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MATERNAL-FETAL MEDICINE

Risk of adverse pregnancy outcomes by pre-pregnancy Body Mass Index among Italian population: a retrospective population-based cohort study on 27,807 deliveries

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Abstract

Purpose To estimate the impact of increasing pre-pregnancy Body Mass Index (BMI) on the risk of adverse maternal and perinatal outcomes, in patients who delivered in an Italian tertiary care Obstetric department.

Methods Data, related to women who delivered at Sant'Anna Hospital, Turin, between 2011 and 2015, were collected retrospectively from the hospital database. According to BMI, women were considered as normal weight, overweight, and class 1, 2 and 3 obese (WHO criteria). Logistic regression analysis studied the impact of BMI on maternal and neonatal outcomes, adjusting results for maternal age and parity. Adjusted absolute risks of each outcome were reported according to incremental values in pre-pregnancy BMI.

Results A total of 27,807 women were included. 75.8% of pregnancies occurred among normal-weight women, whereas 16.7% were overweight, and 7.5% obese women (5.4% class 1, 1.7% class 2 and 0.4% class 3). A 10% decrease in pre-pregnancy BMI was associated with a reduction of at least 15% of Gestational diabetes mellitus (GDM), preeclampsia, maternal admission to intensive care unit (ICU), macrosomia, APGAR 5′ < 6 and neonatal admission to ICU. GDM and preeclampsia resulted in the highest reduction being almost 30%. Larger differences in BMI (20–25%) corresponded to at least a 10% in reduction of risk of preterm and very preterm delivery and emergency cesarean section. Differences in maternal pre-pregnancy BMI had no impact on the frequency of shoulder dystocia and stillbirth.

Conclusions This study offers a quantitative estimation of negative impact of pre-pregnancy obesity on the most common pregnancy and perinatal complications.

Keywords Pre-pregnancy BMI · Obesity · Logistic regression · Risk of adverse outcomes

Introduction

Over the past three decades, the prevalence of overweight and obesity has been increasing dramatically worldwide [1–3].

This trend has involved also women in reproductive-age and pregnant women [4–6]. In the United States, 12–38% of pregnant women are overweight, whereas 11–40% are obese, while in the UK, 33% of pregnant women are overweight or obese [7]. Whereas Italy is the European country with the lowest prevalence of adult obesity (9.8%), the proportion of obese women in reproductive age (25–44 years) has been reported as 18% [8, 9]. Several studies addressed the influence of maternal pre-pregnancy weight on pregnancy outcome: obesity can cause complications both for the woman and her offspring. Maternal risks include gestational diabetes (GDM), gestational hypertension and preeclampsia (PE), infectious morbidity, post-partum hemorrhage (PPH), macrosomia (LGA) [10–12], preterm delivery (PTD < 37 weeks gestational age), and very preterm delivery (VPTD < 32 weeks gestational age) [13, 14]. Fetuses of obese mothers are at increased risk of stillbirth [13–15] and congenital anomalies [12, 16]. Furthermore,

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intra-partum care, normal and operative deliveries, cesarean section, anesthetic and operative interventions in obese women demand extra care and extra costs [10, 11]. Besides, maternal obesity may impact on long-term offspring's risk of metabolic disease [17].

The National Institute of Health (NIH) advises that a 10% reduction (achievable in 6 months of therapy) in body weight is associated with significant health benefits, in non-pregnant obese individuals [18]. Until then, the potential benefits of pre-pregnancy weight reduction on maternal and perinatal outcomes have not been studied properly. Indeed, the most extensive studies were focused on the management of weight gain during pregnancy, showing limited advantages of such an approach [19, 20].

The aim of the present study was to examine pregnancy outcomes in obese and overweight North-Italian women, and evaluate the adjusted risk of adverse maternal and neonatal outcomes as a function of increasing pre-pregnancy BMI. We also aimed to provide useful results to clinicians to calculate risk reductions associated with lowering of pre-pregnancy BMI.

Materials and methods

Study design

A retrospective population-based cohort study was conducted on 30,853 women giving birth to a singleton baby, over a period of 5 years.

Setting

All women admitted to Obstetrics departments of Sant'Anna Hospital in Turin, Italy, a tertiary referral hospital for antenatal care, from January 1st, 2011 to December 31st, 2015, were included in the study. Data were extracted from a database which was updated prospectively, using the software TrakCare (Informative Sanitary System used by the National Health System), and from Hospital Discharge Folders (SDO).

Eligibility criteria

All women with single pregnancies who had delivered between 23 + 1 and 42 + 0 weeks of gestational age were included.

Exclusion criteria

Patients with incorrect data registration and women whose BMI was not computable or whose pre-pregnancy BMI was < 18.5 kg/m^2 were excluded. Pregnancies complicated by pre-existing diabetes and/or hypertension, were also excluded.

BMI was calculated from self-reported pre-pregnancy weight and height, obtained at the first antenatal visit. All women were categorized according to pre-pregnancy BMI following WHO guidelines: normal weight women (BMI 18.5–24.99 kg/m^2), overweight women (BMI 25.00–29.99 kg/m^2), class 1 obese women (BMI 30–35 kg/m^2), class 2 obese women (BMI 35–40 kg/m^2) and class 3 obese women (BMI 40 or higher kg/m^2) [21].

Overweight and obese women were compared with normal weight women for all considered outcomes. Maternal and neonatal complications during pregnancy and delivery were classified according to the International Classification of Diseases 10th Revision (Inter class diseases) [22].

Outcomes

The following maternal outcomes were considered: (1) preeclampsia (PE), (2) gestational diabetes mellitus (GDM), (3) induction of labor, (4) cesarean section after failure of induction, (5) elective cesarean delivery, (6) emergency cesarean delivery, (7) post-partum hemorrhage (PPH), defined as more than 1000 mL of postpartum blood loss, (8) maternal admission to the intensive care unit (ICU), (9) pre-term and very preterm delivery (PTD < 37 weeks and VPTD < 32 weeks).

The following neonatal outcomes were considered: (10) shoulder dystocia, (11) small for gestational age (SGA) infants, defined as birthweight < 10th percentile for gestational age, (12) large for gestational (LGA) infants, defined as birthweight > 90th percentile for gestational age, (13) neonatal distress, defined as APGAR score < 7 at 5 min after birth, (14) congenital malformations, (15) admission to the neonatal intensive care unit (NICU), (16) stillbirth, defined as an APGAR score =0 five min after birth.

Statistics

The statistical approach aimed at providing a direct estimation of risks for each outcome of interest, stratified for each unit of BMI, as described by Shummers et al. [23].

Univariable analysis

The potential relationship between pre-pregnancy BMI and maternal and neonatal outcomes was explored in a crude analysis according to WHO-BMI category. For each outcome of interest, a χ^2-test and a likelihood ratio test comparing a null logistic regression model with a model with a single quantitative variable (pre-pregnancy BMI) were performed.

Multivariable analysis

Logistic regression models were used to estimate the effect of increasing BMI on the most relevant outcomes, adjusting for maternal age and parity.

After performing each logistic regression analysis, the predicted risks and 95% confidence interval (95% CI) [risk=odds/(1 + odds)] at each BMI level were estimated. For those outcomes with a significant association with BMI adjusted risks (and 95% CI) were presented at the population average values of confounders (maternal age and parity) to represent the average risk of each outcome. Because of the small number of cases, the patients with a BMI > 40 were grouped together. For all analyses, a p value < 0.005 was considered significant.

Ethical approval

The study was carried out following the ethical rules of the hospital. Informed consent for using clinical data was given to each patient during hospital intake, before data were entered in a dedicated database. All data were treated as confidential.

Results

Out of 30,853 pregnancies, 2368 were excluded for incomplete follow-up. Pregnancies affected by pre-existing diabetes and/or hypertension (1.3% and 0.9% respectively) were also excluded. Therefore, the final study population included 27,807 pregnancies. Most pregnancies (75.8%) occurred among normal-weight women, whereas 16.7% occurred among overweight women, and 7.5% among obese women (5.4% in class 1, 1.7% in class 2 and 0.4% in class 3 obesity).

The demographic and clinical characteristics of the women included in the study, according to BMI category, are presented in Table 1.

Univariable analysis

The absolute risks of both maternal and neonatal complications are reported for each BMI subgroup in Table 2.

In the crude analysis, increasing BMI categories were associated with an increased proportion of pregnancies complicated by PE, GDM, cesarean section after failure of induction, elective cesarean section, emergency cesarean section, maternal ICU, PTD, VPTD and PPH. Shoulder dystocia and maternal mortality or severe maternal morbidity did not differ between BMI categories.

For what concerns neonatal outcomes, increasing BMI categories corresponded to increasing rates of LGA infants, APGAR score at 5′ < 7 and NICU admissions. In our population, shoulder dystocia and stillbirth incidences did not differ according to pre-pregnancy BMI.

Multivariable analysis

All the outcomes were directly associated with BMI and maternal age. PE, maternal ICU, APGAR 5′ < 7, NICU admission and emergency cesarean section were more

Table 1 Maternal and neonatal demographic and clinical characteristics according to prepregnancy Body Mass Index

Variables	All N = 27,807	Pre-pregnancy Body Mass Index				
		18.50–24.99 N = 21,079 (75.8%)	25.00–29.99 N = 4653 (16.7%)	30.00–34.99 N = 1492 (5.4%)	35.00–39.99 N = 459 (1.7%)	≥ 40 N = 124 (0.4%)
Age (years)	33.4 ± 5.40	33.3 ± 5.40	33.4 ± 5.51	33.4 ± 5.20	33.6 ± 5.34	33.9 ± 4.80
Nulliparous (%)	52.0	54.9	44.4	40.2	41.0	34.7
Congenital anomalies at 20 weeks	6.2	5.9	6.5	7.6	8.9	5.6
Gestational age at delivery (weeks)	38.6 ± 2.05	38.6 ± 2.00	38.5 ± 2.18	383.± 2.27	382 ± 2.20	37.7 ± 2.48
Neonatal weight (g)	3189 ± 544	3177 ± 526	3230 ± 590	3220 ± 602	3210 ± 620	3240 ± 699
Neonatal weight (z-score)	− 0.007 ± 0.99	− 0.06 ± 0.96	0.14 ± 1.03	0.19 ± 1.05	0.24 ± 1.03	0.52 ± 1.15
APGAR 5′	9 (1–10)	9 (1–10)	9 (1–10)	9 (2–10)	9 (4–10)	9 (1–10)

Table 2 Absolute risks (%) of adverse maternal and perinatal outcomes according to prepregnancy Body Mass Index category

Variables	All $N = 27{,}807$	Pre-pregnancy Body Mass Index				
		18.50–24.99 $N = 21{,}079$ (75.8%)	25.00–29.99 $N = 4653$ (16.7%)	30.00–34.99 $N = 1492$ (5.4%)	35.00–39.99 $N = 459$ (1.7%)	≥ 40 $N = 124$ (0.4%)
PE	2.4	1.8	3.6	5.3	6.1	15.3
GMD	8.3	5.4	13.6	21.8	29.4	47.6
Vaginal delivery	72.7	75.1	67.5	61.9	54.5	51.6
Induction of labor[a]	19.9	18.2	22.5	30.0	32.9	37.1
Cesarean section after failure of induction[a]	2.0	1.7	2.5	4.2	5.2	6.4
Elective cesarean section	27.3	24.9	32.5	38.1	45.5	48.4
Emergency cesarean section[a]	7.9	7.7	8.9	7.8	8.0	12.1
PPH	2.4	2.3	2.3	4.2	3.6	3.0
Maternal ICU	1.8	1.6	2.1	2.9	2.2	8.1
PTD < 37[a]	18.1	16.2	18.5	22.7	23.0	34.0
PTD < 32[a]	1.6	1.4	2.1	2.3	1.6	3.6
Shoulder dystocia[a]	0.4	0.4	0.3	0.5	0.4	0.0
Neonatal outcome						
SGA	9.2	9.5	8.4	7.9	6.6	5.6
LGA	9.5	8.2	12.5	14.5	16.2	25.0
APGAR5′ < 7	2.4	2.2	3.1	3.6	4.4	4.8
NICU	3.8	3.3	4.8	5.4	5.9	7.3
Stillbirth	0.3	0.3	0.6	0.4	0.2	0.0

PE preeclampsia, *GDM* gestational diabetes mellitus, *PPH* post-partum hemorrhage (> 1000 mL), *Maternal ICU* maternal admission in intensive care unit, *PTD* preterm delivery (< 37 weeks), *VPTD* very preterm delivery (< 32 weeks), *SGA* small for gestational age, *LGA* large for gestational age, *APGAR 5′ < 7* APGAR at 5′ min < 7, *NICU* neonatal intensive care unit admission

[a]Analyses restricted to 20,206 cases of vaginal delivery

frequently detected in nulliparae, while GDM, PPH, LGA, VPTD and PTD were more frequent in multiparous.

Table 3 quantifies the risks, adjusted for age and parity, of adverse maternal and perinatal outcomes according to pre-pregnancy BMI (with 95% CI). The following pregnancy outcomes were analyzed: PE, GDM, maternal ICU, PPH, LGA infants, APGAR 5′ < 7 and neonatal NICU admission. A sub-analysis of 20,206 pregnancies, not including elective cesarean sections, VPTD, PTD and emergency cesarean section, showed significant correlations with pre-pregnancy BMI.

Figure 1 shows the mean proportions of risk reduction (expressed as percentage) for each adverse outcome corresponding to a 10% decrease in pre-pregnancy BMI. A 10% difference in pre-pregnancy BMI was associated with reduction of at least 15% of GDM, PE, maternal ICU admission, LGA, APGAR 5′ < 6 and NICU admission risk. GDM and PE, in particular, resulted in the highest difference being almost 30%, instead PPH resulted in a 10% risk reduction.

Larger differences in BMI (20–25%) corresponded approximately to 10% reduction in the risk of VPTD, PTD and emergency cesarean section.

Table 4 reports the number needed to "treat" assuming as "treatment" a 10% reduction in pre-pregnancy BMI. As an example, 35 and 51 women should be "treated" with a 10% reduction in BMI, to prevent one case of PE, considering basal BMI of 40 and 36, respectively.

Discussion

This study shows that overweight and obesity affects respectively 16.7% and 7.5% of women who gave birth at Sant'Anna Hospital, a tertiary care University hospital in Turin. These data in pregnant women are in line with the prevalence of female overweight and obesity in the Piedmont Region, as reported by the Italian Statistic Agency (ISTAT) [24].

As far as we know, this is the first report in a sample of Italian population regarding the association between pre-pregnancy BMI and the risk of several negative obstetric outcomes, including PE, GDM, LGA infants, emergency cesarean delivery, maternal ICU admission, NICU admission, PTD and VPTD. In general, our findings are consistent

Table 3 Adjusted risk of each outcome according to pre-pregnancy BMI (with 95% confidence intervals (CI)

BMI	PE			GDM			LGA			PPH		
	Mean (95% CI)			Mean (95% CI)			Mean (95% CI)			Mean (95% CI)		
19	1.27	**1.47**	1.71	3.73	**4.07**	4.44	6.46	**6.98**	7.53	1.77	**2.07**	2.43
20	1.41	**1.63**	1.88	4.30	**4.68**	5.08	6.88	**7.39**	7.95	1.85	**2.15**	2.50
21	1.56	**1.79**	2.05	4.95	**5.35**	5.79	7.41	**7.93**	8.49	1.93	**2.23**	2.57
22	1.72	**1.96**	2.25	5.62	**6.06**	6.53	7.88	**8.42**	8.99	2.00	**2.30**	2.65
23	1.89	**2.16**	2.46	6.47	**6.95**	7.47	8.46	**9.01**	9.59	2.09	**2.39**	2.74
24	2.07	**2.35**	2.68	7.37	**7.90**	8.47	9.08	**9.65**	10.27	2.16	**2.47**	2.83
25	2.24	**2.54**	2.89	8.36	**8.95**	9.58	9.74	**10.36**	11.01	2.21	**2.54**	2.92
26	2.49	**2.82**	3.21	9.51	**10.16**	10.86	10.32	**10.97**	11.66	2.30	**2.64**	3.04
27	2.68	**3.05**	3.48	10.56	**11.29**	12.07	10.97	**11.68**	12.44	2.34	**2.71**	3.15
28	2.95	**3.36**	3.84	11.93	**12.77**	13.66	11.63	**12.41**	13.24	2.41	**2.82**	3.28
29	3.34	**3.82**	4.37	13.61	**14.57**	15.59	12.02	**12.87**	13.78	2.51	**2.96**	3.48
30	3.51	**4.04**	4.64	15.25	**16.34**	17.49	13.14	**14.09**	15.10	2.55	**3.02**	3.59
31	3.88	**4.48**	5.18	16.77	**18.01**	19.32	13.67	**14.72**	15.84	2.61	**3.13**	3.76
32	4.30	**4.99**	5.80	19.05	**20.49**	22.01	14.33	**15.50**	16.74	2.70	**3.28**	3.98
33	4.63	**5.42**	6.34	21.07	**22.70**	24.43	15.03	**16.33**	17.72	2.75	**3.38**	4.16
34	5.19	**6.11**	7.19	22.60	**24.42**	26.34	15.37	**16.78**	18.30	2.81	**3.51**	4.37
35	5.89	**6.97**	8.23	25.69	**27.78**	29.97	15.91	**17.45**	19.11	2.94	**3.71**	4.67
36	6.54	**7.81**	9.30	28.82	**31.19**	33.66	16.62	**18.32**	20.16	3.04	**3.89**	4.97
37	6.54	**7.89**	9.49	31.53	**34.15**	36.86	18.42	**20.36**	22.46	3.02	**3.93**	5.09
38	7.34	**8.91**	10.78	32.20	**35.00**	37.92	18.11	**20.15**	22.36	3.07	**4.04**	5.32
39	8.21	**10.02**	12.17	36.12	**39.20**	42.38	18.99	**21.21**	23.60	3.19	**4.26**	5.67
40	8.64	**10.65**	13.06	38.97	**42.32**	45.74	20.39	**22.86**	25.53	3.21	**4.36**	5.90
> 40	11.98	**15.20**	19.04	51.71	**55.60**	59.41	24.17	**27.47**	31.04	3.52	**5.07**	7.26

BMI	Maternal ICU			APGAR 5′ < 7			NICU		
	Mean (95% CI)			Mean (95% CI)			Mean (95% CI)		
19	1.12	**1.33**	1.58	1.67	**1.94**	2.25	2.67	**3.02**	3.40
20	1.20	**1.42**	1.68	1.77	**2.04**	2.35	2.83	**3.16**	3.55
21	1.29	**1.51**	1.77	1.87	**2.14**	2.45	2.97	**3.31**	3.69
22	1.37	**1.59**	1.86	1.97	**2.25**	2.56	3.12	**3.46**	3.85
23	1.46	**1.70**	1.98	2.07	**2.36**	2.68	3.28	**3.63**	4.02
24	1.55	**1.80**	2.09	2.17	**2.47**	2.80	3.43	**3.79**	4.20
25	1.63	**1.89**	2.20	2.26	**2.57**	2.92	3.57	**3.96**	4.38
26	1.74	**2.02**	2.35	2.38	**2.71**	3.08	3.74	**4.15**	4.60
27	1.80	**2.10**	2.45	2.47	**2.82**	3.23	3.88	**4.32**	4.81
28	1.90	**2.24**	2.63	2.58	**2.97**	3.41	4.04	**4.52**	5.06
29	2.05	**2.43**	2.87	2.74	**3.16**	3.66	4.25	**4.78**	5.37
30	2.13	**2.53**	3.01	2.80	**3.26**	3.80	4.39	**4.96**	5.60
31	2.22	**2.67**	3.21	2.93	**3.44**	4.04	4.55	**5.19**	5.90
32	2.38	**2.89**	3.50	3.07	**3.64**	4.31	4.76	**5.46**	6.27
33	2.47	**3.03**	3.72	3.18	**3.81**	4.57	4.93	**5.70**	6.60
34	2.56	**3.17**	3.94	3.33	**4.04**	4.89	5.11	**5.97**	6.96
35	2.79	**3.51**	4.40	3.53	**4.32**	5.27	5.37	**6.33**	7.44
36	3.01	**3.83**	4.86	3.70	**4.58**	5.66	5.61	**6.67**	7.92
37	3.04	**3.92**	5.05	3.70	**4.65**	5.81	5.71	**6.86**	8.22
38	3.01	**3.95**	5.15	3.90	**4.94**	6.25	5.89	**7.14**	8.64
39	3.28	**4.34**	5.73	4.10	**5.25**	6.71	6.17	**7.55**	9.20
40	3.39	**4.56**	6.09	4.18	**5.43**	7.04	6.33	**7.83**	9.65

Table 3 (continued)

BMI	Maternal ICU			APGAR 5′ < 7			NICU		
	Mean (95% CI)			Mean (95% CI)			Mean (95% CI)		
> 40	4.18	**5.93**	8.36	4.84	**6.61**	8.98	7.30	**9.38**	11.99
BMI	VPTD[a]			PTD[a]			Emergency CS[a]		
	Mean (95% CI)			Mean (95% CI)			Mean (95% CI)		
19	0.75	**0.98**	1.29	11.56	**12.39**	13.28	6.94	**7.48**	8.07
20	0.78	**1.02**	1.32	11.91	**12.72**	13.57	7.13	**7.65**	8.20
21	0.82	**1.04**	1.34	12.33	**13.12**	13.94	7.19	**7.69**	8.22
22	0.85	**1.08**	1.37	12.68	**13.47**	14.29	7.33	**7.82**	8.35
23	0.88	**1.11**	1.41	13.10	**13.88**	14.71	7.37	**7.86**	8.39
24	0.90	**1.14**	1.44	13.51	**14.31**	15.15	7.41	**7.91**	8.44
25	0.92	**1.17**	1.50	13.86	**14.71**	15.59	7.37	**7.88**	8.43
26	0.95	**1.21**	1.56	14.27	**15.16**	16.10	7.48	**8.01**	8.58
27	0.95	**1.24**	1.62	14.52	**15.48**	16.50	7.47	**8.04**	8.66
28	0.97	**1.29**	1.70	14.88	**15.92**	17.01	7.59	**8.20**	8.86
29	1.01	**1.35**	1.82	15.15	**16.28**	17.49	7.88	**8.55**	9.28
30	1.00	**1.37**	1.88	15.67	**16.90**	18.22	7.55	**8.24**	8.99
31	1.01	**1.41**	1.97	15.90	**17.25**	18.68	7.81	**8.58**	9.40
32	1.02	**1.46**	2.10	16.28	**17.76**	19.34	8.04	**8.88**	9.80
33	1.04	**1.54**	2.27	16.50	**18.12**	19.86	7.97	**8.86**	9.84
34	1.05	**1.59**	2.40	16.67	**18.41**	20.29	8.40	**9.40**	10.51
35	1.06	**1.64**	2.55	17.20	**19.10**	21.15	8.61	**9.69**	10.89
36	1.10	**1.75**	2.78	17.67	**19.75**	22.00	8.83	**10.01**	11.33
37	1.06	**1.75**	2.86	17.81	**20.03**	22.46	8.34	**9.54**	10.89
38	1.11	**1.87**	3.13	17.72	**20.05**	22.60	9.12	**10.49**	12.04
39	1.11	**1.92**	3.32	18.39	**20.94**	23.74	9.21	**10.66**	12.31
40	1.13	**2.01**	3.55	18.31	**20.98**	23.92	8.98	**10.49**	12.23
> 40	1.11	**2.22**	4.44	20.21	**23.60**	27.36	9.36	**11.26**	13.49

PE preeclampsia, *GDM* gestational diabetes mellitus, *LGA* large for gestational age, *PPH* post-partum hemorrhage (> 1000 mL), Mat*ernal ICU* maternal admission in intensive care unit, *APGAR 5′ < 7* APGAR at 5′ min < 7, *NICU* neonatal intensive care unit admission, *VPTD* very preterm delivery (< 32 weeks), *PTD* preterm delivery (< 37 weeks), *Emergency CS* emergency cesarean section

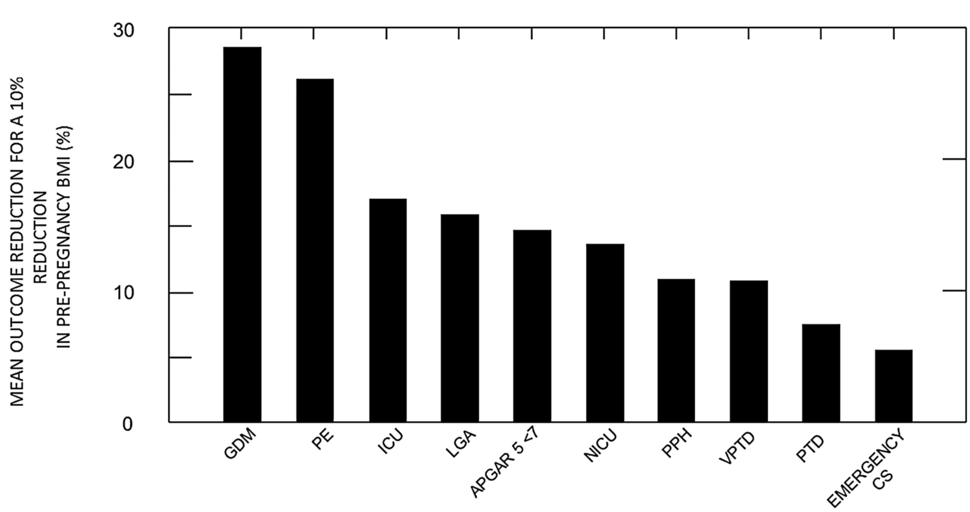

Fig. 1 Mean different percentage probability estimated for each outcome of interest according to a 10% BMI reduction. *GDM* gestational diabetes mellitus, *PE* preeclampsia, *ICU* maternal admission in intensive care unit, *LGA* large for gestational age, *APGAR 5′ < 7* APGAR at 5′ min < 7, *NICU* neonatal intensive care unit admission, *PPH* post-partum hemorrhage (> 1000 mL), *VPTD* very preterm delivery (< 32 weeks), *PTD* preterm delivery (< 37 weeks), *emergency CS* emergency cesarean section

Table 4 Number needed to "treat" for a 10% reduction in Body Mass Index (BMI) to prevent one case of the outcome

	From BMI 40 to 36	From BMI 35 to 32
Outcome		
PE	35.21	50.51
GDM	8.98	13.72
LGA	22.03	51.28
PPH	212.77	230.41
Maternal ICU	136.99	161.29
APGAR 5′ < 7	117.65	147.06
NICU	86.21	114.94
VPTD	384.62	555.56
PTD	81.30	74.63
Emergency CS	208.33	123.46

PE preeclampsia, *GDM* gestational diabetes mellitus, *LGA* large for gestational age, *PPH* post-partum hemorrhage (> 1000 mL), *Maternal ICU* maternal admission in intensive care unit, *APGAR 5′ < 7* APGAR at 5′ min < 6, *NICU* neonatal intensive care unit admission, *VPTD* very preterm delivery (< 32 weeks), *PTD* preterm delivery (< 37 weeks), *Emergency CS* emergency cesarean section

with those reported in previous studies, carried out on other populations [7, 11, 25, 26].

According to the crude analysis performed in BMI subcategories, VPTD and PPH seemed to have a less significant association with BMI in this large series of patients. As a matter of fact, the literature is not univocal on this aspect [13, 23]. Whereas some studies [27–29] found an association between obesity and PPH, mainly attributable to atonic uterus, others [23, 30, 31] failed to find any effect of BMI. Among the potential explanation for such conflicting results, different criteria for PPH definition (either blood loss > 500 mL or > 1000 mL, and/or PPH requiring intervention) could be advocated.

In contrast with many previous reports [31, 32], but in line with several studies [33, 34], we found a constant rate of shoulder dystocia across the BMI sub-groups. Several explanations could exist for these discordance, including the increased systematic use of ultrasonography to detect macrosomia and interventions, such as preterm induction of labor or cesarean delivery. The management of pregnancy in a tertiary referral hospital, as in this case, could indeed explain the low incidence of this severe complication, hence the lack of any correlation with BMI.

The present investigation was prompted by the study by Schummers et al. performed on a North American population. The Italian population is quite different from North American and Canadian in the prevalence of overweight and obesity [3, 35–37]. Furthermore, large differences exist in dietary habits and diet composition; in particular, compared with the American/North European diet, the Mediterranean dietary pattern is lower in red meats and saturated fatty acid and higher in olive oil and seafood, with high amounts of monounsaturated and polyunsaturated fatty acids [38].

We are aware that counseling about the clinical meaningful reduction is hard and challenging outcome and we believe, in accordance with Shummers, that incidence expressed as "risk" instead of "odds ratio" could be very useful for clinical counseling aimed to quantify benefits on health, deriving from weight loss. Additionally, we also reported a simple bar chart (Fig. 1) that describes the mean percentage reduction for each outcome considered for a 10% restriction of pre-pregnancy BMI. GMD and PE resulted in the highest reduction of their incidence followed by ICU admission and LGA. For these diseases, a 10% in BMI reduction would result in at least a 15–20% reduction of disease. For VPTD and emergency cesarean section, to reach a similar result, a BMI shifting of at least 15–20% is instead necessary.

Finally, as secondary results, we also provide information about the number of people to "treat" to prevent one case of the diseases here analyzed, at least in the Italian population.

Limit of the study

Since this is not a longitudinal study we cannot conclude that the inter-woman difference in BMI is clinically equivalent to the intra-woman BMI loss. No data about race have been available even if the racial composition of North Italy is 75.80% Caucasian with a much lower rate of black women in respect with UK and US population.

The pre-pregnancy BMI estimation is quite often self-managed and not performed by a healthcare professional, therefore, a bias of under or overestimation of unknown degree is expected. For women that culturally adopt pounds and feet and inches units, a higher possible degree of mistakes is also possible in the conversion to kilograms and centimeters.

Obese and overweight women investigated in this study were rather multiparous than nulliparous: previous pregnancies, in fact, may cause a weight-gain and specifically, women who were overweight and obese before pregnancy, are two to six times more likely to exceed the weight gain recommendations during pregnancy [39, 40]. Higher weight gain increases the risk of post-partum weight retention even in normal pre-pregnancy BMI women [41].

Strength of the study

This cohort study offers a tool for the physician to counsel more properly obese patients. The risks estimation is much more clinically useful than odds ratio and the use of quantitative BMI improves the clinical applicability. Moreover, information about the "number to treat" and the rate of risk reduction at a given BMI loss is a further message of encouragement for patients who want to deal with a pregnancy.

In conclusion, our study provides, for the first time, in a sample of Italian population, reference values of quantitative pre-pregnancy BMI and risks for the most common maternal and neonatal outcomes, focusing the attention on the importance of maternal weight loss in preventing pathological outcomes of the pregnancy and perinatal age. We acknowledge that similar recent studies with same or higher number of cases have been performed in other Countries including Puerto Rico [42] France [43] and China [44].

Authors contributions BM: protocol/project development, data collection. VF: protocol/project development, data collection. CG: protocol/project development, data collection, manuscript writing. RA: protocol/project development, manuscript writing. GG: data collection, manuscript writing, data analysis. AL: data collection, data analysis, manuscript writing. AR: Protocol/project development, data collection, manuscript writing. CP: protocol/project development, data collection. EB: data collection, manuscript writing. AY: data collection, manuscript writing. TT: protocol/project development, manuscript writing. AF: protocol/project development, data collection, manuscript writing, data analysis.

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Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The committee for this study is Dr. Bianca Masturzo.

Informed consent Informed consent was obtained from all individual participants included in the study.

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