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Paradoxes concerning low birthweight in Spain

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RESUMEN

Las causas de la incidencia del bajo peso al nacer todavía no son bien comprendidas y muchos investigadores consideran como paradójico su incremento a la par que los servicios obstétricos han ido mejorando. Nuestros objetivos son documentar las diferencias en la incidencia del bajo peso al nacer en diferentes grupos poblacionales en España y analizar la posible relación entre la mortalidad fetal y el bajo peso al nacer teniendo en consideración diferentes variables sociodemográficas. Hemos utilizado los microdatos de nacimientos del Instituto Nacional de Estadística desde el año 1975. Hemos aplicado técnicas de análisis de regresión logística para examinar las diferencias en la probabilidad de dar a luz a un bebé con bajo peso controlando por diferentes variables sociodemográficas. Hemos encontrado que la mortalidad fetal pudiera ejercer un efecto selectivo en el bajo peso al nacer de los neonatos cuando algunas variables sociodemográficas son analizadas, pero no ocurre así cuando se tienen en cuenta otras. Algunos aspectos todavía necesitan ser aclarados sobre el posible efecto que las tasas de mortalidad tienen sobre la incidencia del bajo peso al nacer.

ABSTRACT

The causes of low birthweight are still not well understood, and many researchers consider it paradoxical that this has increased as obstetric healthcare services have improved. Our objectives are to document the differences in the incidence of low birthweight in different population groups in Spain, and to analyze the possible relationship between fetal mortality and low birthweight taking several sociodemographic variables into account. We used the microdata on births since 1975 from the Spanish National Statistics Institute. We used logistic regression analysis techniques to examine differentials in the probability of delivering a low birthweight controlling for different sociodemographic covariates. We found that fetal mortality seems to exert a selective effect on the birthweight of live neonates when some sociodemographic variables are analyzed but appears not to do so if others are taken into account. Some aspects remain to be clarified concerning the effect that fetal mortality rates have on the incidence of low birthweight.

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Introduction

The World Health Organization (WHO) defines low birthweight (LBW) as referring to children born alive weighing less than 2,500 grams, regardless of the length of gestation. LBW is still one of the most prevalent risk factors for infant mortality and childhood development disorders. There is now a large volume of evidence concerning the relationship between low birthweight (LBW) and neonatal mortality and infant morbidity. Furthermore, we know that it is a major predictor of psychological development and of the cognitive habits and general health of children in the long term. LBW is still one of the most prevalent risk factors for infant mortality and childhood development disorders (Grillo, Mariani and Ferraris 2022).

Stillbirth is one of the most common but least studied adverse pregnancy outcomes. In many developed countries, somewhere between two-thirds and three-quarters of all stillbirths are preterm and generally LBW. Both fetal growth restriction and preterm birth are important risk factors for stillbirth (Goldenberg and Culhane, 2007). Although most babies born with LBW do not have a clear etiology, a series of sociodemographic factors related to the characteristics of the newborns and their mothers have been identified that could have a significant influence. Over the last decades, many articles have been published seeking to identify the sociodemographic variables related to the incidence of LBW in Spain. In some of these studies (Castro-Martín, 2010; Terán et al., 2015, 2018, 2020; Juárez and Revuelta-Eugercios, 2013; Hidalgo-Lopezosa et al., 2019), the incidence of low birth weight is usually classified according to the nationality and marital status of the mother and the order, gestational age and sex of the newborn. Some other studies analyze both the level of education and the type of work performed by the parents (Rodríguez, Regidor and Gutiérrez-Fisac, 1995; Ronda, Hernández-Mora and García, 2009; Bernis, 2010; Castro-Martín, 2010; Varea, Bernis and González, 2012; Escartín et al., 2014; Fuster et al., 2015; Stanek, Requena and del Rey, 2021). Unfortunately, very few of these provide any explanation concerning why these relationships are positive or negative.

It is surprising therefore that the numerous articles published on this subject make no mention of the relationship that exists between the fetal mortality rate and the prevalence of LBW. This is surely due to the lack of reliable sources for the study of mortality during the fetal stage. The only exception to this is the recent study by Sánchez-Barricarte and Sánchez Arlegui (2023), who link the increase in the incidence of LBW in Spain over recent decades to higher fetal survival rates due to improvements in obstetric care. Continuous advances in medicine have meant that an increasingly large percentage of premature babies with lower birth weights are born alive, which raises the incidence of LBW. Furthermore, in a strikingly large number of cases, researchers express surprise at the paradoxical results obtained (Bernis, 2005; García-Subirats et al., 2011; Speciale and Regidor, 2011; Juárez and Revuelta-Eugercios, 2014; Juárez, Ploubidis and Clarke 2014; Restrepo-Mesa et al., 2015; Cebolla-Boado and Salazar, 2016; Farré, 2016; Juárez et al., 2017; Stanek et al., 2020; Stanek, Requena and del Rey, 2021). The consternation by the statistical evidences clearly indicates that the mechanisms underlying LBW in Spain (and elsewhere) are not yet properly understood, and that it is essential to go more deeply into this phenomenon.

It is well known that stress levels among pregnant women can have a major impact on fetal mortality rates (Catalano et al., 2012; Carolan-Olah and Barry, 2014). We may therefore suspect that sociodemographic factors in different population groups may account for the differences in fetal mortality, and therefore also the incidence of LBW. Our initial research hypothesis is the same as that of Sánchez-Barricarte and Sánchez-Arlegui (2023): the population groups with higher fetal mortality are likely to experience lower rates of LBW, because the former variable exerts a selective effect over the latter one. According to this hypothesis, women who belong to social groups with easier access to obstetric care and more favorable socioeconomic conditions would have a higher incidence of LBW, since a larger percentage of premature fetuses (many of which have a low weight) are born alive.

The aim of this study is to contribute to our understanding of the reasons underlying the incidence of LBW in Spain by incorporating a new variable, fetal mortality, which has been ignored to date, and which we nonetheless consider to be a key factor that can help

us resolve some of the "apparent paradoxes" identified by many of the researchers who have addressed this subject.

Materials and methods

Live births

To perform this research, we made use of the information in the microdata available in the *Boletín estadístico de parto* [Birth statistical bulletin] from 1996 to 2020. These data are available on the website of the Spanish Instituto Nacional de Estadística [National Statistics Institute] (INE): https://www.ine.es/.

Period of analysis

From 1975 to 1995, it is not possible to classify births according to the mother's nationality, although during those years the vast majority of women who gave birth in Spain were Spanish from birth. From 1996 to 2006, it is possible to classify births by the mother's nationality. From 2007 onwards, we can find out whether the mother obtained Spanish nationality at birth or later. In the case of those mothers who obtained Spanish nationality at a later stage, we know their country of origin. We performed these analyses for two different time periods: 1996-2000 and 2016-2020. We confined our study to these two periods for the following reasons:

We consider that it is fundamental to classify mothers by nationality, given the significant conditioning factors among many immigrant groups. The first year for which it was possible to classify women by nationality is 1996.

Our aim is not to evaluate the development over time of the relationship between LBW incidence and fetal mortality rates. This has already been published by Sánchez-Barricarte and Sánchez-Arlegui (2023). The aim of the present study is to analyze the effect of mortality rates in different population subgroups on LBW. For this reason, we chose the two furthest apart five-year periods for which information was available, to detect whether there was any significant change in the incidence of LBW.

Mothers' nationality

In the present study, from 2007 onwards, we include in the group of "foreign mothers" those who, albeit being in possession of Spanish nationality when their child was born, had obtained this nationality by a process of naturalization. In these cases, we assigned them the nationality of their country of birth. The group of foreign mothers is very heterogeneous. The migratory process of a woman from Africa has nothing in common with that of a woman from Germany, France or Finland. An African or Latin American woman who migrates to Spain and stays for several years in an administratively irregular situation (which is very frequent) is subject to much greater socioeconomic stress. Since she does not have the appropriate work permit, the jobs available to her will be less well paid and less stable. She will certainly have difficulties finding decent accommodation, and she is more likely to live in crowded lodgings. By contrast, women from Western Europe not only have legal access to the employment market in Spain, but, thanks to their higher educational level, can generally aspire to better paid positions that offer greater stability. Given the major socioeconomic variability among migrant women in Spain, and the different stress levels to which they are subjected, we considered it appropriate to divide them into subgroups.

In this study, we did not include western women (women from Western Europe, the USA, Canada, Australia and New Zealand) within the "foreign" group. As our aim was to identify whether the difficult socioeconomic conditions experienced by many immigrant mothers had influenced the incidence of LBW, it would seem reasonable not to include foreign mothers from western countries in the same group as women from other regions of the world, because their experiences of migration were obviously completely different. In concrete, we established the following subgroups by places of origin: Spain, Africa, East Europe, Western countries, Latin America and Asia.

Fetal mortality rates

To calculate the fetal mortality rates, we used the microdata from the *Boletín estadístico de muertes fetales tardías* [Statistical bulletin of late fetal deaths]

also published by the INE. It is important to take in account that a not insignificant percentage of stillbirths is not registered in Spain (Cassidy, 2018). It is also necessary to explain that in the case of some of the fetal deaths registered no gestational age was given (in concrete, in 13% of those from 1996 to 2020). Of the fetal deaths for which gestational age was given, 84% were at 27 weeks or later. Taking in account these data, we decided to calculate the fetal mortality rate (FMR) for a given year as follows:

$$\frac{All\ registered\ stillbirths}{All\ live\ births + all\ registered\ stillbirths}\ x\ 1{,}000$$

Singleton deliveries

As a result of the increasingly frequent use of assisted reproduction techniques, the percentage of children born in multiple births has increased continually in Spain: 1.67% (1975-1979), 2.83% (1996-2000) and 3.87% (2016-2020). The incidence of LBW among multiple births is much higher than for singleton deliveries. According to the INE's microdata on births, 5.7% of the children born in singleton deliveries in the period 1996-2020 had LBW compared to 59.6% of those born in multiple deliveries. To facilitate the analysis of LBW rates, in the present study we will only take singleton births into account.

Sociodemographic variables

We used the information from the microdata of the INE's *Boletín estadístico de parto* [Birth Statistical Bulletin] to apply logistic regression techniques in order to examine differentials in the probability of delivering a LBW neonate, controlling for different sociodemographic covariates. The novel aspect of this research lies in detecting the possible influence of the fetal mortality rate on the incidence of LBW in different population subgroups. These subgroups were established on the basis of the sociodemographic information provided in the *Boletín estadístico de parto* [Birth statistical bulletin]. We selected the variables according to the availability of information in this database, using data about genetic, sociocultural and economic aspects that previous studies had shown to be relevant as far as LBW rates are concerned: sex, birth order, gestational age, marital status, mother's age, labor force status, nationality, educational level and town size of residence (Castro-Martín, 2010; Hidalgo-Lopezosa et al., 2019; Terán et al., 2020; Stanek, Requena and del Rey, 2021).

Results and discussion

Adjusted odds ratios and 95% confidence intervals are presented in Table 1. The results show that in both periods analyzed (1996-2000 and 2016-2020), the statistical signs of the sociodemographic variables considered here maintained both the type of relationship (positive or negative) and its statistical significance. The results are fully consistent with those in previous studies (Castro-Martín, 2010; Hidalgo-Lopezosa et al., 2019; Stanek et al., 2020):

a) Married mothers have a lower LBW rate than unmarried mothers.
b) The mothers in the youngest and oldest age groups have more likelihood of having babies with LBW.
c) With the exception of Asian women, foreign women have a lower likelihood of having babies with LBW.
d) Mothers living in cities with more than 100,000 inhabitants or in provincial capitals have a lower risk of LBW.
e) The higher the mother's educational level, the lower the likelihood is that she will have children with LBW.
f) The prevalence of LBW is higher among female than male babies.
g) The incidence of LBW is higher among firstborns than among subsequent children.
h) The longer the pregnancy, the lower the probability is of LBW.

The aim of this research is not only to identify the sociodemographic factors with a statistically significant relationship to the incidence of LBW, but also to explain why these relationships are positive or negative. Both in the concrete case of Spain and in other countries, the explanations provided to date concerning the relationship between the incidence of LBW and various sociodemographic variables have often been unsatisfactory, or, as we mention above, have occasioned some perplexity among researchers (this is the case, above all, as we shall see, when we look at the

lower incidence of LBW among the immigrant population). In what follows, we shall try to explain the statistical relations described above, taking in account one further variable which has been ignored up until now: the fetal mortality rate. We should alert readers to the fact that the relations found between fetal mortality rates and LBW incidence in different population subgroups should not necessarily be taken as causal in nature. Nevertheless, they could be useful to guide future research using more detailed information, linking, for example, the information about individuals in the *Boletín estadístico de parto* [Birth statistical bulletin] with that of the *Boletín estadístico de muertes* fetales tardías [Statistical bulletin of late fetal deaths]. In concrete, we are going to distinguish between two types of variables in function of the sign of the

Table 1. Odds ratios (OR) and 95% confidence intervals (CI) from logistic regressions predicting low birthweight, Spain 1996-2000 and 2016-2020.

		1996-2000			2016-2020					
					Model 1			Model 2		
		Adjusted OR		95% CI	Adjusted OR		95% CI	Adjusted OR		95% CI
Mother's										
Marital status	(Married)	1,00			1,00					
	Unmarried	1,45	***	(1.42 - 1.48)	1,25	**	(1.23 - 1.27)			
Union status	(Married)							1,00		
	Cohabiting							1,20	***	(1.17 - 1.23)
	Lone mother							1,20	***	(1.18 - 1.22)
Age	<20	0,95	*	(0.90 - 0.99)	1,05		(1.00 - 1.11)	1,04		(0.90 - 0.99)
	(20-24)	1,00			1,00			1,00		
	25-29	0,95	***	(0.93 - 0.98)	0,92	***	(0.89 - 0.95)	0,96	**	(0.93 - 0.98)
	30-34	0,97	*	(0.94 - 1.00)	0,92	***	(0.90 - 0.95)	1,00		(0.94 - 1.00)
	35-39	1,06		(0.99 - 1.06)	1,01		(0.98 - 1.04)	1,13	***	(0.99 - 1.06)
	40+	1,17	***	(1.10 - 1.23)	1,11	***	(1.06 - 1.14)	1,24	***	(1.10 - 1.23)
Nationality	(Spain)	1,00			1,00			1,00		
	Africa	0,92	*	(0.85 - 0.98)	1,08	***	(1.04 - 1.12)	0,98		(0.95 - 1.01)
	East Europe	0,88		(0.76 - 1.02)	0,86	***	(0.83 - 0.90)	0,81	***	(0.78 - 0.85)
	Western countries	0,89	**	(0.83 - 0.96)	1,00		(0.99 - 1.02)	1,00		(0.98 - 1.02)
	Latinamerica	0,71	***	(0.66 - 0.77)	0,71	***	(0.70 - 0.74)	0,68	***	(0.66 - 0.70)
	Asia	1,16	*	(1.02 - 1.32)	1,41	***	(1.33 - 1.49)	1,29	***	(1.22 - 1.36)
Town size	(<10,000)	1,00			1,00			1,00		
	10,001 - 50,000	0,98		(0.91 - 1.06)	0,94	***	(0.92 - 0.96)	0,95	***	(0.93 - 0.97)
	50,001 - 100,000	0,97		(0.88 - 1.06)	0,90	***	(0.88 - 0.93)	0,92	***	(0.89 - 0.94)
	100,000+ and province capitals	1,05		(0.98 - 1.11)	0,92	***	(0.90 - 0.94)	0,95	***	(0.93 - 0.97)
Education	(Illiterate or primary)							1,00		
	Secundary							0,97	*	(0.95 - 1.00)
	University							0,73	***	(0.71 - 0.75)
Residence location	(North)	1,00			1,00			1,00		
	Center	1,08	***	(1.06 - 1.11)	1,04	**	(1.01 - 1.07)	1,04	**	(1.01 - 1.07)
	South	0,94	***	(0.92 - 0.97)	1,10	***	(1.07 - 1.13)	1,08	***	(1.05 - 1.11)
New born's										
Sex	(Boy)	1,00			1,00			1,00		
	Girl	1,42	***	(1.40 - 1.45)	1,51	***	(1.49 - 1.53)	1,51	***	(1.48 - 1.53)
Birth order	(1)	1,00			1,00			1,00		
	2	0,69	***	(0.68 - 0.70)	0,63	***	(0.62 - 0.64)	0,61	***	(0.61 - 0.63)
	3+	0,73	***	(0.71 - 0.76)	0,62	***	(0.61 - 0.64)	0,59	***	(0.58 - 0.61)
Gestational age	<36	57,93	***	(56.50 - 59.40)	74,68	***	(72.86 - 76.53)	74,52	***	(72.71 - 76.37)
	36-37	4,56	***	(4.46 - 4.66)	8,45	***	(8.29 - 8.62)	8,43	***	(8.27 - 8.60)
	38	1,40	***	(1.36 - 1.44)	1,82	***	(1.78 - 1.87)	1,83	***	(1.78 - 1.87)
	(39)	1,00			1,00			1,00		
	40	0,45	***	(0.44 - 0.46)	0,31	***	(0.30 - 0.32)	0,32	***	(0.31 - 0.33)
	41+	0,20	***	(0.19 - 0.21)	0,17	***	(0.16 - 0.18)	0,17	***	(0.16 - 0.18)
Log likelihood		*-251.304,26*			*-272.278,79*			*-271.756,68*		
df		*24*			*24*			*27*		
N		*1.720.751*			*1.755.664*			*1.755.664*		

relationship between fetal mortality rates and the incidence of LBW.

a) *Variables with a negative relationship between fetal mortality rates and the incidence of low birthweight*

Sex of neonate

As in previous studies (Bernis, 2010; Castro-Martín, 2010; Hidalgo-Lopezosa et al., 2019), our analysis (Table 1) indicates that the prevalence of LBW in Spain is higher among females than males. Why do females systematically have a higher incidence of LBW? One possible explanation is to be found in the selection effect of fetal mortality by sex. Throughout all the stages of human life, men have higher mortality rates than women. The fetal stage is no exception, which is why the term "frail males" was coined. Di Renzo et al. (2007) concluded that there are gender differences that originate in the intrauterine environment and that male gender is an independent risk factor for adverse pregnancy outcome (females appear to have an advantage over males). Table 2 shows that in Spain, the fetal mortality rates are higher among males than females throughout the period of study. Irrespective of whether biological differences might exist that allow males to gain more weight during the fetal stage, it is also very likely that the higher mortality among males exerts a selective effect, eliminating the weaker ones, which weigh less, and thus only allowing the stronger ones that weigh more to be born alive. The lower fetal mortality among female fetuses thus allows fetuses that weigh less to be born alive.

Table 2. Fetal mortality rates in Spain by sex.

Sex	1996-2004	2005-2012	2013-2020
Male	3.8	3.3	3.3
Female	3.5	3.1	3.1

Mother's nationality

Many international studies of perinatal mortality according to the mother's migration history conclude that the children of immigrants have a lower likelihood of LBW. Migrant status may represent a source of advantage in terms of birth outcomes. In the USA there is evidence that immigrants' children, regardless of their ethnic or racial background, have a lower incidence of LBW (Cervantes, Keith and Wyshak,1999). Guendelman et al. (1999) conducted a study of the USA, France and Belgium and found that the adjusted odds for LBW were lower for immigrants than natives by more than 30%. The many studies that have compared the incidence of LBW in Spain concur that the children of foreign mothers are less likely to suffer from LBW (Bernis, 2005; Agudelo-Suárez et al., 2009; Castro-Martín, 2010; Speciale and Regidor, 2011; Varea, Bernis and González, 2012; Escartín et al., 2014; Juárez et al., 2014; Fuster et al., 2015; Restrepo-Mesa et al., 2015; Cebolla-Boado and Salazar, 2016; Farré, 2016; Juárez et al., 2017; Hidalgo-Lopezosa et al., 2019; Stanek et al., 2020; Stanek, Requena and del Rey, 2021). In the results of the present study shown in Table 1, although this rule generally holds, we can observe some exceptions. According to Luque-Fernández, Bueno-Cavanillas and de Mateo (2011), and Stanek et al. (2020), we think that we should move beyond the dichotomy native/foreign born because migrants are an extremely heterogeneous group. In particular, we can see in Table 1 that mothers of Asian origin are more likely to have LBW children than Spanish mothers.

What explanations have been proposed so far to explain the differences in terms of the mother's origin? All the researchers appear to be perplexed by these results. Bernis (2005) stated that "in contradiction to our working hypothesis, the group of immigrant women has offspring that weighs significantly more than that of Spanish women". Many authors do not hesitate to label this "the epidemiological paradox" or "the healthy immigrant paradox" (García-Subirats et al., 2011; Speciale and Regidor, 2011; Juárez and Revuelta-Eugercios, 2014; Juárez et al., 2014; Restrepo-Mesa et al., 2015; Cebolla-Boado and Salazar, 2016; Farré, 2016; Juárez et al., 2017; Stanek et al., 2020; Stanek, Requena and del Rey, 2021). They argue that this could be due to positive selection underlying the immigrant population: immigrants might not be representative of the population of their country of origin, but rather represent the strongest and healthiest persons who were able to take the decision to

go and live in another country. Other researchers point out that pregnant immigrant mothers have healthier lifestyles (they are less likely to smoke) and generally enjoy better health than natives (Reichman, 2008). Agudelo-Suárez et al. (2009) say that newborns with foreign mothers have a lower risk of LBW than those with Spanish mothers, "possibly as a result of the bias caused by being a healthy immigrant, and because immigrant women engage in fewer risk practices during gestation". None of these studies relates the rate of fetal mortality and LBW according to the mother's nationality. It is well known that both in Spain and in other countries, immigrant women (particularly those from Sub-Saharan Africa) have higher fetal mortality rates than local women (Racape et al., 2010; Luque-Fernández et al., 2012, 2013; Barona-Vilar et al., 2014; Fuster, Zuluaga and Román-Busto, 2014; Hidalgo-Lopezosa et al., 2018). The social barriers that immigrant women have to face can limit both access to antenatal screening and the ability to detect fetal growth restriction. The higher fetal mortality among immigrants might be evidence of a selection process that makes it harder for weaker fetuses with lower weight to reach term. As a consequence, it is logical to expect the children of immigrant mothers to have a lower incidence of LBW than those of native mothers.

The higher fetal mortality among the immigrant population can mainly be explained by two factors. The first has to do with the greater difficulty that foreign women have to get access to healthcare services, for bureaucratic reasons (this is harder or even impossible for them), or for linguistic reasons (problems communicating in Spanish make it harder for them to get adequate follow-up during their pregnancy). Even in Spain, where there is universal access to healthcare, the immigrant population has greater difficulty when it comes to making use of public healthcare services (Malmusi and Ortiz-Barreda, 2014). The second factor is related to the different stress levels to which native and immigrant populations are subjected. For many years, obstetricians have linked the stress levels among pregnant mothers with fetal mortality. The studies by Catalano et al. (2012), Carolan-Olah and Barry (2014) and Catalano (2021) have confirmed the hypothesis that pregnant mothers subjected to a higher stress level have a greater likelihood of miscarriage. It has been shown that different types of stress (terrorist attacks, massive job losses, earthquakes, wars, financial crises, religious fasting, famines, precarious work situations, etc.) increase the number of natural abortions (Ruckstuhl et al., 2010; Grech, 2015). Pregnant immigrant women are subjected to considerably higher stress levels than local women. In the first place, they lack a family support network, as they are far from their countries of origin. They also have to face more – and more serious – socioeconomic problems: they are often in irregular administrative situations, which prevent them from working legally, and they usually have to do less attractive jobs (which are more stressful, inconvenient, hard, unstable and badly paid); their living conditions are usually worse (accommodation with structural problems, unhealthy conditions and overcrowding), and they find it harder to get access to the subsidies and benefits provided by the social services for people in need. Unlike other colleagues, we find no paradox in the fact that, owing to the selective effect exerted through higher fetal mortality, immigrant women have a lower probability of giving birth to children with LBW.

Town size

The mother's place of residence can also affect the prevalence of LBW. In recent years, studies have been published in Spain documenting a positive relationship between the air pollution levels and the incidence of LBW (Arroyo et al., 2016, 2019). If we assume that, in general, cities have higher air pollution than villages, we should find higher percentages of LBW in the larger centers of population. But it is also true that cities are better equipped with healthcare infrastructure, and that the population mobility within these cities is much faster and more effective, which means that the disadvantages of having higher air contamination could be counteracted by the advantages of having closer, more comprehensive healthcare facilities.

The adjusted odds ratios predicting LBW in Spain presented in Table 1 indicate that in the period 2016-2020, living in cities with >100,000 inhabitants or provincial capitals reduces the risk of LBW, in contradiction to the results obtained by Castro-Martín (2010) and Hidalgo-Lopezosa et al. (2019). The adjusted odds ratios for the period 1996-2000 were not

statistically significant. The fetal mortality rates are slightly higher in Spanish cities with over 100,000 inhabitants and in provincial capitals (Table 3). Although these are precisely the places with the best healthcare infrastructure, the higher fetal mortality rates can be explained by the higher pollution levels, and perhaps also because the mothers living there are subjected to more acute levels of stress. The higher fetal mortality rates in the larger center of population therefore may also exercise a selective effect on fetuses, which leads to a lower likelihood of giving birth to a LBW child.

Table 3. Fetal mortality rates in Spain according to size of town or city where mother lives.

	1996-2004	2005-2012	2013-2020
<10,000	3.4	3.0	3.0
10,001 - 50,000	3.4	3.0	3.0
50,001 - 100,000	4.0	3.1	3.0
100,000+ and province capitals	3.9	3.4	3.3

b) Variables where a positive relationship is found between the fetal mortality rates and the incidence of low birthweight Birth order

The relationship between maternal parity and birthweight has been the subject of considerable research. The literature has consistently shown that there is a positive relationship between maternal parity and birthweight, the largest difference being between the first and the second order births (Wilcox, Chang and Johnson, 1996). The biological mechanism of how parity may influence the incidence of LBW is not clearly understood. According to Bisai et al. (2006), a possible explanation of lower birthweight among first order births could be a consequence of biological immaturity as compared to later-born infants. All the studies performed in Spain agree that the incidence of LBW is higher among first order births than among subsequent children, even when controlling for the effect of different covariables (Castro-Martín, 2010; Escartín et al., 2014; Fuster et al., 2015; Hidalgo-Lopezosa et al., 2019; Aparicio, González and Vall Castelló, 2020). Our models shown in Table 1 also confirm these results. The meta-analyses on this subject do not even mention the possible effect of the fetal mortality rates according to birth order (Shah et al., 2010).

Some studies from the USA indicate that fetal mortality rates according to birth order follow a U-shaped trajectory. Mortality is higher among first children, declines notable for the second child, and then goes up again from the third child onwards (Selvin and Garfinkel, 1976). Table 4 shows that the same pattern can be observed for Spain. Therefore, higher fetal mortality rates in first order births than in second order births do not correspond to lower incidences of LBW. The positive relationship between variables observed in birth order 1 and 2 disappears from birth order 3 onwards.

Table 4. Fetal mortality rates according to birth order in Spain.

Birth order	1996-2004	2005-2012	2013-2020
1	4.2	3.8	3.8
2	2.6	2.2	2.2
3+	4.4	3.5	3.1

Marital status

Many studies in different countries have found that unmarried mothers have a higher probability than married mothers of giving birth to children with low weight (Raatikainen, Heiskanen and Heinonen, 2005; Shah, Zao and Ali, 2011). Research carried out in Spain on this subject also confirms this relationship (Castro-Martín, 2010; Hidalgo-Lopezosa et al., 2019; Stanek et al., 2020; Stanek, Requena and del Rey, 2021). It is well known that cohabitation is increasingly common among the younger generations in Spain (García-Pereiro, Pace and Didonna, 2014) and therefore for some decades an increasing percentage of pregnant women have had the support of a partner, although they were not legally married (it was not until 2007 that the parents' cohabitating status started to be registered officially in Spain). For this reason, Table 1 distinguishes between three major groups of mothers: married, cohabiting and single. The results of our models shown in Table 1 corroborate the previous findings: Married women have lower probabilities again, the selective effect supposedly exerted by fetal

mortality paradoxically ofhaving children with LBW than non-married women (whether they are cohabiting or alone).

Several reasons have been put forward to explain these differences in the incidence of LBW according to the mother's marital status:

1- Unmarried pregnant women face greater economic difficulties, are subject to higher psychological stress levels, and go less frequently to medical checkups (Reime et al., 2006).

2- Unmarried women take less care of their health (e.g., they smoke more).

3- Married women are more likely to have the emotional and economic support of their partner during the pregnancy.

4- The proportion of unwanted pregnancies is lower among married women (Williams, 1994).

According to Castro-Martín (2010), these factors, together with the social stigma and disapproval of maternity outside marriage in Spain, represent a threat to the healthcare status of unmarried mothers and their children during gestation, which leads to a higher incidence of LBW (although with the passing of time, the differences between married and unmarried mothers have undergone a notable decrease). Once again, all the studies focusing on Spain (and elsewhere) have ignored the possible relationship between the mortality rates and the incidence of LBW according to mother's marital status. In Table 5 we can see that the rates of LBW for unmarried mothers are practically twice those for married mothers. These results might be expected because, as we have seen, the higher stress levels to which unmarried pregnant women are subject, lead to an increase in the levels of fetal mortality. As most of these women do not have a partner to rely on, they are much more likely to suffer from situations of socioeconomic precarity and, as a result, from tension, anxiety and fatigue. That is, rather than the impact of social stigma and disapproval mentioned by Castro-Martín (2010), it is the situations of stress that pregnant women without a partner have to face that lead to a raised likelihood of fetal mortality.

If we accept that fetal mortality exerts a selective effect on the more vulnerable fetuses, that is, those at earlier gestational stages and with lower weights, it would be logical for the children born alive of unmarried mothers to have a lower incidence of LBW than those of married mothers, but the results observed systematically show the opposite. In our view, this is indeed a paradox that calls for investigation and explanation: why does the raised fetal mortality (caused by higher stress levels) suffered by unmarried mothers have a different effect on LBW from the raised fetal mortality found among immigrant mothers?

Table 5. Fetal mortality rates according to mother's marital status in Spain.

Marital status	1996-2004	2005-2012	2013-2020
Married	3.1	2.6	2.4
Non married	6.3	4.4	4.1

Mother's age

The graph in which the mother's age is related to the LBW rate follows a U-shaped course. Figure 1 shows that the incidence of LBW in Spain declines from the age of 15 to 32, but then rises again proportionally to the mother's age. According to Lee et al. (1988) "advancing maternal age is associated with a decreased potential for fetal growth, possibly reflecting biologic aging of maternal tissues and systems or the cumulative effects of disease". Both the results from our own models (Table 1) and the other studies carried out in Spain (Rodríguez, Regidor and Gutiérrez-Fisac, 1995; Castro-Martín, 2010; Hidalgo-Lopezosa et al., 2019) show that increasing maternal age is an independent risk factor for LBW. When we control for other factors, however, adolescent mothers appear not to have an increased risk of having children with LBW. For this reason, although biological immaturity may also play a role, the high incidence of this factor that we find in the youngest group of pregnant women (Figure 1) apparently reflects their poor sociodemographic and prenatal care status.

In the case of the USA, we know that the stillbirth rates are much higher at the extremes of maternal age. The rates of stillbirths for women over 39 years old double those for women aged 20-24. Several studies have confirmed that stillbirth risk in older women in the USA persists even after adjusting for

medical conditions (hypertension, placental problems, diabetes, and multiple gestation) (MacDorman, 2011). Just as in the case of the USA, the fetal mortality rates by mother's age also follow a U-shaped pattern in Spain (Figure 2). There would also seem to be a positive correlation between fetal mortality rates according to the mother's age and the percentage of children born with LBW. In this case, again, the selective effect supposedly exerted by fetal mortality paradoxically is not reflected in a decrease in the incidence of LBW.

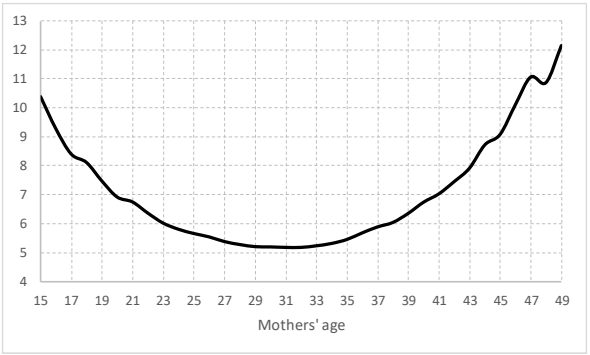

Figure 1. Percentage of singleton births with low weight according to mother's age. Spain, 1996-2020.

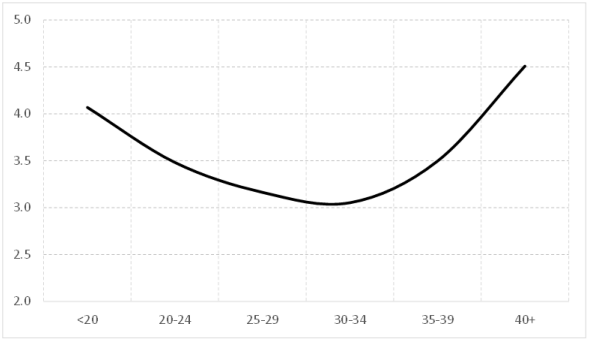

Figure 2. Fetal mortality rate according to mother's age in Spain, 1996-2020.

Educational level and mother's occupation

Various studies conducted in Spain have shown that the higher the educational level of pregnant women, the lower their likelihood is of giving birth to children with a low weight (Castro-Martín, 2010; Juárez and Revuelta-Eugercios, 2013; Hidalgo-Lopezosa et al., 2019; Stanek et al., 2020; Stanek, Requena and del Rey, 2021). Our results shown in Table 1 also confirm the existence of this relationship. According to Ronda, Hernández-Mora and García (2009), women in Spain who are on the lowest level of the occupational hierarchy (those employed in the service sector, who do manual labor in industry or construction, those who work in agriculture, home-makers, etc.) have a greater risk of having children with low weight in comparison with professional women. Fuster et al. (2015) also found that LBW is negatively related to the mother's low level of professional training in Spain. Using data for Spain between 1980 and 2015, Aparicio, González and Vall Castelló (2020) show that the health of newborn babies improves (on average) when the local unemployment rate is high. Various studies conducted in Spain also indicate that mothers with a lower level of education have higher rates of fetal mortality (Hidalgo-Lopezosa et al., 2018). Luque-Fernández et al. (2012) found that the risk of fetal death among mothers with secondary or lower education attainment was double that of mothers with tertiary education. Luque-Fernández et al. (2013, 2019) demonstrate that in Spain there is a greater stillbirth risk among mothers of low socioeconomic status (lower education, higher unemployment).

Once more, the higher stress levels that pregnant women with low socioeconomic status probably have to suffer probably account for the higher levels of fetal mortality encountered in this group. The data at our disposal therefore suggest that when we take into account the educational and occupational level of the mothers, the greater fetal mortality rate does not find correspondence in a lower incidence of LBW. Again, this result contradicts our initial hypothesis.

Conclusions

Many studies performed in Spain (and other countries) have identified several sociodemographic variables that have been related to the incidence of low birthweight (LBW). However, hardly any of them has provided an explanation concerning the positive or negative relationships that emerge. Although the possible influence of fetal mortality rates on LBW has traditionally been ignored, we have shown that this variable should definitely be taken in account. By including this variable in our analysis, we have been

able to explain some apparent paradoxes, such as the fact that the immigrant population suffers lower levels of LBW than the native population. This also helps us to explain why male fetuses have a lower incidence of LBW than female ones, or why the incidence of LBW is lower in larger cities.

In these cases, the data analyzed suggest that fetal mortality has a selective effect on the children who are born alive. If medical progress allows more fetuses with a younger gestational age to be born alive, the immediate result will be that the percentage of children born with LBW will rise. We should therefore expect to find a negative relationship between the fetal mortality rate and the incidence of LBW.

However, this selective effect of fetal mortality seems not to happen when we analyze other sociodemographic variables. We found that our initial hypothesis (that population groups with higher fetal mortality rates should have a lower incidence of LBW) does not always hold. This relationship even becomes positive when other variables are taken into account, such as birth order, mother's age, marital status or educational level and mother's occupation.

We can therefore conclude that although the inclusion of fetal mortality in our analysis enables us to resolve some apparent paradoxes, it also brings others to light that were previously concealed. It is necessary to do further research to understand better the influence of fetal mortality on determining birth weight.

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