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ORIGINAL ARTICLE

Does maternal obesity explain trends in caesarean section rates? Evidence from a large Irish maternity hospital

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Abstract

Background A feature of contemporary obstetrics in wealthy countries has been both the continuing increase in caesarean section (CS) rates and the emergence of high levels of maternal obesity.

Aims The purpose of this study was to examine whether the increasing CS rate in a large university maternity hospital was attributable in part to maternal obesity.

Methods We studied all women who delivered a baby weighing ≥ 500 g from 2009 to 2014 in one of the largest maternity hospitals in Europe. Logistic regression techniques were employed to examine the contribution of trends in maternal BMI on the prevalence of CS.

Results Obese women were more likely to be delivered by CS in 2014 than in 2009. Multivariate analysis shows that the increase in CS rates could not be explained by changes in obesity levels in either nulliparas or multiparas. The increase in CS rates during the 6 years was strongly associated with advancing maternal age, particularly for nulliparas.

Conclusions The study found that although the prevalence of being overweight or obese changed little over the period, the odds of having a CS if a woman is obese have increased for multiparas. For nulliparas, increasing CS rates were found to be strongly associated with an increase in maternal age over the period which is important because of the evidence that Irish women are choosing to defer having their first baby until later in life.

Keywords Body mass index · Caesarean section · Maternal age · Obesity

Background

A feature of contemporary obstetrics has been the relentless escalation in Caesarean section (CS) rates which shows little sign to date of plateauing [1]. There are many explanations for this escalation, including major advances in the safety of the operation [2]. If the increasing rate is to be reversed, therefore, it is important to identify risk factors that are potentially modifiable.

Another feature is the increase in the incidence of maternal obesity, based on a body mass index (BMI) ≥ 30.0 kg/m^2. Examination of obesity trends in pregnant women both

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nationally and internationally has shown significant increases in obesity levels over time [3–9]. Nationally representative measured data on BMI in females in Ireland found that large proportions of women of childbearing age were either overweight or obese (BMI ≥ 25.0 kg/m^2) in 2007 (24% aged 18–24 years, 49% aged 25–34 years, and 48% aged 35–44 years). By 2015, this proportion had increased further in the younger and older age groups (28% aged 15–24 years, 46% aged 25–34 years, and 53% aged 35–44 years) [10, 11].

Almost one in five women delivered in 2017 in the Coombe Women and Infants University Hospital was obese at her first antenatal visit and the number of women with obesity, including obesity class III (≥ 40.0 kg/m^2), has been shown to be increasing over time. Between 2010 and 2017, the proportion of obese women delivering in the Coombe increased by 18.1% [8, 9]. Numerous analyses have established that the risk of CS is increased in obese women [12–14]. In particular, the risk of emergency CS is increased in nulliparas and the risk of elective CS is increased in multiparas [15].

The objective of this paper is to examine, for the first time using Irish data, whether trends in maternal BMI are a contributing factor to the increase in the prevalence of CS which has occurred in one of the largest maternity hospitals in the European Union over the last half decade.

Methods

The data for these analyses were obtained from the computerised birth records of the Coombe Women and Infants University Hospital in Dublin, Ireland. The dataset available for these analyses contains records of all 50,992 women who gave birth (≥ 500 g) in the Hospital between January 1, 2009, and December 31, 2014. The hospital is one of the largest maternity hospitals in Europe with approximately 8000 deliveries per year. It provides care to women from all socioeconomic groups and nationalities (30% born outside Ireland), including those with private health insurance [16]. The hospital is a national tertiary referral centre for specialised services including maternal and perinatal medicine.

All women presenting for antenatal care have their clinical and sociodemographic details computerised by a trained midwife using a bar code system and standardised questions. These details are printed in hard copy at the end of consultation and form part of the clinical records. After delivery, the pregnancy outcomes are again computerised before the woman is discharged to the postnatal ward and a hard copy forms part of the clinical records. The computerised details are also used to notify the family doctor and public health nurse.

The dataset for these analyses contains variables that are not available for births at a national level in Ireland, including BMI and maternal smoking during pregnancy. The main independent variables of interest were year and maternal BMI (kg/m^2). Year refers to the year of delivery and when specified as a dummy variable for each year allows an examination of the CS trend over the period. In these data, BMI was calculated at the first antenatal clinic appointment by trained midwives. In all cases, height was measured (shoes removed) in centimetres to one decimal point using a wall-mounted metre stick (Seca 242) while weight was measured to the nearest decimal point in a standardised way using digital weighing scales (Seca M). Maternal BMI was classified according to the categorisation of the World Health Organization, i.e. underweight (BMI < 18.5 kg/m^2), normal (BMI 18.5–24.9 kg/m^2), overweight (BMI 25.0–29.9 kg/m^2), and obese class I (mild) (BMI 30.0–34.9 kg/m^2), class II (moderate) (BMI 35.0–39.9 kg/m^2), and class III (severe) (BMI ≥ 40.0 kg/m^2). In the models, two dummy variables representing overweight and obese (all classes) are included.

Like all 19 maternity units in the country, all women are delivered in the same delivery rooms and operating theatres with the same medical and midwifery staff following identical clinical guidelines. The management of women who have private insurance is provided by a consultant obstetrician or if not available, by a colleague. If available, private patients are provided with a single room for antenatal or postnatal admissions.

Previous research has shown that the increased risk of CS in the presence of obesity can, in part, be accounted for by other clinical factors such as the presence, for example, of diabetes mellitus [15]. In August 2010, new national guidelines on screening for gestational diabetes mellitus (GDM) were published and were implemented in the Coombe in January 2011. The criteria made the 75 g Oral Glucose Tolerance Test more sensitive and compliance with selective screening improved. Obese women are more likely to be screened than non-obese women and thus, the contribution of GDM to the increase in CS rates from 2009 was not possible to determine reliably.

Analysis of CS is often disaggregated by whether it was classified as an elective or an emergency procedure. However, this disaggregation was not possible with these data as the classification of CS into elective and emergency changed in the Coombe during the period under consideration. The dependent variable in each model is a binary indicator of whether the woman had a CS.

In addition to the variable of interest maternal BMI, independent variables entered into the models include a number of other factors which are known to be associated with the risk of CS including maternal age, mother country of birth, multiple gestation, induction, birthweight, and smoking during pregnancy.

To examine the contribution of trends in maternal BMI on the prevalence of CS, we estimated logistic models of the probability of CS for all births at the Coombe Women and

Infants University Hospital between January 2009 and December 2014. Adjustment for the year of birth in the baseline model (model 1) provides a measure of the unadjusted risk of CS between 2009 and 2014. The reduction in the year coefficient with the addition of different variables provides a quantification of the role of those factors in CS trends.

Adjustment is made for confounding factors in model 2 (maternal country of birth, maternal smoking, child birthweight, and gestation). Model 3 adjusts for maternal age whilst model 4 adjusts for maternal BMI. Model 5 adjusts for interaction effects of overweight and obese with year. The addition of the interactions measures any change in the effect of being overweight or obese across the years of the observation period. Should the interactions be significant, this would suggest changing clinician behaviours in relation to overweight and obesity which are associated with the risk of CS. Ten models are estimated overall, five each for nulliparas and multiparas separately.

Results

Over the 6 years covered by these data, 2009–2014, 50,992 women delivered. Of these, 25.6% had a CS in 2009 and 28.7% had a CS in 2014 which was slightly lower than the national rate in both years (26.0% and 29.6% respectively) [17]. Between 2009 and 2014, the prevalence of being overweight decreased significantly (29.8 to 27.4%, $p = 0.001$), while the prevalence of obesity increased but the change was not significant (16.2 to 16.8%, $p = 0.274$) (Fig. 1).

Table 1 shows that for multiparas, the prevalence of overweight fell between 2009 and 2014 (33.4 to 29.3%, $p < 0.001$). For nulliparas, the fall in prevalence of overweight over the same period was not significant (24.9 to 24.5%, $p = 0.721$). However, there was an increase in the prevalence of nulliparas measured as obese over the period (12.0 to 14.2%, $p = 0.007$) while there was no change for multiparas (19.1 to 18.5%, $p = 0.396$).

In the overweight category, there was a small but significant increase in mean BMI (27.0 to 27.1; $p = 0.014$) between 2009 and 2014. When disaggregated by parity, the increase was only significant for multiparas ($p = 0.005$). In the obese category, there was a significant increase in mean BMI (34.0 to 34.7; $p < 0.001$) which remained when disaggregated by parity (nulliparas $p = 0.047$; multiparas $p < 0.001$) (Table 2).

During the same period, the CS rate for women classified as either overweight or obese increased for both parity groups (Fig. 2). The increase in the nulliparas CS rates for the overweight (30.3 to 32.5%, $p = 0.330$) and obese (42.0 to 45.6%, $p = 0.294$) groups were not significant but the increases in the multiparas CS rates were significant for both the overweight (27.1 to 30.3%, $p = 0.046$) and obese (32.6 to 38.5%, $p = 0.008$) groups (Table 2).

The full results of the multivariate analyses are provided in the Supplementary Table where results are disaggregated by parity group (nulliparas and multiparas). Five models were estimated for each parity group, with each differentiated by the addition of variables. Figure 3 shows the unadjusted year effect and component of this effect associated with confounding factors, maternal age, maternal BMI, and unexplained, separately for nulliparas (Fig. 3a) and multiparas (Fig. 3b). Figure 3a shows that the unadjusted risk of CS increased in an almost linear fashion between 2009 and 2014 for nulliparas (see nulliparas model 1, Supplementary Table).

Figure 3a shows that adjustment for confounding factors such as the prevalence of smoking and birthweight explains a growing proportion of the increasing CS trend, from 25% in 2011 to 39% by 2014. Additionally, adjustment for trends in BMI also explains an increasing

Fig. 1 CS rate and BMI group (4 categories), 2009 and 2014

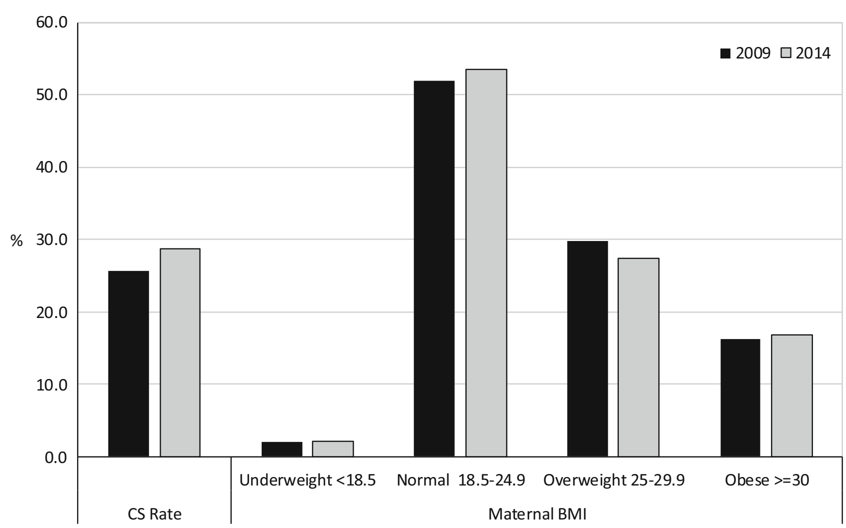

Table 1 Descriptive statistics for total women delivered: prevalence by parity, 2009 and 2014

	Nulliparas					Multiparas				
	2009		2014		p value[a,b]	2009		2014		p value[a,b]
	N	%	N	%		N	%	N	%	
Total	3594	100.0	3372	100.0		5059	100.0	5259	100.0	
Age at delivery										
< 20	265	7.4	146	4.3	< 0.001***	27	0.5	19	0.4	0.189
20–24	700	19.5	487	14.4	< 0.001***	427	8.4	315	6.0	< 0.001***
25–29	1064	29.6	817	24.2	< 0.001***	1045	20.7	925	17.6	< 0.001***
30–34	1057	29.4	1201	35.6	< 0.001***	1694	33.5	1910	36.3	0.003**
35–39	419	11.7	572	17.0	< 0.001***	1569	31.0	1691	32.2	0.213
40+	89	2.5	148	4.4	< 0.001***	297	5.9	399	7.6	0.001**
Maternal country of birth[c]										
Ireland	2434	67.9	2432	72.3	< 0.001***	3758	74.6	3792	72.4	0.011*
EU 14	139	3.9	130	3.9	0.978	188	3.7	193	3.7	0.897
EU 13	575	16.0	488	14.5	0.076*	290	5.8	562	10.7	< 0.001***
Other	435	12.1	312	9.3	< 0.001***	801	15.9	692	13.2	< 0.001***
Smoking in pregnancy										
No smoking	3067	85.3	3030	89.9	< 0.001***	4151	82.1	4597	87.4	< 0.001***
Smoking	527	14.7	342	10.1		251	5.0	112	2.1	
Induced labour										
Not induced	2353	65.5	2049	60.8	< 0.001***	3716	73.5	3920	74.5	0.209
Induced	1241	34.5	1323	39.2		1343	26.5	1339	25.5	
Multiple birth										
Singleton	3548	98.7	3292	97.6	< 0.001***	4973	98.3	5156	98.0	0.327
Multiple	46	1.3	80	2.4		86	1.7	103	2.0	
Birthweight										
< 2500 g	241	6.7	245	7.3	0.357	307	6.1	300	5.7	0.434
2500–2999 g	611	17.0	485	14.4	0.003**	614	12.1	666	12.7	0.415
3000–3499 g	1349	37.5	1250	37.1	0.696	1717	33.9	1716	32.6	0.160
3500–3999 g	1097	30.5	1027	30.5	0.959	1656	32.7	1870	35.6	0.002**
4000–4499 g	264	7.3	321	9.5	0.001**	656	13.0	598	11.4	0.013**
≥ 4500 g	32	0.9	43	1.3	0.120	109	2.2	108	2.1	0.722
BMI										
Underweight < 18.5	107	3.0	94	2.9	0.714	62	1.3	87	1.7	0.050
Normal 18.5–24.9	2109	60.1	1895	58.4	0.159	2290	46.2	2544	50.5	< 0.001***
Overweight 25–29.9	872	24.9	794	24.5	0.721	1652	33.4	1476	29.3	< 0.001***
Obese ≥ 30	421	12.0	461	14.2	0.007**	948	19.1	931	18.5	0.396

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Missing values are not included in the calculation of percentages

[a] Chi-square test of independence. The results in each case refer to testing across 2009 and 2014 in a 2 × 2 table

[b] Independent samples *t* test. The results in each case refer to testing across 2009 and 2014 in each sub-category

[c] EU-14: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK. EU-13: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia

proportion of the CS trend from 13% in 2011 to 17% in 2014. Over the same period, the proportion of the trend explained by increasing maternal age increases from 6% in 2011 to 56% in 2014 suggesting that the increasing maternal age profile was the dominant process in statistical terms, during the period among nulliparas. This leaves open the specific mediating process(es) that explained the effect of maternal age.

Table 2 Descriptive statistics for total women delivered: mean BMI and CS rate by parity, 2009 and 2014

	Nulliparas						Multiparas					
	Mean BMI			CS rate			Mean BMI			CS rate		
	2009	2014	p value[a]	2009	2014	p value[b]	2009	2014	p value[a]	2009	2014	p value[b]
Total	24.6	24.9	0.015*	26.4	29.7	0.002**	26.1	26.0	0.191	25.1	28.0	0.001**
Age at delivery												
< 20	23.1	23.1	0.977	14.7	10.3	0.202	24.3	24.9	0.666	14.8	10.5	0.671
20–24	24.4	24.8	0.241	20.9	17.7	0.172	25.9	25.6	0.453	16.4	19.4	0.294
25–29	24.5	24.8	0.242	22.3	23.5	0.530	26.0	26.2	0.294	18.6	22.8	0.020**
30–34	24.7	24.8	0.625	30.0	31.4	0.472	26.1	25.6	0.003**	25.2	25.7	0.731
35–39	25.3	25.4	0.746	39.1	41.3	0.502	26.2	26.1	0.314	29.7	32.4	0.095*
40+	25.7	25.8	0.934	51.7	65.5	0.035*	25.9	26.8	0.018*	36.0	40.6	0.220
Maternal country of birth[c]												
Ireland	25.0	25.2	0.180	28.3	30.6	0.075	26.0	25.9	0.554	25.2	28.7	0.001**
EU 14	24.3	25.1	0.155	25.2	28.5	0.544	26.1	25.8	0.665	22.9	25.9	0.491
EU 13	23.3	23.3	0.835	19.5	25.0	0.030*	24.6	24.5	0.766	19.7	19.0	0.829
Other	23.9	24.4	0.146	26.0	30.4	0.179	26.9	27.2	0.319	26.8	31.8	0.036*
Smoking in pregnancy												
No smoking	24.6	24.9	0.009*	27.1	30.9	0.001**	26.1	25.9	0.150	26.0	28.7	0.005**
Smoking	24.8	24.8	0.915	22.2	19.9	0.415	26.0	26.0	0.965	20.8	23.6	0.194
Induced labour												
Not induced	24.3	24.4	0.354	26.6	29.0	0.083	25.9	25.8	0.186	31.7	35.6	< 0.001***
Induced	25.1	25.5	0.037*	25.9	30.9	0.005**	26.5	26.5	0.840	6.8	6.0	0.443
Multiple birth												
Singleton	24.6	24.9	0.019*	25.8	28.6	0.011**	26.1	25.9	0.165	24.5	27.4	0.001**
Multiple	24.2	25.1	0.382	69.6	77.5	0.325	25.9	26.3	0.566	58.1	60.2	0.775
Birthweight												
< 2500 g	24.3	24.5	0.634	46.5	53.5	0.123	25.6	25.8	0.770	46.6	57.7	0.006**
2500–2999 g	23.9	24.5	0.017**	25.7	29.7	0.141	25.0	25.2	0.625	32.6	30.6	0.455
3000–3499 g	24.4	24.4	0.888	22.4	24.1	0.307	25.8	25.6	0.200	21.7	26.3	0.002**
3500–3999 g	24.9	25.3	0.049**	24.8	28.3	0.065	26.2	26.2	0.958	22.5	24.6	0.136
4000–4499 g	25.7	25.4	0.479	33.3	35.8	0.529	27.4	26.7	0.041**	22.9	25.3	0.323
≥ 4500 g	26.0	28.7	0.034**	56.3	46.5	0.404	27.7	28.1	0.613	27.5	32.4	0.432
BMI												
Underweight < 18.5	17.6	17.7	0.365	15.0	16.0	0.844	17.8	17.7	0.301	8.1	19.5	0.052
Normal 18.5–24.9	22.1	22.0	0.112	22.3	24.2	0.169	22.3	22.3	0.258	21.2	22.2	0.406
Overweight 25–29.9	26.9	27.0	0.722	30.3	32.5	0.330	27.0	27.2	0.005**	27.1	30.3	0.046*
Obese ≥ 30	33.9	34.4	0.047**	42.0	45.6	0.294	34.1	34.8	< 0.001***	32.6	38.5	0.008**

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

Missing values are not included in the calculation of percentages

[a] Independent samples t test. The results in each case refer to testing across 2009 and 2014 in each sub-category

[b] Chi-square test of independence. The results in each case refer to testing across 2009 and 2014 in a 2 × 2 table

[c] EU-14: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK. EU-13: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia

Figure 3b presents a more complex account of developments among multiparas. In unadjusted multivariate models (see multiparas model 1, Supplementary Table), only the year effects for 2013 and 2014 are significantly different from the reference year of 2009. The annual trend observed for multiparas only emerged once adjustment was made for confounding factors in model 2. The vast majority of the year trend remained unexplained by the observed characteristics in our models.

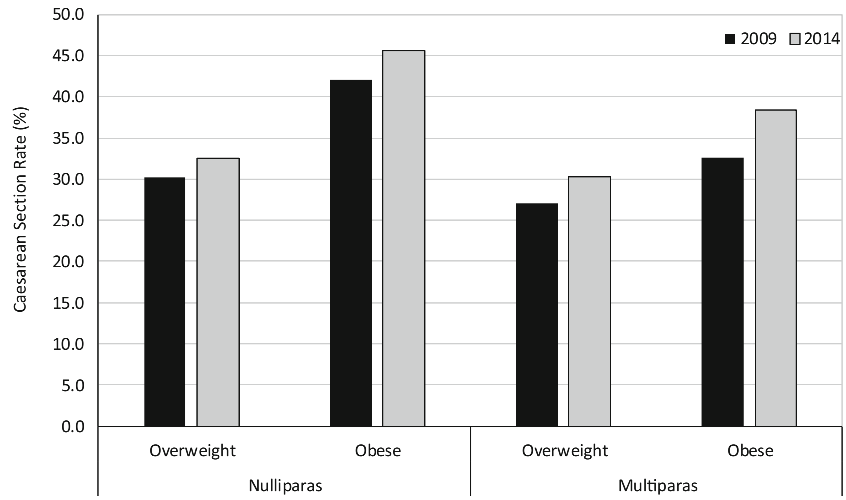

Fig. 2 CS rate by BMI category and parity, 2009 and 2014

Adjusting for the distribution of confounding factors and maternal age, multivariate models (see Supplementary Table, model 5) show that the effect for maternal overweight and obesity increased each year for multiparas between 2009 and 2014 (Fig. 4).

Discussion

Using logistic regression analysis, this observational study in a large maternity hospital found that while the prevalence of being overweight or obese changed little over the years 2009 to 2014, the odds of having a CS if a woman was obese increased in multiparas. However, a strong driver of increased CS rates, regardless of parity, was advancing maternal age which is important because national data have shown that Irish women are increasingly choosing to defer childbirth until later in life [18]. The maternal ageing trend is evident in the Coombe where in 2009 women aged 35 years or older comprised 27.4% of those delivering compared to 32.6% in 2014. This trend has continued at pace with 37.2% of women delivering in 2017 aged 35 years or older [16].

Higher birthweights were associated with increased CS rates, but locally and nationally the evidence is that the level of fetal macrosomia, however defined, is stable [18]. It is also notable that self-reported maternal smoking was associated with lower CS rates and thus, a possible unforeseen consequence of a successful smoking cessation programme in the future may be a further increase in CS rates.

Maternal obesity is an important risk factor for CS because it is common, the CS itself may be technically challenging, and the risk of CS is increased due, for example, to the increased risks of haemorrhage, infection, and thromboembolism [19]. It is also potentially modifiable pre-pregnancy. The interaction effects in the models have shown that obese multiparas were at greater odds of having a CS in 2013 than in 2009. This may indicate that there has been a reduction in the threshold at which the decision to deliver these women by CS is made, although it is not possible to explain why this change in behaviour has occurred.

This study has strengths. Clinical and sociodemographic details were computerised at the first antenatal visit and immediately after delivery under the supervision of a trained midwife. These details form part of the clinical records and the information provided is a major contributor to clinical practice. The computerised information is also used for clinical audit and the Coombe's long established Annual Clinical Reports, which includes details on CS [20]. Since January 2009, the categorisation of BMI has been based on the accurate measurement of maternal weight and height at the first antenatal visit by a midwife, and not on self-reporting or pre-pregnancy BMI which have been shown to be unreliable [21]. This is the first time the effect of maternal BMI on trends in CS rates in Ireland has been explored. Neither national level datasets, the National Perinatal Reporting System or Hospital In-Patient Enquiry scheme, currently collect data on maternal BMI.

The study also has some limitations. The change in the risk of CS over the period may be as a result of characteristics that are not available in these data. For example, we were unable to identify the presence key clinical characteristics such as diabetes mellitus, either gestational or pre-existing, which is strongly associated with obesity and have been increasing over time [22]. In addition, the information in the dataset on the indication for CS is not detailed enough [23]; for example, we do not know if the CS was undertaken on an elective or emergency basis. A possible driver of the escalating CS rate in obese multiparas is the increase in repeat elective CS in women with one previous CS. A recent paper illustrated that trends in delivery after one previous CS in Dublin were following international trends in Germany and the USA [24].

A previous decomposition analysis using two large national databases in Ireland found that advancing maternal age was

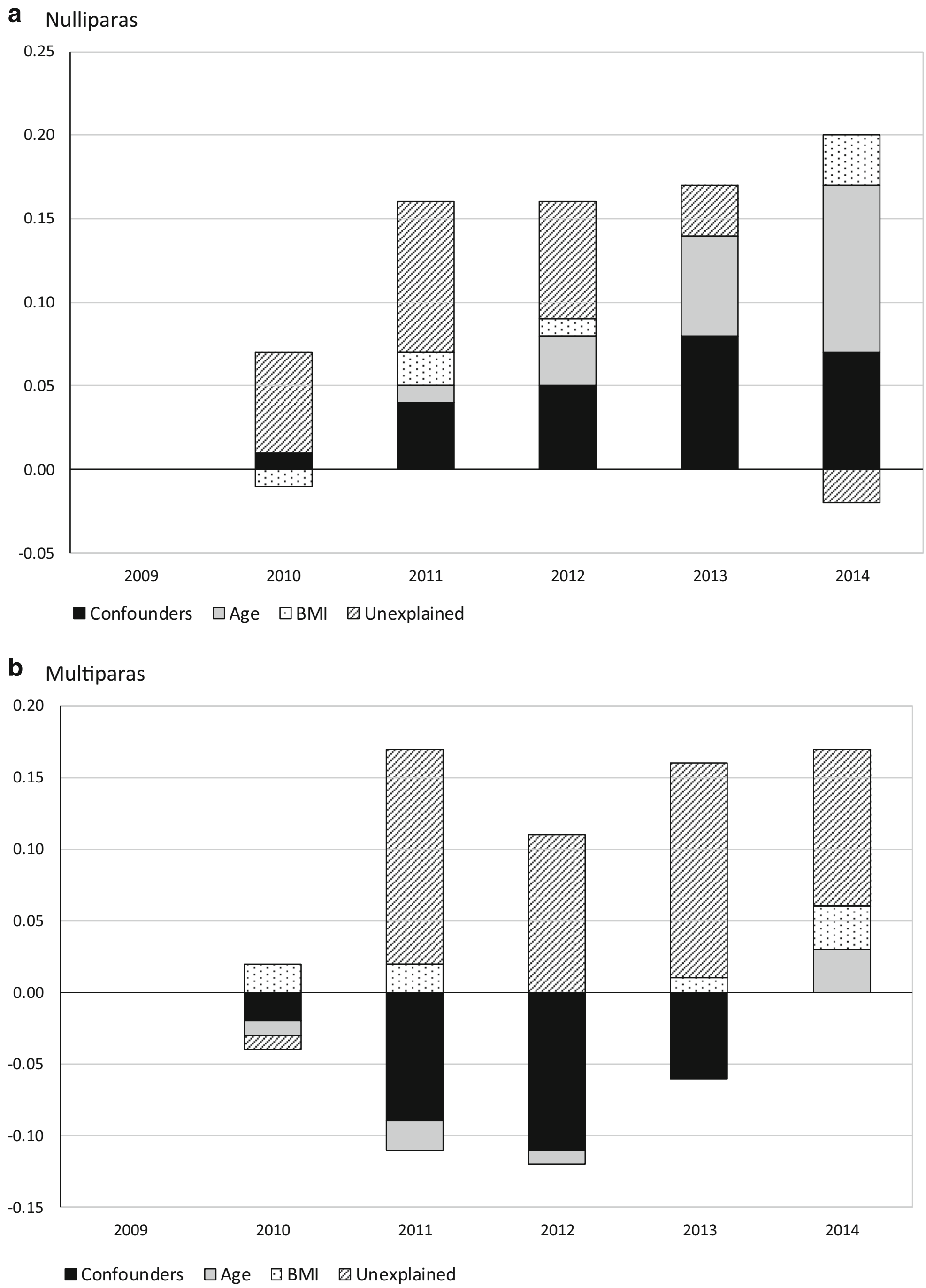

Fig. 3 Effect of explanatory variables on unadjusted year trend in CS 2009–2014

a major contributor to differences in emergency CS across models of care but the datasets employed did not contain information on maternal BMI [25]. This hospital-level analysis confirms the importance of advancing maternal age as a driver of CS rates in contemporary obstetrics. This demographic trend is beyond our control and it is a matter for a woman's personal choice but, it does raise a number of questions. Is a public health campaign required to inform women that deferring childbirth until after 30 years of age may increase their risk of interventions such as CS? Is the increase in CS rates in older women due to deteriorating reproductive performance or it is due to a lower threshold for obstetric intervention? It also should be noted however that the strong effects observed for age in the models may be in part due the absence of clinical characteristics in existing datasets which may need to be revised.

Trends in CS rates in Ireland are representative of those in other European and OECD countries [12]. Trends in maternal BMI in Ireland cannot be compared with other developed countries because it is not customary to

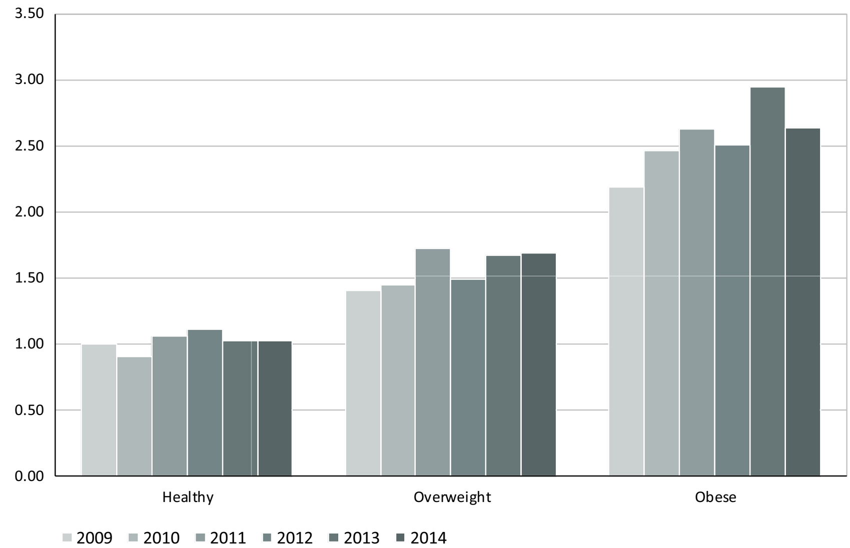

Fig. 4 Odds of CS for multiparas by year and maternal BMI category

calculate BMI based on measurement of maternal weight and height in early pregnancy. However, our findings suggest that maternal obesity is not a strong driver for CS rates continuing to escalate and that advancing maternal age in nulliparas and a previous CS in multiparas are likely stronger drivers in the current escalation [23].

Conclusion

This study found that although the prevalence of being overweight or obese changed little between 2009 and 2014, the odds of an obese woman having a CS have increased for multiparas. Increasing CS rates were found to be associated with an increase in maternal age which is important because the evidence is that women in Ireland are choosing to defer having their first baby until later in life. Women need to be made aware that deferring childbirth until after 30 years of age increases their risk of CS, whether they are obese or not.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical statement Ethical approval for this study was obtained from the Coombe Women and Infants University Hospital Ethics Committee upon submission of a written application. As the study involved collection of anonymised data, patient consent was not required following Committee review.

Abbreviations *CS*, Caesarean section *BMI* Body Mass Index *GDM* Gestational Diabetes Mellitus

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