血锰浓度每增加一个对数浓度，1岁婴儿体重平均减少0.10 kg（95%CI：-0.12~-0.07， $P=0.021$ ），Q2组1岁婴儿体重平均减少0.68 kg（95%CI：-1.11~-0.26， $P=0.002$ ），Q3和Q4组未出现此关联。按性别分层后，脐血锰浓度每增加一个对数浓度，1岁男婴体重平均减少0.28 kg（95%CI：-0.42~-0.14， $P<0.001$ ），Q2、Q3、Q4组1岁男婴体重分别减少0.81、0.87、0.83 kg（95%CI：-1.42~-0.21， $P=0.009$ ；95%CI：-1.49~-0.25， $P=0.006$ ；95%CI：-1.46~-0.19， $P=0.011$ ），1岁女婴中未出现此关联。

[结论] 随着脐血锰浓度的升高，1岁婴儿体重有下降的趋势，对男婴的影响可能比女婴更明显。

关键词： 微量元素；锰；体重；脐带血；出生队列研究

Relationship between umbilical serum manganese level and weight of one-year-old infants: Based on Laizhou Wan Birth Cohort Study YU Jin-xia, LU Qi, ZHANG Yan, YAO Qian, SHI Rong, GAO Yu (Department of Environmental Health, School of Public Health, Shanghai Jiao Tong University School of Medicine, Shanghai 200025, China)

Abstract:

[Background] A large number of studies have shown that manganese can affect the growth and development of human body. The infant stage is a critical period of rapid growth and development, and it is more susceptible to the toxic effects due to manganese exposure.

[Objective] The study is designed to investigate the relationship between umbilical serum manganese level and the weight of one-year-old infants.

[Methods] The present study was based on the Laizhou Wan Birth Cohort Study. A total of

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183 mother-child pairs were finally enrolled, who completed questionnaires and umbilical cord blood measurement. The participants' demographic characteristics and one-year-old infants' diet were collected, and infants' height, weight, and umbilical cord blood levels of manganese, lead, arsenic, and iron were measured. The study subjects were divided into four groups (Q1-Q4) according to quartiles of manganese exposure level, and the general demographic characteristics were described. Univariate regression analysis was used to study the influencing factors of infants' weight at one year old. After adjusting for pregnant woman's body mass index (BMI), family monthly income, parity, infant's weight at birth, infant's sex, infant's staple food intake frequency, lead, iron, and arsenic in umbilical cord blood, generalized linear model was used to analyze the relationship between umbilical blood manganese level and the weight of one-year-old infants, and the effect on different genders was further studied.

[Results] The average age of the 183 pregnant women was (27.90 ± 4.61) years old, and the pre-pregnancy BMI was $(21.72 \pm 3.04) \text{ kg} \cdot \text{m}^{-2}$. Among them, 132 pregnant women were primiparas (72.1%), and 136 pregnant women had no active or passive smoking behaviors (74.3%). Most infants of one year old often consumed staple foods (83.6%). The one-year-old infants weighed $(10.55 \pm 1.15) \text{ kg}$, and was $(76.97 \pm 2.71) \text{ cm}$ in height. The demographic characteristics of pregnant women showed no significant differences among Q1 to Q4 umbilical cord blood manganese concentration groups ($P > 0.05$), while the weight and height of the one-year-old infants showed significant differences ($F = 4.111, P = 0.008; F = 2.717, P = 0.046$). The positive rates of manganese, lead, iron, and arsenic in umbilical cord blood samples were 82.5% (151/183), 85.8% (157/183), 99.5% (182/183), and 79.8% (146/183), respectively. The median umbilical cord blood concentrations of manganese, lead, iron, and arsenic were $106.1 \mu\text{g} \cdot \text{L}^{-1}$, $36.3 \mu\text{g} \cdot \text{L}^{-1}$, $462.7 \text{ mg} \cdot \text{L}^{-1}$, and $6.4 \mu\text{g} \cdot \text{L}^{-1}$, respectively. The correlations of the weight of one-year-old infants were significant with the concentration of manganese in umbilical cord blood ($P = 0.005$), the concentration of lead in umbilical cord blood ($P = 0.030$), the frequency of staple food intake of one-year-old infants ($P < 0.05$), and the sex of infants ($P < 0.001$). For each increase of a logarithmic unit of umbilical blood manganese, the average weight of selected one-year-old infants was reduced by 0.10 kg (95% CI: $-0.12 - -0.07, P = 0.021$), that of the Q2 group was reduced by 0.68 kg (95% CI: $-1.11 - -0.26, P = 0.002$), while there was no such an association in the Q3 group or the Q4 group. After sex stratification, for every logarithmic unit increase of umbilical blood manganese, the average weight of the one-year-old boys was reduced by 0.28 kg (95% CI: $-0.42 - -0.14, P < 0.001$), and those of the Q2, Q3, and Q4 boy groups were reduced by 0.81, 0.87, and 0.83 kg (95% CI: $-1.42 - -0.21, P = 0.009$; 95% CI: $-1.49 - -0.25, P = 0.006$; 95% CI: $-1.46 - -0.19, P = 0.011$), respectively. This association was not found in the one-year-old girls.

[Conclusion] With the increase of umbilical cord blood manganese concentration, the weight of one-year-old infants shows a downward trend, and the effect may be more pronounced in boys than in girls.

Keywords: trace element; manganese; weight; umbilical cord blood; birth cohort study

锰是人体发育和机体功能所必需的微量元素,在骨形成、新陈代谢^[1]、免疫调节以及神经发育^[2]等方面起重要作用。锰广泛存在于自然环境中的空气、水和土壤里,而饮食是人类接触锰的主要途径。《中国居民膳食指南(2016)》推荐的成年人膳食锰适宜摄入量为 $4.5 \text{ mg} \cdot \text{d}^{-1}$ ^[3]。锰对人体健康的效应存在两面性,当体内锰的储存量过低或过高时,都可能会对健康产生不利影响^[4]。

在锰对人体健康影响的研究领域中,学者们主要关注职业环境中锰暴露对工人的神经毒性^[5],目前也开始关注环境锰暴露对生命早期(尤其是婴儿期)健康的影响。由于孕酮和催乳素会增加锰超氧化物歧化酶的表达,孕妇血锰水平在怀孕期间会升高^[6-7]。锰可通过主动转运的方式透过胎盘屏障^[8],从母体转移给胎儿,可能对发育中的胎儿产生影响,如神经管畸形、骨骼畸形和胎儿生长受限等^[9-11]。健康与疾病的发育起源(developmental origins of health and disease, DOHaD)理论表明胎儿基因与宫内环境的相互作用决定了个体出生后的患病风险及个体应对出生后环境的能力^[12],生命早期暴露于不良因素会改变婴儿的生长模式^[13],如婴儿体重降低。

体重是婴儿生长发育的重要预测指标^[14],同时也是成人慢性疾病的一个预测因子^[15-16]。目前有关婴儿锰暴露的研究主要集中在出生体重^[17-23],有关1岁婴儿体重的研究尚有限。本研究基于山东莱州湾出生队列,拟探讨脐血锰质量浓度(后称浓度)与1岁婴儿体重的关系。

1 对象与方法

1.1 研究对象

本研究依托于在山东省渤海莱州湾南岸普通人群中建立的莱州湾出生队列。选取当地唯一有产科病房的二级甲等医院,以2010年9月—2013年12月在该院生产的孕妇为研究对象。纳入标准^[24]:(1)年龄 ≥ 18 岁,在该地区连续居住年限 ≥ 3 年;(2)未患高血压、糖尿病及甲状腺功能异常等疾病,无性传播疾病等传染性疾病;(3)无吸毒史、无体外受精史;(4)同意参加并配合该调查研究(签署知情同意书)。本研究已通过上海交通大学医学院伦理委员会审查和批准(编号: SJUPN-201701)。

1.2 资料收集

本研究采用自行编制的孕期健康影响因素调查

问卷^[24-25]，由经过培训的调查员在孕妇分娩后进行问卷调查，问卷内容包括孕妇年龄、身高、孕前体重、教育程度、家庭收入、吸烟，及新生儿性别、胎龄、出生体重等信息。通过自行编制的半定量食物频率问卷获取1岁婴儿膳食信息，主食摄入频次分为无（没吃过）、偶尔（每月1次或更少）、有时（每周1~3次）、经常（几乎每天都吃）。1岁婴儿的人体指标测量由专业人员按统一的测量方法^[26]进行。

1.3 实验室检测

采集新生儿脐带静脉血4 mL，加入乙二胺四乙酸抗凝，颠倒混匀后放置于-80℃冰箱待测。(1) 锰、铁和砷的测定：取200 μL脐血样品，加入400 μL体积分数为69%的硝酸，采用微波消解仪（Mars-5型，CEM公司，美国）进行消解。将消解后的原液用纯水稀释至4.5 g左右，采用电感耦合等离子质谱系统（7500CE，安捷伦公司，美国）进行测定^[27]，使用CORTOX质控品（HMB59311，Kaulson Laboratories，美国）。(2) 铅的测定：使用石墨炉原子吸收分光光谱仪（Thermo Elemental M6，赛默飞世尔公司，美国）进行测定^[28]，使用CORTOX质控品。锰、铁和砷的检测均在质控通过后进行；10%的样本进行重复测量。铅的测定过程中全程采用严格的实验室内外质控措施，质控回收率为90%~110%。锰、铅、铁和砷检出限分别为 $7.41 \times 10^{-2} \mu\text{g} \cdot \text{L}^{-1}$ 、 $0.10 \mu\text{g} \cdot \text{L}^{-1}$ 、 $0.16 \text{mg} \cdot \text{L}^{-1}$ 和 $1.31 \times 10^{-3} \mu\text{g} \cdot \text{L}^{-1}$ 。

1.4 统计学分析

EpiData 3.1用于数据管理，SPSS 19.0用于数据分析，检验水准 $\alpha=0.05$ 。按脐血锰暴露水平对数值的四分位数将研究对象分为四组（Q1~Q4），剔除极端值。孕妇年龄、身高、孕前体质量指数（body mass index, BMI）、婴儿出生体重、1岁婴儿身高和体重符合正态分布，以 $\bar{x} \pm s$ 表示。脐血中锰、铅、铁和砷元素的含量不符合正态分布，以M表示；定性资料采用构成比或率表示。对定性资料采用 χ^2 检验，定量资料采用方差

分析。脐血中锰、铅、铁和砷元素浓度进行对数值转换后近似呈正态分布，采用单因素回归分析研究1岁婴儿体重的影响因素；根据既往研究^[16-23, 29]将孕前BMI、家庭月收入、产次、出生体重、婴儿性别、1岁婴儿主食摄入频次、脐血铅浓度、脐血砷浓度和脐血铁浓度作为模型的协变量，采用广义线性模型分析不同脐血锰浓度对体重的影响，按性别分层研究脐血锰水平对不同性别婴儿体重的影响。

2 结果

2.1 一般人口学信息和金属元素检出情况

本队列共招募773例孕妇，对298例脐血样进行了金属元素测定，剔除110例1岁婴儿信息缺失和5例脐血锰极端值，最终样本量为183。本次研究中纳入和未纳入分析的孕妇年龄、身高、是否主动或被动吸烟、受教育水平和家庭月收入的差异无统计学意义（ $P>0.05$ ）。孕妇人口学特征在脐血锰浓度Q1~Q4组间差异均无统计学意义（ $P>0.05$ ），1岁婴儿体重和身高在脐血锰浓度Q1~Q4组间差异具有统计学意义（ $F=4.111$ ， $P=0.008$ ； $F=2.717$ ， $P=0.046$ ）。见表1。

183例孕妇年龄为（ 27.90 ± 4.61 ）岁，孕前BMI为（ 21.72 ± 3.04 ） $\text{kg} \cdot \text{m}^{-2}$ 。其中132例为初产妇（72.1%），136例孕妇无主动或被动吸烟情况（74.3%）。大多数1岁婴儿经常摄入主食（83.6%）。1岁婴儿体重为（ 10.55 ± 1.15 ）kg，身高为（ 76.97 ± 2.71 ）cm。见表1。锰、铅、铁和砷元素在脐血中的检出率分别为82.5%（151/183）、85.8%（157/183）、99.5%（182/183）和79.8%（146/183）。脐血锰、脐血铅、脐血铁和脐血砷中位数浓度分别为 $106.1 \mu\text{g} \cdot \text{L}^{-1}$ 、 $36.3 \mu\text{g} \cdot \text{L}^{-1}$ 、 $462.7 \text{mg} \cdot \text{L}^{-1}$ 、 $6.4 \mu\text{g} \cdot \text{L}^{-1}$ 。此外，经共线性诊断，铅、砷、锰和铁的容差分别为0.99、1.01、0.91、1.10，方差膨胀因子分别为0.93、1.07、0.85、1.18；容差均大于0.1，方差膨胀因子均小于10，故不存在共线性。

表1 不同脐血锰浓度母婴的一般人口学特征

Table 1 Distribution of general demographic characteristics of mother-and-infant pairs by quartiles of umbilical cord blood manganese levels after logarithmic transformation

项目 Item	全体 (n=183) Total	Q1 (n=46)	Q2 (n=46)	Q3 (n=46)	Q4 (n=45)	F/ χ^2	P
孕妇年龄/岁 (Pregnant woman's age/years) ($\bar{x} \pm s$)	27.90±4.61	27.75±4.68	27.97±4.87	27.66±4.37	28.24±4.66	0.143	0.934
孕妇身高/cm (Pregnant woman's height/cm) ($\bar{x} \pm s$)	162.61±4.19	161.89±4.47	162.00±4.09	163.24±4.13	163.31±3.95	1.559	0.201
孕前BMI/ ($\text{kg} \cdot \text{m}^{-2}$) [(BMI before pregnancy/ ($\text{kg} \cdot \text{m}^{-2}$))] ($\bar{x} \pm s$)	21.72±3.04	21.57±3.35	21.77±2.65	21.98±2.86	21.57±3.33	0.192	0.902
产次 (Parity) [n (%)]						3.124	0.373
初产妇 (Primipara)	132 (72.1)	34 (73.9)	32 (69.6)	37 (80.4)	29 (64.4)		
经产妇 (Multipara)	51 (27.9)	12 (26.1)	14 (30.4)	9 (19.6)	16 (35.6)		

续表 1

项目 Item	全体 (n=183) Total	Q1 (n=46)	Q2 (n=46)	Q3 (n=46)	Q4 (n=45)	F/χ^2	P
受教育水平 (Education level) [n (%)]						3.316	0.768
初中及以下 (Middle school and below)	90 (49.2)	25 (54.3)	22 (47.8)	18 (39.1)	25 (55.6)		
高中或中专 (High school or secondary technical school)	47 (25.7)	10 (21.7)	13 (28.3)	14 (30.4)	10 (22.2)		
大专及以上 (College and above)	46 (25.1)	11 (23.9)	11 (23.9)	14 (30.4)	10 (22.2)		
家庭月收入 / 元 (Family monthly income/yuan) [n (%)]						5.91	0.433
≤3000	123 (67.2)	35 (76.1)	33 (71.7)	29 (63.1)	26 (57.8)		
3000~5000	48 (26.2)	9 (19.6)	9 (19.6)	15 (32.6)	15 (33.3)		
>5000	12 (6.6)	2 (4.3)	4 (8.7)	2 (4.3)	4 (8.9)		
孕妇是否主动或被动吸烟 (Mother's active or passive smoking behavior) [n (%)]						0.731	0.866
否 (No)	136 (74.3)	35 (76.1)	32 (69.6)	35 (76.1)	34 (75.6)		
是 (Yes)	47 (25.7)	11 (23.9)	14 (30.4)	11 (23.9)	11 (24.4)		
1岁婴儿主食摄入频次 (Infant's staple food intake frequency at age one) [n (%)]						9.265	0.413
无 (No)	1 (0.5)	0 (0)	1 (2.2)	0 (0)	0 (0)		
偶尔 (Rarely)	2 (1.1)	1 (2.2)	0 (0)	1 (2.2)	0 (0)		
有时 (Sometimes)	27 (14.8)	5 (10.9)	11 (23.9)	5 (10.9)	6 (13.3)		
经常 (Regularly)	153 (83.6)	40 (87.0)	34 (73.9)	40 (87.0)	39 (86.7)		
婴儿出生体重/kg (Infant's weight at birth/kg) ($\bar{x}\pm s$)	3.41±0.46	3.35±0.39	3.51±0.45	3.41±0.43	3.35±0.55	1.292	0.279
1岁婴儿体重/kg (Infant's weight at age one/kg) ($\bar{x}\pm s$)	10.55±1.15	10.82±1.28	10.06±1.18	10.64±0.93	10.68±1.06	4.111	0.008
1岁婴儿身高/cm (Infant's height at age one/cm) ($\bar{x}\pm s$)	76.97±2.71	76.86±3.01	76.14±2.36	77.19±2.95	77.70±2.30	2.717	0.046
婴儿性别 (Infant's sex) [n (%)]						4.46	0.216
男 (Boy)	87 (47.5)	21 (45.7)	17 (37.0)	27 (58.7)	22 (48.9)		
女 (Girl)	96 (52.5)	25 (54.3)	29 (63.0)	19 (41.3)	23 (51.1)		

[注] Q1~Q4组脐血锰浓度分别为0~42.0、42.0~106.1、106.1~641.8、641.8~1585.0 μg·L⁻¹。

[Note] The concentrations of manganese in cord blood of Q1~Q4 groups are 0-42.0, 42.0-106.1, 106.1-641.8, and 641.8-1585.0 μg·L⁻¹, respectively.

2.2 1岁婴儿体重的影响因素 1岁婴儿体重与脐血锰浓度 ($P=0.005$)、脐血铅浓度 ($P=0.030$)、1岁婴儿主食摄入频次 ($P<0.05$) 以及婴儿性别 ($P<0.001$) 的关联具有统计学意义。见表 2。

表 2 1岁婴儿体重影响因素的单因素分析 (n=183)

Table 2 Univariate analysis of influencing factors for body weight of one-year-old infants (n=183)

因素 (Factor)	b (95% CI)	P
孕妇年龄 (Pregnant woman's age)	-0.01 (-0.05~0.02)	0.521
孕妇身高 (Pregnant woman's height)	0.00 (-0.04~0.04)	0.867
孕前 BMI (BMI before pregnancy)	0.01 (-0.05~0.07)	0.716
脐血锰浓度 Manganese level in umbilical cord blood	-0.19 (-0.319~-0.057)	0.005
脐血铅质量浓度 Lead level in umbilical cord blood	-0.15 (-0.28~-0.14)	0.030
脐血铁质量浓度 Iron level in umbilical cord blood	-0.15 (-0.51~0.21)	0.411
脐血砷质量浓度 Arsenic level in umbilical cord blood	-0.03 (-0.34~0.28)	0.856
产次 (Parity)		
初产妇 (Primipara)	—	—
经产妇 (Multipara)	-0.00 (-0.37~0.37)	0.998
受教育水平 (Education level)		
初中及以下 (Middle school and below)	—	—
高中或中专 High school or secondary technical school	-0.27 (-0.67~0.13)	0.192
大专及以上 (College and above)	-0.03 (-0.43~0.37)	0.884

续表 2

因素 (Factor)	b (95% CI)	P
家庭月收入 / 元 (Family monthly income/yuan)		
≤3000	—	—
3000~5000	0.15 (-0.23~0.53)	0.429
>5000	-0.02 (-0.69~0.66)	0.959
孕妇是否主动或被动吸烟 Mother's active or passive smoking behavior		
否 (No)	—	—
是 (Yes)	-0.14 (-0.52~0.24)	0.456
1岁婴儿主食摄入频次 Infant's staple food intake frequency at age one		
无 (No)	—	—
偶尔 (Rarely)	-2.40 (-5.10~0.30)	0.082
有时 (Sometimes)	-2.70 (-4.95~-0.45)	0.018
经常 (Regularly)	-2.43 (-4.64~-0.21)	0.032
出生体重 (Infant's weight at birth)	-0.26 (-0.62~0.10)	0.152
婴儿性别 (Infant's sex)		
男 (Boy)	—	—
女 (Girl)	-0.84 (-1.15~-0.53)	<0.001

2.3 不同脐血锰浓度对1岁婴儿体重的影响

广义线性模型结果显示, Q2组与体重呈负相关, 脐血锰浓度每增加一个对数浓度, 1岁婴儿体重下降 0.68 kg (95% CI: -1.11~-0.26, $P=0.002$), 而 Q3 和 Q4 组未出现此关联。见表 3。

表3 不同脐血锰浓度对1岁婴儿体重的影响 ($n=183$)Table 3 Effects of different cord blood manganese concentrations on body weight of one-year-old infants ($n=183$)

脐血锰浓度的对数值分组 Grouping of umbilical cord blood manganese levels after logarithmic transformation	<i>n</i>	<i>b</i> (95% <i>CI</i>)	<i>P</i>
Q1	46	—	
Q2	46	-0.68 (-1.11~-0.26)	0.002
Q3	46	-0.34 (-0.76~0.08)	0.111
Q4	45	-0.18 (-0.61~0.25)	0.403
趋势性检验 (Trend test)	183		0.002

2.4 不同脐血锰浓度对不同性别1岁婴儿体重的影响

广义线性模型结果显示,以脐血锰浓度对数值Q1组为参照,Q2、Q3、Q4组均与1岁男婴体重呈负相关,脐血锰浓度每增加一个对数浓度,1岁男婴体重分别下降0.81、0.87、0.83 kg (95% *CI*: -1.42~-0.21, $P=0.009$; 95% *CI*: -1.49~-0.25, $P=0.006$; 95% *CI*: -1.46~-0.19, $P=0.011$)。1岁女婴中未出现此关联。见表4。

表4 不同脐血锰浓度对1岁婴儿体重的影响 (性别分层)

Table 4 Effects of different cord blood manganese concentrations on body weight of one-year-old infants (sex stratification)

性别 Sex	脐血锰浓度的对数值分组 Grouping of umbilical cord blood manganese levels after logarithmic transformation	<i>n</i>	<i>b</i> (95% <i>CI</i>)	<i>P</i>
男婴 (Boy)	Q1	22	—	—
	Q2	22	-0.81 (-1.42~-0.21)	0.009
	Q3	22	-0.87 (-1.49~-0.25)	0.006
	Q4	21	-0.83 (-1.46~-0.19)	0.011
	趋势性检验 (Trend test)	87		0.028
女婴 (Girl)	Q1	24	—	—
	Q2	24	-0.52 (-1.11~0.06)	0.079
	Q3	24	-0.18 (-0.77~0.42)	0.558
	Q4	24	0.34 (-0.25~0.93)	0.260
	趋势性检验 (Trend test)	96		0.256

3 讨论

本研究是以山东莱州湾人群为基础的前瞻性出生队列研究,探讨脐血锰暴露与1岁婴儿体重的关联。结果显示,脐血锰中位数水平为 $106.1 \mu\text{g}\cdot\text{L}^{-1}$,这与其他研究结果相比偏高,如中国上海孕妇脐血锰中位数浓度为 $77 \mu\text{g}\cdot\text{L}^{-1}$ [17],美国渥太华孕妇脐血锰中位数浓度为 $40 \mu\text{g}\cdot\text{L}^{-1}$ [18],中国台湾南部孕妇脐血锰中位数浓度为 $45 \mu\text{g}\cdot\text{L}^{-1}$ [19],牙买加金斯敦孕妇脐血锰中位数浓度为 $41 \mu\text{g}\cdot\text{L}^{-1}$ [20]。渤海莱州湾富含矿石资源,且附近有工业开发区。渤海水样中锰含量丰富[30],Li等[31]研究显示渤海蛤蜊体内12种重金属中锰含量最高。因此本研究中孕妇脐血锰水平较高可能与当地环境介

质和食物中锰含量丰富有关。

张保丽等[21]发现安徽马鞍山优生优育队列孕妇脐血锰中位数浓度为 $5.4 \mu\text{g}\cdot\text{L}^{-1}$,随着低水平脐血锰浓度的升高婴儿体重呈下降趋势。Vigeh等[22]发现伊朗德黑兰孕妇脐血锰中位数浓度为 $38.2 \mu\text{g}\cdot\text{L}^{-1}$,脐血锰浓度与婴儿出生体重呈现负相关。这与本研究结果相似。Guan等[23]发现中国大连孕妇脐血锰中位数浓度为 $77 \mu\text{g}\cdot\text{L}^{-1}$,脐血锰浓度与婴儿出生体重呈倒U型剂量效应曲线关系。而加拿大魁北克孕妇脐血锰中位数浓度为 $32 \mu\text{g}\cdot\text{L}^{-1}$,脐血锰浓度与婴儿出生体重之间的关联无统计学意义[16]。结果不一致的原因可能是脐血锰暴露水平与婴儿体重的关联受到遗传、种族和地理区域等的影响[32]。

本研究发现,男婴体重与脐血锰浓度呈负关联,而女婴无此关联。尽管目前没有相关研究,但此性别差异与另一项研究结果相似。Yamamoto等[33]发现母亲血锰水平与男婴出生体重呈非线性关系,与女婴无此关联。这可能与男婴和女婴生长模式及生物标志物等方面的差异有关[34-35]。与女婴相比,男婴的抗氧化防御机制更容易受到破坏,导致不良的发育结果[36]。锰不足或过量会引起机体的氧化应激增加,这可能会减少男婴对营养的吸收[37]。因此锰暴露对男婴的生长发育的影响更明显。这种差异也可能是由于内源性激素水平的变化所致。一项动物研究[38]显示,锰可以干扰大鼠睾丸功能,影响其体内雄性激素水平。

本研究未分析分娩前母亲血锰水平、分娩时锰代谢过程,且锰胎盘转运机制尚不清楚。本研究的样本量较小,仅在Q2组发现脐血锰浓度与婴儿体重呈负关联,Q3和Q4组无此关联。性别分层后脐血锰浓度仅与男婴体重呈负关联,女婴组无此关联。性别分层后样本量更少,这可能会影响结果的稳健性。另外,脐血锰浓度更多代表宫内暴露情况,与1岁婴儿体重关联分析需要考虑更多营养因素。同时本研究虽然控制了部分重金属可能的影响,如铅、铁和砷,但是可能还存在其他环境污染物的混杂作用。铅和砷这两种重金属可透过胎盘屏障并影响体重[39-40],铁可能影响机体锰水平[29],因此本研究对这3种金属进行了控制,以减小结果的偏倚。在未来,这些金属的相互作用及其对出生结果的影响值得进一步探索。

综上所述,本研究表明脐血锰浓度对1岁婴儿体重有影响,并且随脐血锰浓度的升高,婴儿体重呈下降趋势,男婴比女婴的影响更明显。

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