

1. Title Page

Trends in Maternal Obesity Incidence Rates, Demographic Predictors, and Health Inequalities in 36,821 Women over a 15-Year Period.

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Short Headline: Maternal Obesity Incidence, Trends, and Predictors

2. Abstract

Objective: This study aimed to identify trends in maternal obesity incidence over time, and identify those women most at risk and potential associated health inequalities

Design: Longitudinal database study

Setting: James Cook University Hospital maternity unit, Middlesbrough, UK

Sample: 36,821 women from 1st January 1990 to 31st December 2004

Methods: Trends in maternal obesity incidence over time were analysed using CHI squared test for trend. Demographic predictor variables were analysed using multivariate logistic regression, adjusting for confounding factors after testing for multicollinearity. National census data were used to place the regional data into the context of the general population.

Main Outcome Measures: Trends in maternal obesity incidence. Demographic predictor variables included ethnic group, age, parity, marital status, employment, and socio-economic disadvantage

Results: The proportion of obese women at the start of pregnancy has increased significantly over time from 9.9% to 16.0% ($p < 0.01$). This is best described by a quadratic model ($p < 0.01$) showing that the rate is accelerating; by 2010 the rate will have increased to 22% of this population if the trend continues. There is also a significant relationship with maternal obesity and mothers' residing in areas of most deprivation (OR=2.44, 95%CI=1.98, 3.02, $p < 0.01$), with increasing age (OR=1.04, 95%CI=1.04, 1.05, $p < 0.01$), and parity (OR=1.17, 95%CI=1.12, 1.21, $p < 0.01$).

Conclusion: The incidence of maternal obesity at the start of pregnancy is increasing and accelerating. Predictors of maternal obesity are associated with health inequalities; particularly socio-economic disadvantage.

3. Main Body of Text

Introduction

The increasing prevalence of obesity in the general population is a serious public health concern in the UK. The HSE reports an increase in the prevalence of obesity among women of childbearing age¹. In addition to this the Confidential Enquiry into Maternal and Child Health (CEMACH) reported that between 1993 and 2002 obesity prevalence among women aged 25–34 years rose by 10%². This suggests that the number of women who are obese at the start of pregnancy will also be increasing, which will have an impact on maternity services in the UK. Obesity in pregnancy has serious health implications for the mother and her infant, and increases the complications throughout pregnancy and the demand placed on maternity unit resources³. The scale of maternal obesity needs to be determined in order to plan service delivery, and identify 'at risk' groups to target priority areas for interventions.

Whilst Kiran et al⁴ reported that the incidence of maternal obesity had more than doubled in Cardiff over the past 10 years, there remains a lack of English data relating to maternal obesity incidence rates and populations 'at risk'. This study provides data for the trends and incidence of maternal obesity gained from a large North East group of women tracked over 15 years. Further analyses place this dataset into the context of the national population, in addition to examining potential risk factors through the relationship between BMI and maternal age, parity, ethnic origin, marital status, employment status, and deprivation.

Methods

Data Collection

Data have been prospectively collected and electronically recorded in a large maternity unit in Middlesbrough since 1990. Maternal height and weight is recorded at the initial booking appointment from a direct measurement by midwives at GP practice bookings, with only a small proportion of self reported measurements from home booking appointments (approximately 5%, personal communication, Helen Simpson).

The data were examined for all booking appointments between January 1st 1990 and December 31st 2004. As pregnancy naturally incurs weight gain, a cut off of 16 weeks gestation at booking was used to eliminate any potential false positives of maternal overweight. The gestational age at booking was calculated by subtracting the number of days between booking and delivery from the gestational age at delivery. Dating scans have been carried out for all women since 2000; pre 2000 the dating was based on dates only, so there may be some cases where the dating is less accurate in this group. If there is a discrepancy between the dating scan and the last menstrual period date then the scan date is always used at the unit. Data were retrieved for 61,850 subjects. Exclusions were made for: 1) missing BMI data (n=8758); 2) data entry errors (n=1601, including unrealistic BMI⁵, and errors in date records); 3) booking date after 16 weeks gestation (n=8420), and 5) missing gestational age (n=6250, due to incomplete data or incomplete pregnancies). In total 36, 821 subjects remained for the analysis (population characteristics in table 1).

Data Analysis

Chi squared analysis was used to identify any significant differences between the included and excluded populations. The included study population was categorised based on their BMI at booking: lean (BMI <18.5kg/m²), ideal (BMI 18.5–24.9kg/m²), overweight (25-29.9kg/m²), and obese (BMI>30kg/m²). [BMI categories for the general population were used for this study population as there are no agreed categories for pregnant women, and we were primarily interested in trends over time]. The trends in incidence over time were calculated using the chi squared test for trend for each BMI group (ideal v non-ideal, obese v non-obese etc). Linear and nonlinear regression analysis identified the most appropriate model for these incidence trends and to predict future rates of maternal BMI.

Multivariate logistic regression analysis was used to examine predictors of BMI category at the start of pregnancy. Maternal age and parity were analysed as continuous data; the remaining data were categorical and maternal ethnic group, marital status, and employment were categorised according to the national census data. The reference data for the level of deprivation was taken from the Index of Multiple Deprivation for England⁶. The deprivation scores were assigned in quintiles where 1=most deprived, and 5= least deprived.

The statistical analyses were performed using SPSS (version 13). Chi squared analysis showed all variables to have an independent association with BMI category. Prior to deriving the final regression model the data were screened for multicollinearity using linear regression diagnostics.

The England census and IMD data were used to compare all predictor variables for women of childbearing age in Middlesbrough and England, to place the findings from this study into context with the national population.

Results

This study population mainly consisted of Caucasian women residing in the most deprived quintile 1. There were significant differences between the BMI groups for all characteristics with the exception of height.

Trends in BMI Category over Time

The crude trends for incidence of maternal BMI are illustrated in Figure 1. The rates were not adjusted for change in maternal age over time as the mean age of the samples varied less than 1 year over the 15-year period (minimum 26.49, SD 5.16; maximum 27.30, SD 6.05). The gestational age at booking also remained relatively constant over time with a difference of approximately 2 weeks between the minimum and maximum mean booking gestational age (minimum 11.16, SD 5.22, maximum 13.31, SD 6.01).

Over the 15-year period there has been a significant decrease in the incidence of women in the ideal BMI group from 64.8% in 1990 to 54.7% in 2004 (χ^2 159.13, df=1, $p<0.001$). Conversely there is a significant increase in the incidence of women in the overweight BMI group (21.5% to 25.3%, χ^2 19.01, df=1, $p<0.001$), and obesity in the

study population has risen from 9.9% in 1990 to 16.0% in 2004 (χ^2 141.36, df=1, p<0.001).

The regression analysis showed that obesity incidence is best explained by a quadratic model: Incidence = a + b*(x²) (where x is the time point in years; 1=1990 and 15=2004), with the linear term of the second order polynomial making no contribution to the model fit. This model indicates that the rate of maternal obesity is accelerating over time. If the trend that has been shown in the 15 year period is assumed to continue increasing at the same rate, then the predicted incidence of obesity in this study population will be 22% by the year 2010. This prediction is based on an assumption that the trend remains constant and does not account for saturation of high risk groups, specifically socio-economic deprivation, which would cause the accelerating rate to slow down and eventually level off at some point in the future.

The increasing incidence of maternal obesity is accelerating over time at a similar rate to that of obesity in all women of childbearing age in the general population in England, although the incidence of maternal obesity lags behind that of the general population (see figure 1).

Predictors of Obesity at the Start of Pregnancy

All variables had an independent association with BMI category and no multicollinearity; therefore all were included in the final regression model (table 2). The subjects in the

ideal BMI category were used as the reference group.¹ Following adjustment for confounding variables, the subjects in the obese group were significantly older, more parous, and residing in the more deprived quintile areas 1 to 3; this was more pronounced in the most deprived quintile 1, where women were almost two and a half times more likely to be obese at the start of pregnancy than those women living in the least deprived quintile 5. For women who were separated, divorced, widowed, or participating in education, there was significant reduction in the incidence of maternal obesity. Ethnicity was not found to have a significant association with maternal obesity, although interpretation of this data is limited due to the small sample size representing the non-Caucasian populations.

The overweight group had a significant association with residing in the two lowest quintile areas, being slightly older and slightly more parous, and less likely to be single or in education. The lean group were significantly younger, single, in education, and not in paid employment.

Excluded Population

There were statistically significant differences between the included and excluded groups for all variables except parity, where both groups had a mean parity of 1 ($p=0.46$). There was a difference in the mean age of 0.86 years ($p<0.001$), although this is not of clinical significance. Chi squared analysis showed that there was a significant

¹ The results for ethnic group used the Caucasian population as the baseline for comparison as this was the majority group (91.7% of the total cohort). The employment status and deprivation categories used paid employment and residing in the least deprived quintile (5) as baselines for comparison as they were considered to be the best social circumstance when considering health inequality issues. Being in the married group was arbitrarily chosen as the comparison group for the marital status category.

association between ethnic group and exclusion; proportionally more Caucasians were included (60.5%), while more Black (63.5%) and Asian (53.0%) subjects were excluded. The average inclusion rate relating to deprivation was 59.6%, however this relationship was not evenly distributed across all quintiles with the least deprived having an inclusion rate above average (63.1%), whereas the most deprived was the only quintile that had an inclusion rate below average (57.7%). As there is a potential association with these factors and inequality, the high exclusion rate of certain groups was further investigated. Chi squared analysis showed missing BMI data to explain the relationship with certain groups: Caucasian, and quintiles 2 to 4. A gestational age at booking of more than 16 weeks was the leading explanation for exclusion of all other ethnic groups, not being in paid employment, and being in the least or most deprived quintiles (1 and 5).

Middlesbrough and English Population

Middlesbrough contains some of the most deprived parts of England, with nearly 60% of the population living in one of the 10% most deprived wards in England⁷. As there are no national statistics on maternal BMI status at the start of pregnancy, the population of women of childbearing age in Middlesbrough was compared with the population of women of childbearing age in England. The national census data⁸ and the IMD data⁶ were used to place the results from this study into a more national context; the results are shown in Table 3. Confidence Interval analysis shows that women of childbearing age in Middlesbrough are more likely to be residing in areas of most deprivation (quintile 1, 62.2% versus 21.5% in England, $p < 0.05$), whereas the proportion residing in quintile 5 is significantly lower in Middlesbrough (1.7% versus 18.5% in England, $p < 0.05$). The Middlesbrough population also has a significantly higher than average proportion of

caucasians, and lower proportions of the remaining ethnic groups (although the difference between Asian groups is only 0.3%), more likely to be unemployed or in education, to have 3 or more dependant children, and to not be married.

Discussion

The Government has identified obesity as one of the most serious problems of the 21st century⁹. A joint report from the Audit Commission, the Healthcare Commission, and the National Audit Office suggested the cost of obesity to the NHS in England is approximately £1 billion and by 2010 the cost to the economy could be close to £3.6 billion¹⁰. Obesity is also one of the six priorities in the English White Paper Choosing Health: Making Healthy Choices Easier¹¹. In terms of maternal obesity, there is a body of evidence which suggests that the offspring of overweight and obese mothers are at increased risk of themselves becoming overweight or obese in childhood or adult hood¹², and evidence to show that pregnancy is a key stage in the life-course associated with weight gain¹³.

This study has confirmed that the incidence of maternal obesity is rising in this study population at a rate similar to that of all women of childbearing age in the general population, although the incidence of maternal obesity lags behind that of the general population. The relationship between obesity and fertility is well documented^{14 15}, and it is likely that this lag effect is primarily due to physiological factors which hinder fertility.

This study has shown that the increasing incidence of maternal obesity is accelerating, however there is a potential that this is underestimated. Women whose pregnancies

were incomplete were excluded from the study population, and the relationship with obesity, miscarriage, and late foetal death¹⁶ could potentially have resulted in the exclusion of a significant proportion of the obese women. The exclusion of women who presented after 16 weeks gestation could also have added to the underestimation of maternal obesity due to the association with irregular menstruation^{17 18}, and slight changes in weight status may not be as noticeable therefore confirmation of the pregnancy may be later in these women. There is also evidence to show that self reported weight is underestimated and height overestimated¹⁹, therefore this could have led to a further underestimation of the overweight or obese BMI groups in this study, however the majority of bookings use measured weights and heights and there has been no change in the location of booking appointments over the 15-year period studied making the variation in self reported heights and weights over time limited due to this factor. There has however been more stringent measurement of BMI by staff in the maternity unit since 2001, due to the Confidential Enquiry into Maternal Death²⁰ emphasising the need to use BMI as a risk assessment for thrombosis post delivery, this was further emphasised in 2004 in the CEMACH enquiry²; therefore there is a potential for a higher level of accuracy in the representation of BMI status following 2001.

The Health Select Committee reports that an increased prevalence of obesity in the general population is associated with health inequalities and deprivation²¹, which fully supports the findings of this study in relation to maternal obesity. There is also an association with prevalence of obesity in women in the general population and increasing age¹. The relationship with incidence of maternal obesity and increasing age following adjustment for all other confounders was highly significant in this study;

however the relationship showed only a slight increase. The relationship with increasing age and obesity in women in the general population is most significant following menopause¹, therefore the magnitude of this significant relationship is not going to be reflected in the women in this study population, and the high significance of the slight increase in odds ratio is realistic for the age group in this study population.

The results of this study show increasing parity to be a predictor of maternal obesity, published evidence supports this as the time period during and between pregnancies is shown to be a critical period in the development of obesity^{22 23 24}. Being in education had a highly significant reduced odds ratio of being obese at the start of pregnancy. The mothers who are in education are more likely to be a younger group, and the significant relationship with increasing age and obesity makes the younger group less likely to be in the obese category, however there was no collinearity between the age and education variables. Also, age as a confounder had been accounted for in the regression model; therefore this cannot explain the inverse phenomenon between this group of mothers and obesity. As this research was looking at independent demographic predictors to identify health inequalities that may have a relationship with maternal BMI status, lifestyle factors were not taken into consideration and this may have influenced the inverse relationship with obesity and mothers being in education.

There was no significant association with any of the ethnic minority groups and maternal obesity, although the numbers in this study population were relatively low, and there was a significantly increased proportion of women excluded from ethnic minority groups, particularly in the Asian and Black groups. One theory that might potentially explain why

proportionately more women from some ethnic minority groups had late booking appointments, could be related to inequalities in access to services; a theory which is supported by evidence such as that published in the House of Commons Select Committee report; Inequalities in Access to Maternity Services²⁵.

There are certain limitations when trying to quantify health inequality issues, as there is a great deal of speculation when it comes to defining data such as deprivation. The traditional categorisation of socio-economic status is outdated as it is reliant upon the occupation of the male in a household, which is unlikely to be an adequate representation in the modern day, particularly in populations that have a higher proportion of single mothers. Deprivation has been numerically categorised for the purposes of this research using area of residence as an indicator of deprivation based on the IMD, which uses postcodes to calculate deprivation based on the areas level of income deprivation, employment deprivation, health deprivation and disability, education, skills and training deprivation, barriers to housing and services, living environment deprivation, and crime. Although there is still the argument that someone living in an area of deprivation does not mean they are necessarily deprived, and also that boundaries of areas of deprivation change with time making it difficult to attribute a deprivation score to one postcode over any length of time, it was considered to be a more accurate indicator of deprivation than the household male occupation.

Conclusion

The results of this study should be comparable to other populations in England where women of childbearing age are mainly caucasian (with Asian being the highest

proportion of ethnic minority groups), have a higher than average level of deprivation, unemployment, and single mothers. The rise in maternal BMI over time in this study population is highly significant, with proportions of maternal obesity accelerating at a rate far greater than any other BMI status. The trends in incidence for the data predict that the proportion of mothers who are obese at the start of pregnancy could potentially have increased from 10% in 1990 to 22% by 2010 assuming that the trend continues, and that the proportion of mothers in the ideal BMI category could potentially have reduced from 65% in 1990 to 47% by 2010. Maternal BMI status is also shown to relate to health inequalities, particularly for women who live in the areas of the most deprivation who are almost two and a half times more likely to be obese at the start of pregnancy than women who live in areas of least deprivation. There are also potentially issues relating to inequalities within ethnic groups and access to maternity services; a theory that is supported by published evidence. The results from this study indicate serious implications both in terms of public health and service delivery. Given the concerning elevation in the incidence of maternal obesity, future research programmes aimed at preventing the continuation of this trend are imperative.

4. Ethics

This research was approved by the University of Teesside Ethics Committee, and the South Tees NHS Trust ethics and research and development committees.

5. Acknowledgements

The authors would like to thank Barbara Woodward, Women and Children's Information Manager at James Cook University Hospital for her time and help in retrieving and anonymising the data for analysis, Sue Walrond and Meg Newark at the NEPHO for assistance in providing the census and IMD data, and medical statistician Vicki Whittaker for her assistance in the CHI squared trend data analysis.

6. Competing Interests

The North East Public Health Observatory and the University of Teesside provided the funding for this study; there are no competing interests from any of the authors or organisations involved.

7. Contribution to Authorship

The authors contributing to the design of the study were NH, CS, JW, and LE. The statistical analysis was conducted by NH and AB. All authors contributed to paper writing.

8. Duplicate Publications The results from this piece of research have not been published elsewhere in a peer reviewed journal.

9. References

1. Department of Health. Health Survey for England 2003: HMSO: London, 2003.
2. Confidential Enquiry into Maternal and Child Health. Why mothers die 2000-2002: RCOG:London, 2004.
3. North East Public Health Observatory. OP22: Maternal Obesity and Pregnancy Outcome: A Scoping Study: <http://www.nepho.org.uk/>, 2006.
4. Kiran TSU, Hemmadi, S., Bethal, J., Evans, J. Outcome of pregnancy in a woman with an increased body mass index. *BJOG* 2005;112:768–772.
5. Henry CJK. Body mass index and the limits of human survival. *Eur J Clin Nutr* 1990;44:329-335.
6. Index of Multiple Deprivation IMD. The English Indices of Deprivation: Office of the Deputy Prime Minister, 2000.
7. Department of the Environment Transport and the Regions (DETR). Measuring Multiple Deprivation at the Small Area Level: The Indices of Deprivation 2000. In: Department of the Environment Transport and the Regions, editor, 2000.
8. Census. Standard Tables: ST001 Age by Sex and Marital Status, ST028 Sex and Age by Economic Activity, ST101 Sex and Age by Ethnic Group, ST007 Age of FRP (Family Reference Person) and Number and Age of Dependent Children by Family Type. Office of National Statistics, 2001.
9. South East Public Health Observatory. Choosing Health in the South East: Obesity, 2005.
10. Comptroller and Auditor General. Tackling Childhood Obesity - The First Steps. London: The Stationary Office, 2006.
11. Department of Health. Delivering Choosing Health: Making Healthier Choices Easier. London: Department of Health, 2005.
12. Parsons TJ, Power, C., Logan, S., Summerbell, C. D. Childhood predictors of adult obesity: a systematic review. [Review] [283 refs]. *Int J Obes Relat Metab Disord* 1999;23 Suppl 12:S1-S107.
13. National Institute of Health and Clinical Excellence. Obesity Consultation. <http://www.nice.org.uk/> 2006.
14. Clark AM, Ledger W, Galletly C, et al. Weight loss results in significant improvement in pregnancy and ovulation rates in anovulatory obese women. *Hum Reprod* 1995;10(10):2705.
15. Wang JX, Davies MJ, Norman RJ. Obesity increases the risk of spontaneous abortion during infertility treatment. *Obes Res* 2002;10(6):551.
16. Lashen H, Fear K, Sturdee DW. Obesity is associated with increased risk of first trimester and recurrent miscarriage: matched case-control study. *Hum Reprod* 2004;19(7):1644.
17. Lake JK, Power C, Cole TJ. Women's reproductive health: the role of body mass index in early and adult life. *Int J Obes Relat Metab Disord* 1997;21(6):432.
18. Linne Y. Effects of Obesity on Women's Reproduction and Complications During Pregnancy. *Obes Rev* 2004;5:137-143.
19. Engstrom JL, Paterson, S.A., Doherty, A., Trabulsi, M., Speer, K.L. Accuracy of Self-Reported Height and Weight in Women: An Integrative Review of the Literature. *J Midwifery Womens Health* 2003;48(5):338-345.
20. Confidential Enquiry into Maternal Deaths. Why Mothers Die 1997-1999: RCOG: London, 2001.

21. Health Committee. Obesity - Third report of session 2003-2004, Volume 1, HC 23.1: HMSO: London, 2004.
22. Gore SA, Brown, D.M., Smith West, D. The role of postpartum weight retention in obesity among women: A review of the evidence. *Annals Behaviour Med* 2003;26(2):149-159.
23. Siega-Riz AM, Evenson, K.R., Dole, N. Pregnancy-related weight gain - a link to obesity? *Nutr Rev* 2004;62(7):S105-111.
24. Gunderson EP, Abrams, B. Epidemiology of Gestational Weight Gain and Body Weight Changes After Pregnancy. *Epidemiol Rev* 2000;22(2):261-274.
25. House of Commons Health Committee. Inequalities in Access to Maternity Services. London: The Stationary Office, 2003.

10. Table / Figure Caption List

Figure 1: Incidence of Maternal Obesity in 36,821 Women Over a 15-year Period, the Projected Incidence of Maternal Obesity by 2010, and the Prevalence of Obesity in Women of Childbearing Age (16-44 years) in England's General Population

Table 1: Study Population Characteristics

Table 2: Adjusted Logistic Regression Results

Table 3: Characteristics of Women of Childbearing Age in Middlesbrough and England