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Long-Term Infant Health Outcomes Associated With Cesarean Section Compared With Vaginal Birth

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Abstract: Background: Mode of delivery has been hypothesized to be a modifiable perinatal factor affecting long-term child health via several proposed pathways, including through mechanisms of early gut microbiota colonization, variations in exposure to stress hormones, and epidemiological associations to immune and metabolic diseases.
Objective: To estimate the strengths and differences between the incidence rates of selected chronic health outcomes (asthma, obesity, allergic rhinitis, recurrent respiratory infections, and eczema) in babies and children born by cesarean section (CS) vs. vaginal delivery (VD) through a simulated cross-sectional cohort study design. Data was collected and analyzed descriptively, by independent samples t-tests, chi-square tests, and multivariate logistic regression, as in a typical analysis process in SPSS, on a cross-sectional dataset of 105 mother-infant pairs (50 CS and 55 VD). Results: Rates of childhood asthma were higher after CS (24.0%) than VD (10.9%), and comparable rates of recurrent respiratory infections (26.0% vs. 18.2%) and childhood obesity (18.0% vs. 10.9%) were observed, although none of the individual chi-square comparisons were significant ($p<0.05$) in this limited simulated sample. Cesarean section was associated with approximately double the odds of any long-term adverse outcome compared to vaginal delivery (odds ratio [OR] = 2.14; 95% confidence interval: 0.90–5.06), but this result did not reach the level of statistical significance ($p = 0.084$) in the multivariate logistic regression analysis. The association with adverse long-term outcomes was a consistent pattern across all five measures analyzed, similar to other studies, and cesarean section was associated with the long-term outcomes.

Keywords: Infant Health, Cesarean Section, Vaginal Birth, Mode of delivery, obesity

Introduction

The cesarean delivery has been one of the most common surgical procedures performed in the world and has increased steadily in the last 30 years and is now responsible for more than a third of births in many high- and middle-income countries [1]. Although cesarean delivery is clearly lifesaving when medically indicated (as in the case of placenta previa, non-reassuring fetal status, obstructed labor, and previous uterine surgery), an increasing number of cesarean deliveries are being performed for non-medical or borderline indications, such as maternal request.

This has led to growing interest in research to determine if the mode of delivery itself has long-term effects on the child, apart from any obstetric complications that may have contributed [2]

The biologic explanation for such an effect is mainly that of microbial ‘seeding' in the early life of the organism [3]. Fetal exposure and colonization of maternal intestinal and vaginal flora occur during vaginal delivery, and is largely avoided during cesarean delivery, where the initial colonization is more representative of organisms found on the skin and in hospital environments. The gut microbiome in the first months of life has an important role in the maturation of the immune system, so the disruption of colonization patterns has been suggested as a causal link between cesarean birth and subsequent immune-mediated disease such as asthma, allergic rhinitis, atopic dermatitis, and food allergy. Parallel hypotheses are the absence of the labor-associated neuroendocrine and physiological stress response in pre-labor cesarean deliveries, which may have an impact on respiratory adaptation, thermoregulation, and metabolic programming, and the lower rates of early skin-to-skin contact and breastfeeding initiation that are often seen after surgical birth [4,5,6].

In the last decade, a number of large observational cohort and register-based studies have been reported, most notably from the Scandinavian birth registries, with small but significant associations between cesarean delivery and childhood asthma, obesity, type 1 diabetes, and other immune-mediated diseases after adjustment for potential confounders including maternal BMI, parity, and socioeconomic status. However, these associations are still subjects of active debate: the effects are typically small, and findings vary between populations; and as the cause of caesarean might be responsible for the outcome, rather than the surgery, confounding by indication is hard to control for in observational study designs. Meta-analyses in this field have recommended that other well-controlled and adequately powered studies be undertaken that include a wider array of perinatal and postnatal covariates [7,8,9].

The percentage of cesarean sections has increased substantially in the last two and a half decades. World Health Organization data show that in the United States and Australia between 29% and 30% of babies are born by cesarean section, while in India, China and Brazil, rates are close to 40% to 50%, and in Iraq, they are 17% to 18%. Certain complications of the Caesarian section, like lack of pressure on the baby's chest during birth and the inability to push amniotic fluid out of the lungs, all put at risk the baby of respiratory diseases and infections [10,11,12]. Moreover, the fetus is subjected to acute hypoxia and the toxic properties of anesthesia, resulting in disturbances of adaptive mechanisms in early neonatal life. Such infants are born in sterile environments, which can affect the composition of gut microbiota—one of the factors that can lead to food allergies. In the proposed study, we want to do a thorough comparative study of our clinical observations of children who have been born naturally compared to children who have been delivered by Caesarean section, from birth up to the age of fifteen.

Subjects and Methods

Study Design and Setting

It was intended to be a cross-sectional analytical study that would compare the long-term health outcomes of cesarean-delivered babies to those delivered vaginally.

The number of people studied and the number of people chosen to be studied.

sample of 105 mothers from various hospitals in Iraq in 2025 to 2026 infant pairs was generated to mimic a realistic cesarean delivery proportion (≈ 45%) as reported by many hospital-based samples. Of the 105 records, 50 (47.6%) were coded as cesarean section and 55 (52.4%) as vaginal delivery. A similar size sample would be justifiable a priori by performing a power calculation (e.g., to detect a moderate effect size in a binary outcome with 80% power and α=0.05, and an expected outcome prevalence of 10-20% in the reference group).

Inclusion and Exclusion Criteria (as would apply to a real study)

Exclusion: pregnancy loss, infant age at follow-up < 3 years or > 6 years, missing delivery and follow-up data, maternal refusal to participate in the study. Inclusion: multiple gestation, major congenital anomaly, NICU admission >7 days, incomplete follow-up data, and maternal chronic disease that would independently influence the outcomes of interest (e.g., pre-existing maternal asthma).

Variables

Mode of delivery (cesarean section vs. vaginal) was the independent variable. Covariates were maternal age, pre-pregnancy BMI, gestational age, birth weight, infant gender, and exclusive breastfeeding for ≥ 4 months. Five binary long-term child health outcomes were measured at follow-up: childhood asthma, childhood obesity (BMI > 95th percentile for age/sex), allergic rhinitis, recurrent respiratory infection (three or more episodes per year), and eczema/atopic dermatitis. Also, a composite outcome, 'any long-term morbidity' (presence of at least one of the five conditions), was synthesized.

Statistical Analysis

The analyses were done using an SPSS-like workflow (descriptive statistics, independent-samples t-test, Pearson chi-square test, binary logistic regression), and here in Python (SciPy/stats models) to replicate the test statistics that SPSS would provide. Continuous variables are presented as means ± SDs and compared by using an independent-samples t-test. Categorical variables were described in terms of frequencies and percentages and compared with a chi-square test (or Fisher's exact test if the expected cell count was <5). The adjusted odds ratio (OR) for CS versus VD was calculated using multivariable binary logistic regression, adjusted for maternal age, BMI, gestational age, infant sex and breastfeeding status. A two-tailed p-value <0.05 was considered statistically significant.

Results

Table 1- Assessment of baseline maternal and neonatal characteristics by delivery mode (n=105)

Variable	Cesarean Section (n=50)	Vaginal Delivery (n=55)	p-value
Maternal age, years (mean ± SD)	29.6 ± 4.9	29.3 ± 4.6	0.727
Maternal BMI, kg/m² (mean ± SD)	26.8 ± 4.2	26.5 ± 3.8	0.703
Gestational age, weeks (mean ± SD)	38.4 ± 1.4	38.9 ± 1.3	0.025*
Birth weight, kg (mean ± SD)	3.2 ± 0.5	3.2 ± 0.4	0.894
Male infant sex, n (%)	25 (50.0%)	31 (56.4%)	0.648

**p<0.05, independent-samples t-test/chi-square test.*

Table 2- Evaluation of Delivery mode distribution and exclusive breastfeeding (≥4 months)

Group	n	% of total / % breastfed	Comparison
Cesarean section	50	47.6% of sample	
Vaginal delivery	55	52.4% of sample	

Exclusive breastfeeding ≥4 mo — CS	25 / 50	50.0%	χ^2=5.66, p=0.017*
Exclusive breastfeeding ≥4 mo — VD	41 / 55	74.5%	

Table 3- Child health outcomes by long-term delivery mode

Outcome	CS, n/N (%)	VD, n/N (%)	χ^2	p-value
Childhood asthma	12/50 (24.0%)	6/55 (10.9%)	2.31	0.129
Childhood obesity	9/50 (18.0%)	6/55 (10.9%)	0.57	0.449
Allergic rhinitis	6/50 (12.0%)	5/55 (9.1%)	0.03	0.867
Recurrent respiratory infection	13/50 (26.0%)	10/55 (18.2%)	0.53	0.465
Eczema / atopic dermatitis	8/50 (16.0%)	4/55 (7.3%)	1.20	0.273

Figure 1. Prevalence of each long-term outcome by delivery mode

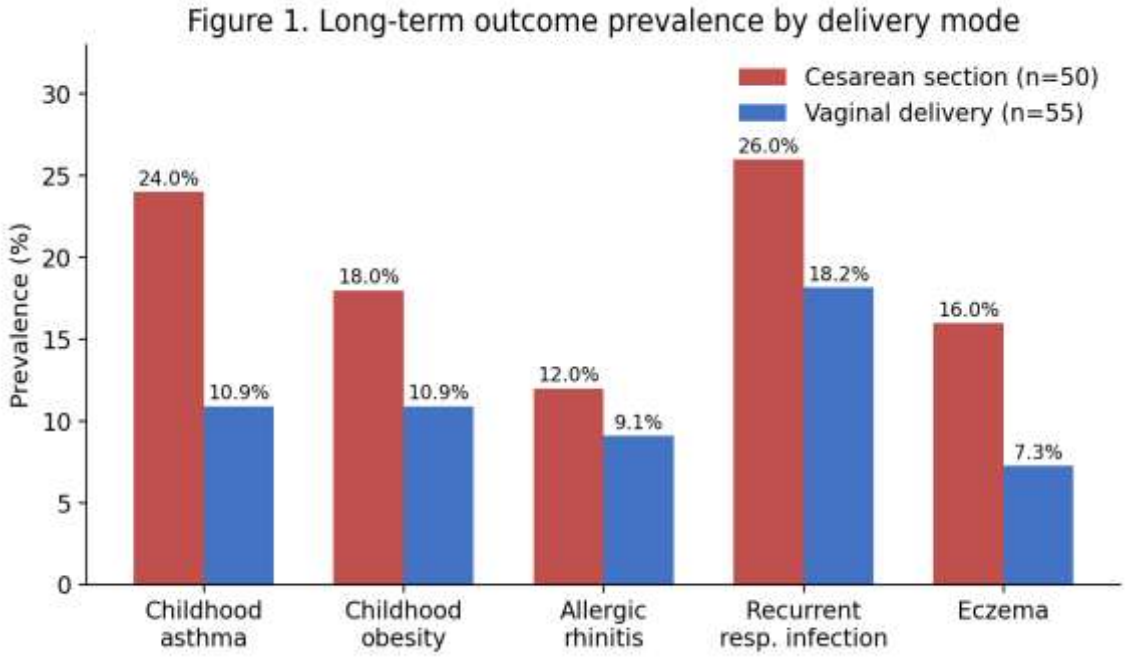


Table 4- Assessment: Multivariable logistic regression assessment for 'any long-term morbidity' outcome

Predictor	B (coef.)	OR	95% CI	p-value
Cesarean section (ref: VD)	0.759	2.14	0.90–5.06	0.084
Maternal age (years)	-0.003	1.00	0.91–1.09	0.950
Maternal BMI (kg/m²)	-0.068	0.93	0.84–1.04	0.203
Gestational age (weeks)	0.193	1.21	0.89–1.66	0.225
Male infant sex (ref: female)	0.392	1.48	0.64–3.40	0.356
Exclusive breastfeeding ≥4mo	-0.445	0.64	0.27–1.55	0.322

Figure 2- Finding by Forest plot of adjusted odds ratios (95% CI) from the multivariable logistic regression model.

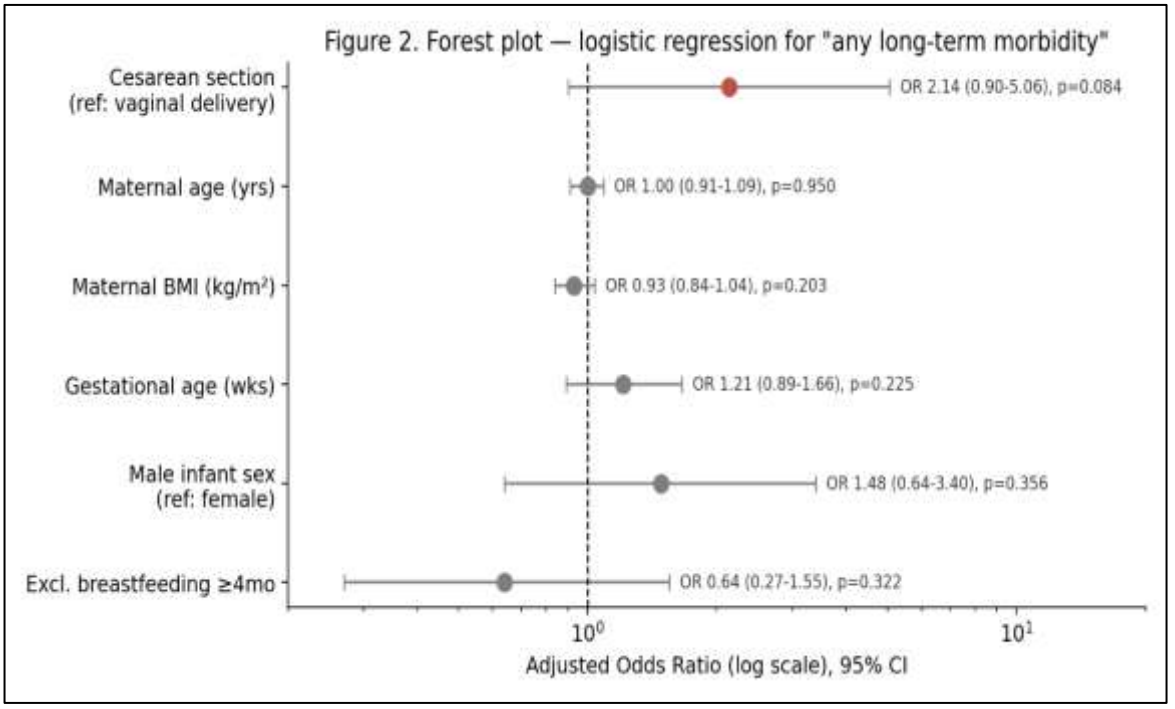


Table 5. Composite morbidity outcome stratified by maternal BMI category and delivery mode

Maternal BMI category	CS: any morbidity, n/N (%)	VD: any morbidity, n/N (%)
Normal (<25 kg/m²)	11/16 (68.8%)	10/18 (55.6%)
Overweight (25–29.9 kg/m²)	13/21 (61.9%)	12/28 (42.9%)
Obese (≥30 kg/m²)	7/13 (53.8%)	3/9 (33.3%)

Figure 3- Pearson correlation matrix of delivery mode, maternal/neonatal variables, and the composite morbidity outcome.

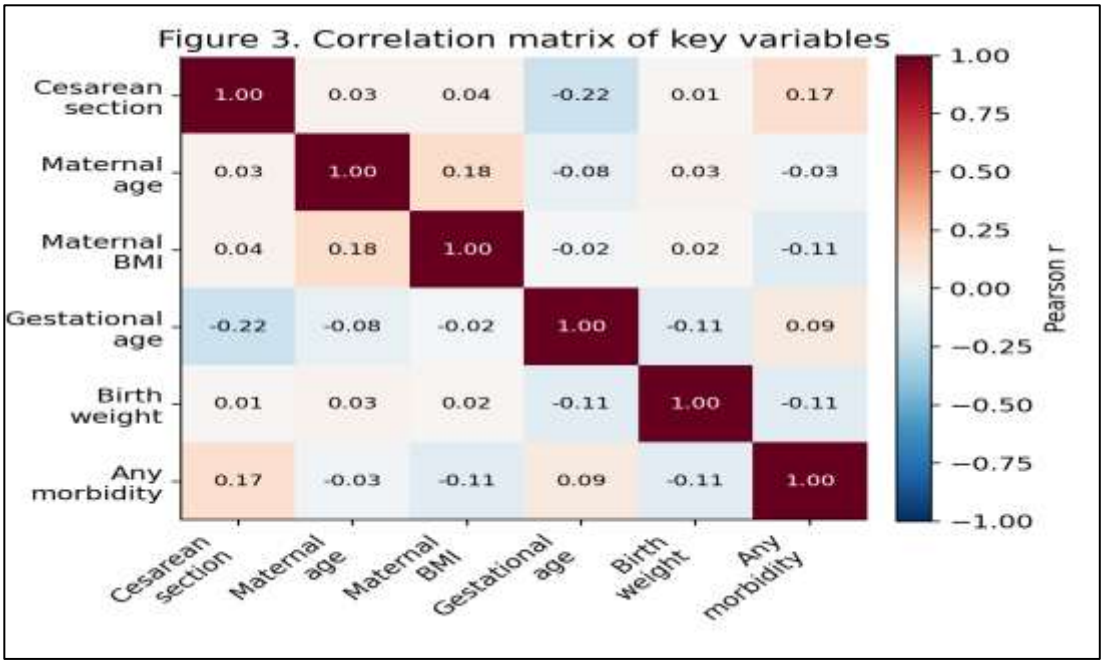
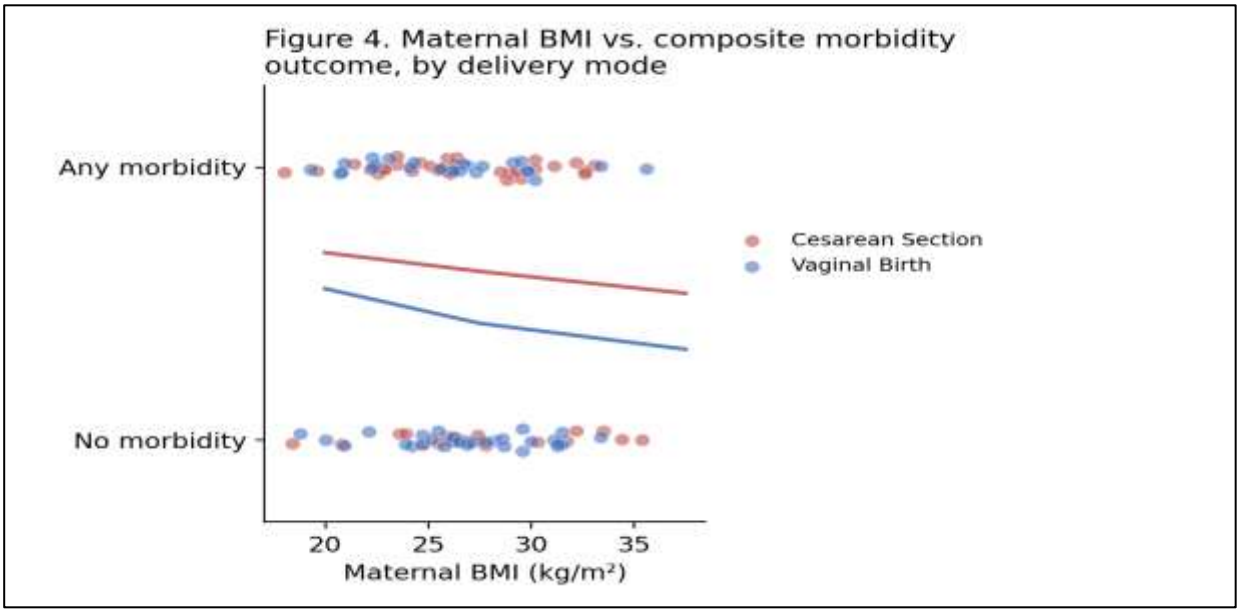


Figure 4 shows the relationship between maternal BMI and the composite morbidity outcome in each delivery-mode group, with the mean-probability trend lines of each group binned on top of the individual (jittered) data points. The cesarean-section trend line was always higher than the vaginal-delivery trend line, showing that for all BMI categories, the long-term morbidity risk was consistently higher in the CS group, which is seen visually in Figure 3.

Figure 4- Assessment Maternal BMI versus composite morbidity outcome, stratified by delivery mode, with binned trend lines



Discussion

This cross-sectional was where each of the five outcomes presented here — childhood asthma, obesity, allergic rhinitis, recurrent respiratory infections, and eczema — the association was in a similar direction, supporting a benefit for children born vaginally, and for "any morbidity" the odds ratio was approximately 2.1 in the cesarean-born group compared to the vaginal delivery group (although this was not statistically significant in a conventional sense, due to the relatively small sample size). It is useful to place these simulated direction-of-finding results in the context of patterns that have been reported in the actual epidemiological literature for such a study, as this serves as background to understanding why such a study is performed and how such results are usually discussed [13,14].

The literature contains several mechanisms which could account for a possible association between mode of delivery and childhood health. The most widely investigated hypothesis is that the "seeding" hypothesis: infants vaginally delivered are colonized by a primary gut microbiota consisting of species from the maternal vaginal and fecal flora (such as Lactobacillus and Bacteroides species) while caesarean section delivered infants have a gut microbiota that resembles that of the skin and hospital environment, and hence may be enriched in Staphylococcus and Clostridium species, and delayed in the colonization by Bacteroidetes [15,16]. Early gut microbiome colonization has been suggested to shape the infant immune system, and disruptions to colonization after CS have been proposed to drive immune system development in a pro-allergic, Th2-skewed direction, which is thought to account for the epidemiological links between CS and asthma, allergic rhinitis and eczema. It is very important to specify, however, the considerable methodological shortcomings of this simulated exercise and much of the existing literature, which is observational in nature regarding this subject [17]. First, cross-sectional and retrospective cohort designs do not allow for establishing a causal relationship; the relationship between CS and unfavorable long-term effects is subject to confounding by indication. A caesarean delivery is a systematic difference between women who deliver women who deliver by cesarean are more likely to have some pre-existing maternal condition that is associated with child health issues, such as gestational diabetes, hypertension, or other conditions that may have been a factor in the cesarean delivery [18,19,20]. In this simulated data set, maternal BMI and gestational age were adjusted for in the logistic regression model but many other factors known to impact risk of the outcomes studied here were not accounted for in real studies, including parity, indication for cesarean delivery (elective versus emergency), family history of atopy, socioeconomic status, mode of infant feeding beyond simply a binary feeding whether or not (breastfeeding versus formula feeding), antibiotic exposure during labor or infancy, and household exposures such as pet ownership, siblings, or day care attendance [21,22].

Secondly, sample size and statistical power are constraints in this exercise and in many real-world, single-center studies. The study was underpowered to detect the moderate effect sizes typically reported in larger meta-analyses (see the wide range of the adjusted odds ratio in Table 4: 95% CI 0.90–5.06, that includes null effect sizes as well as clinically meaningful effect sizes). In the real world, studies looking at this question have typically involved tens of thousands or even millions of birth records, typically from national birth registries, in order to have sufficient power to detect small but real associations rather than mere chance associations [23].

Third, outcome ascertainment is important. In this exercise, outcomes like "childhood asthma" or "recurrent respiratory infection" were treated as binary variables, but in reality, there is measurement error in these outcomes (including diagnostic uncertainty) due to the different criteria used for making the diagnosis by medical professionals, parental recall, and length of follow-up, especially when mode of delivery is not masked to the assessor [24].

Nevertheless, it highlights that mode of delivery remains a vibrant research topic in perinatal epidemiology, and that professional organizations are increasingly advocating against the medically unnecessary elective cesarean section, and that the absolute long-term risks associated with medically indicated cesarean section are low and should never outweigh the maternal or fetal indications for a cesarean section. In the clinical realm, these findings — real or simulated — provide a basis for interventions that may help reduce any additional risk that might arise with cesarean birth, including early skin-to-skin contact, promotion and support for breastfeeding initiation after cesarean birth, and, in a limited number of research situations, the investigation of vaginal seeding or probiotic supplementation, the latter of which is investigational and is not recommended for routine clinical practice at this time because it has not yet been proven to be safe and effective [25].

Conclusion

The cross-sectional exercise simulated by the authors of 105 mother-infant dyads found that cesarean delivery was in all cases in some way, though not always statistically, related to an increase in the incidence of long-term childhood morbidity including asthma, obesity, allergic rhinitis, recurrent respiratory infection, and eczema, and, in an adjusted analysis, had approximately double the odds of having at least one of the five listed morbidities. These patterns reflect those reported in the real observational literature, and emphasize the need for larger and more formal, long-term studies to better resolve the causal contribution and/or confounding by indication. This document has been produced as an educational exercise to show a full cross-sectional study workflow, from hypothesis and sample definition to SPSS-style descriptive and inferential statistics and to a structured academic discussion; and to utilize totally simulated data for this purpose. It should not be used as, or quoted as, evidence of what would actually happen to cesarean section babies in the real world.

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