Journal of Public Health | Vol. 39, No. 3, pp. 514–522 | doi:10.1093/pubmed/fdw098 | Advance Access Publication September 9, 2016

Ethnic differences in the clustering and outcomes of health behaviours during pregnancy: results from the Born in Bradford cohort

E.S. Petherick[1], L. Fairley[2], R.C. Parslow[2], R. McEachan[3], D. Tuffnell[4], K.E. Pickett[5,6], D. Leon[7], D.A. Lawlor[8], J. Wright[3]

[1]School of Sport, Exercise & Health Sciences, University of Loughborough, Loughborough, UK
[2]Division of Epidemiology, University of Leeds, Leeds, UK
[3]Born in Bradford, Bradford Institute for Health Research, Bradford Royal Infirmary, Bradford, UK
[4]Bradford Teaching Hospitals NHS Foundation Trust, Bradford BD9 6RJ, UK
[5]Department of Health Sciences, University of York, Heslington, UK
[6]Hull York Medical School, University of York, Heslington, UK
[7]Department of Non-Communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, UK
[8]MRC Centre for Causal Analyses in Translational Epidemiology, School of Social and Community Medicine, University of Bristol, Bristol, UK
Address correspondence to ES Petherick, E-mail: e.petherick@lboro.ac.uk

ABSTRACT

Background Pregnancy is a time of optimal motivation for many women to make positive behavioural changes. We aim to describe pregnant women with similar patterns of self-reported health behaviours and examine associations with birth outcomes.

Methods We examined the clustering of multiple health behaviours during pregnancy in the Born in Bradford cohort, including smoking physical inactivity, vitamin d supplementation and exposure to second-hand smoke.

Latent class analysis was used to identify groups of individuals with similar patterns of health behaviours separately for White British (WB) and Pakistani mothers. Multinomial regression was then used to examine the association between group membership and birth outcomes, which included preterm birth and mean birthweight.

Results For WB mothers, offspring of those in the 'Unhealthiest' group had lower mean birthweight than those in the 'Mostly healthy but inactive' class, although no association was observed for preterm birth. For Pakistani mothers, group membership was not associated with birthweight differences, although the odds of preterm birth was higher in 'Inactive smokers' compared to the 'Mostly healthy but inactive' group.

Conclusions The use of latent class methods provides important information about the clustering of health behaviours which can be used to target population segments requiring behaviour change interventions considering multiple risk factors. Given the dominant negative association of smoking with the birth outcomes investigated, latent class groupings of other health behaviours may not confer additional risk information for these outcomes.

Introduction

Making positive changes to health behaviours during pregnancy have dual benefits for the health of both the mother and the child, making it a key time for behaviour change interventions. There are strong social pressures for pregnant women to behave in healthy ways and many women do make positive behavioural changes when pregnant. Findings from the Southampton Women's study showed that 27% of women smoked prior to pregnancy decreasing to 15% in

E.S. Petherick, Lecturer in Epidemiology and Biostatistics
L. Fairley, Statistician
R.C. Parslow, Senior Lecturer in Epidemiology
R. McEachan, Programme Manager
D. Tuffnell, Consultant in Obstetrics and Gynaecology
K.E. Pickett, Professor of Epidemiology
D. Leon, Professor of Epidemiology
D.A. Lawlor, Professor of Epidemiology
J. Wright, Director in Bradford Institute for Health Research

early pregnancy,[1] although few studies have looked at how behaviours change together during pregnancy.[1,2]

Health promotion and disease prevention rely on behaviour change by individuals which are ideally informed by theories of behaviour change.[3] However, the majority of behaviour change models are applied to single behaviours, for example, quitting smoking or increasing physical activity.[4,5] Noar *et al.* argue that studies of single behaviours essentially remove the behaviour from the context of multiple behaviours in which they take place.[6] This raises the question about how individuals change multiple health behaviours, and whether the changes occur sequentially or simultaneously. This was further highlighted in the recent report from the policy think tank the Kings Fund which concluded that 'Less is known about how these behaviours cluster together in the population and how these differ between different population groups'.[7] Multiple behaviour interventions have been defined by Prochaska *et al.* as 'efforts to promote two or more health behaviours'.[8]

There are two aims of this study. First is to determine whether there are subgroups of pregnant women with unique clusters of health behaviours during pregnancy. Second is to examine if pregnant women's membership of these different clusters of behavioural risk factors is associated with offspring birthweight and risk of preterm birth.

Methods

Study population

Born in Bradford (BiB) is a longitudinal multi-ethnic birth cohort study aiming to examine the impact of environmental, psychological and genetic factors on maternal and child health and wellbeing.[9] Bradford is a city in the North of England with high levels of socio-economic deprivation and ethnic diversity. Women were recruited at the Bradford Royal Infirmary at 26–28 weeks gestation. For those consenting, a baseline questionnaire was completed, which was then linked to maternity data from the hospital to obtain birth outcomes. The full BiB cohort recruited 12 453 women comprising 13 776 pregnancies between 2007 and 2010 and the cohort is broadly characteristic of the city's maternal population. Ethical approval for this study was granted by Bradford Research Ethics Committee (Ref 07/H1302/112).

Study inclusion and exclusion criteria

Pregnant women completing either Phase 2 or 3 of the baseline questionnaire (completed between the dates of September 2007 to December 2010, $N = 9620$) with complete data available for the health behaviours examined and ethnic group who had a live singleton birth with linked birth outcome data were eligible for inclusion in this study. If women had more than one study enrolment over the study period, only their first pregnancy and resulting offspring data were included in order to ensure that multiple dependent observations did not influence results. All covariable and health behaviour data were collected at the time of baseline questionnaire data collection, at 26–28 weeks pregnancy, unless otherwise stated. All data on pregnancy related covariables and outcomes were obtained from the electronic maternity record system or maternity notes if not available electronically.

Complete data on covariables for Latent Class Aanalysis are not required as these models utilize all data under a full maximum likelihood approach.[10,11] For all covariable adjustment models complete case analysis only was performed.

Health behaviours

Health behaviours evaluated included smoking in the 3 months prior to pregnancy, in the first 3 months of pregnancy, from the fourth month of pregnancy onwards, exposed to passive smoking, taking vitamin D supplements and inactivity (defined as inactive if scored 0 or 1 on the General Practice Physical Activity questions).[12] All health behaviour variables were examined as binary (yes versus no) variables, with yes used as the reference category. The full description of the definitions of health behaviours and rationale for their inclusion can be found in Table S1.

Ethnic classification

Ethnicity of the mothers was based on their self-report on the baseline questionnaire and was grouped as White British (WB), Pakistani or Other. Other ethnic groups were not able to be included in these analyses as due to cultural and behavioural heterogeneity.[13]

Birth outcomes

The two birth outcomes examined were birthweight and preterm delivery (PTD), which were obtained from the hospitals electronic maternity records system or from the mothers maternity notes if not available electronically. PTD was defined as birth before gestational week 37 + 0. Gestational length defined as length of gestation in weeks, which was based on last menstrual period date confirmed by dating ultrasound conducted at 12 weeks gestation. If there were <7 days difference between these two dates the last menstrual period date was used for the estimated date of delivery, otherwise the ultrasound dating scan was used.

Covariables for adjustment

We selected covariables known to be associated with the outcomes of interest and/or hypothesized to be associated with probability of latent class membership. These included booking BMI (Body mass index) collected from maternity records (underweight <18.5, normal ≥18.5–24.9, overweight ≥25–29.9 or obese ≥30), maternal age (<21 years, 21–35 years, >35 years), parity (0,1,2,3+), marker of acculturation (born in the UK or migrated to the UK aged five or less versus migrated to the UK aged >5 years), father UK born (yes versus no), maternal employment status (currently worked, ever worked or never worked), marital status (married, single or divorced/widowed), highest level of maternal and paternal education (<5 General Certificate of Secondary Education (GCSEs) qualification, 5 GCSEs ('standard minimum level of education when leaving school'), A level equivalent ('highest qualification in high school'), higher than A level ('diploma or degree level qualification'), other, do not know), housing status (mortgage, owns with no mortgage, rents it, lives here rent free or other) in receipt of means tested benefits (yes versus no), subjectively poor (yes versus no), English Index of Multiple Deprivation 2010 quintile of residence and consanguinity (in consanguineous relationship versus not in consanguineous relationship) defined according to Sheridan *et al.*[14] Means tested benefits were defined as being in receipt of income support, income tested job seekers allowance, working families tax credit or housing benefit[15] and subjectively poor if women responded that they were finding it hard to get by or they were finding it very hard to get by financially versus reporting that they were living comfortably, doing alright or just about getting by.

For birth outcomes we further adjusted for offspring gender, route of birth (vaginal versus caesarean), gestational and pre-existing diabetes, pregnancy induced hypertension (defined as a blood pressure >140/90 measured at two or more periods at least 6 hours apart) and pre-eclampsia (defined as proteinuria (+0.3 gms with blood pressure ≥140/90 after 20 weeks of pregnancy on more than one occasion)). Additionally for birthweight, further adjustment was made for length of gestation in weeks.

Statistical methods

As our previous analyses have highlighted,[2,16] health behaviours differed between cohort participants of different ethnic backgrounds we decided *apriori* to stratify analyses and explore the consistency of overall latent class groups amongst two of our largest participating ethnic groups, the WB and Pakistani women.

Latent class analyses were used to explore the number of distinct classes of women undertaking different self-reported health behaviours during pregnancy using the statistical package Mplus 6 (Muthén & Muthén, Los Angeles, CA). This statistical method creates a classification of individuals into groups based on conditional probabilities as within each class individuals will have a similar pattern of response.[17] A two stage approach was used, the first stage determined the optimal number of classes by evaluating best fit model fit using multiple indices including Akaikes Information Crtierion, Bayesian Information Criterion, entropy and likelihood ratio test using bootstrapping as well as assessing the face validity and meaningfulness of the resultant classes, testing out models that considered between one and nine latent class groups. The second stage of the modelling process, to determine the relationship between covariables, (as listed above) and the latent class groups, was conducted using probability weighted multinomial logistic regression, calculating relative risk ratios using Stata SE 13.1 (Stata Corporation, College Station, TX). We used the 'runmplus' command to export data from Stata to MPlus.[18] Finally, the relationship between latent class membership and birthweight was evaluated using probability weighted linear regression analyses and the relationship between latent class membership and preterm birth evaluated using probability weighted logistic regression.

Results

Of the total population of 9620 women, 8693 (90.4%) women were eligible for inclusion in the study, the baseline characteristics of the included population can be found in Table S2. The numbers of included and excluded participants are shown in Fig. 1 below.

The three most commonly reported negative health behaviours reported by all participants were not taking Vitamin D supplements (79.1%) inactivity (58.4%) and exposure to second-hand smoke (33.3%). Lower rates of exposure were reported for smoking in the 3 months prior to pregnancy (21.2%). Consumption of cigarettes was shown to decline throughout pregnancy from their pre pregnancy values. (Full details of all reported health behaviours and the ethnic differences between these can be found in Table S3).

Models were created to consider between one and eight latent classes of behavioural subgroups. The final model chosen, after consideration of the statistical model fit parameters and the interpretability of the results, was the model with four classes for the WB and three classes for the Pakistani groups, with a brief description of the classes provided in Table 1. The predicted probabilities of individual health behaviours within each latent class group are shown

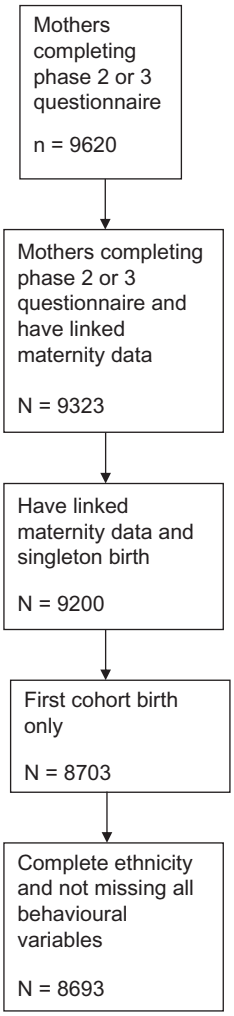

Fig. 1 Flow chart of study participation.

below in Fig. 2 for the WB group and Fig. 3 for the Pakistani group.

A total of 3477 WB women were included in the analysis and the four latent class groups named (WB1) 'Non smoke exposed smokers' (1.4%, $n = 50$), (WB2) 'Unhealthiest' (33.9%, $n = 1179$), (WB3) 'Mostly healthy but inactive' (43.9%, $n = 1525$) and (WB4) 'Smoked exposed and inactive' (20.7%, $n = 723$). Figure 2 below shows the probability of undertaking health behaviours within each latent class group for WB women.

A total of 3855 Pakistani women were included in the analysis examining the clustering of maternal health behaviours. The three groups based on most likely latent class membership were named (P1) 'Inactive smokers' (3.9%, $n = 148$), (P2) 'Smoke exposed and inactive' (3.7%, $n = 144$) and (P3) 'Mostly healthy but inactive' (92.5%, 3586). Figure 3 below shows the probability of undertaking health behaviours within each latent class group for Pakistani women.

Shown in Supplementary Tables S4 and S5 are the multivariate relationships associated with latent class membership with the (WB3) 'Mostly healthy but inactive' or the (P3) 'mostly healthy but inactive' used as reference groups for the WB and the Pakistani women, respectively. In summary, it was observed that clustering of multiple unhealthy behaviours were more consistently observed for women who were unmarried and had lower indicators of socio-economic status including lower education. The full details of the association between Covariables and latent class membership can be found in the supplementary material.

Birth outcomes

Results for birthweight

Compared to those in the healthiest WB class, 'Mostly healthy but inactive' (WB3) group, women in all other latent class groupings were shown to give birth to babies with lower mean birthweight. This difference only remained statistically significantly lower in the 'Unhealthiest' (WB2) group after adjustment for pregnancy and other socio-demographic factors demonstrating a difference in birthweight of −242 grams (95% confidence interval (CI) −290.5 to −193.6 grams). For the Pakistani mothers, those in the 'Inactive smokers' (P1) and the 'Smoked exposed and inactive' (P2) showed a statistically significant relationships of lower mean birthweight compared to mothers in the reference category of the 'Mostly healthy but inactive' class. After mutual adjustment for birth related factors and then full adjustment for covariates this negative relationship with birthweight was attenuated and no longer statistically significant (full results shown below in Table 2).

Results for preterm birth

For WB mothers, no particular class membership was shown to be statistically significantly associated with preterm birth, although odds ratios were shown to be elevated in the WB2 'Unhealthiest' group both before and after adjustment for covariables. For the Pakistani mothers membership of class one, P1 'Inactive smokers' class was associated with a higher odds of preterm birth compared to the reference 'Mostly healthy but inactive' class. In contrast mothers who were members of the 'Smoked exposed and inactive' P2 class showed no statistically significant difference in odds of preterm births either before or adjustment for covariables (full results are shown in Table 3 below).

Table 1 Description of health behaviour by most likely latent class grouping

Class	*Size of class,* N *(%)*	*Description*
WB women		
1 Non smoke exposed smokers (WB1)	50 (1.4)	Smoking before and during pregnancy Least likely to be inactive Unlikely to take vitamin D supplement during pregnancy
2 Most unhealthy (WB2)	1179 (33.9)	Very likely to be smoking before and during pregnancy Likely to be exposed to second-hand smoke Highest levels of inactivity Highest levels of not taking vitamin D supplements during pregnancy
3 Mostly healthy but inactive (WB3)	1525 (43.9)	Unlikely to take vitamin D supplement during pregnancy Fairly likely to be inactive Not likely to smoke or be exposed to smoke
4 Smoke exposed and inactive (WB4)	723 (20.7)	Highly likely to be exposed to smoke but not to smoke themselves Highly likely to be inactive
Pakistani women		
1 Inactive smokers (P1)	148 (3.8)	Very likely to be smoking both before and during pregnancy Less likely to be exposed to smoking Highly likely to be inactive Very unlikely to be taking vitamin D
2 Smoke exposed and inactive (P2)	2829 (72.9)	Most likely to be exposed to second-hand smoke Quite likely to be inactive Very unlikely to be taking vitamin D
3 Mostly healthy but inactive (P3)	902 (23.3)	Most likely to be inactive Very unlikely to be taking vitamin D Small probability of smoke exposure Non smokers

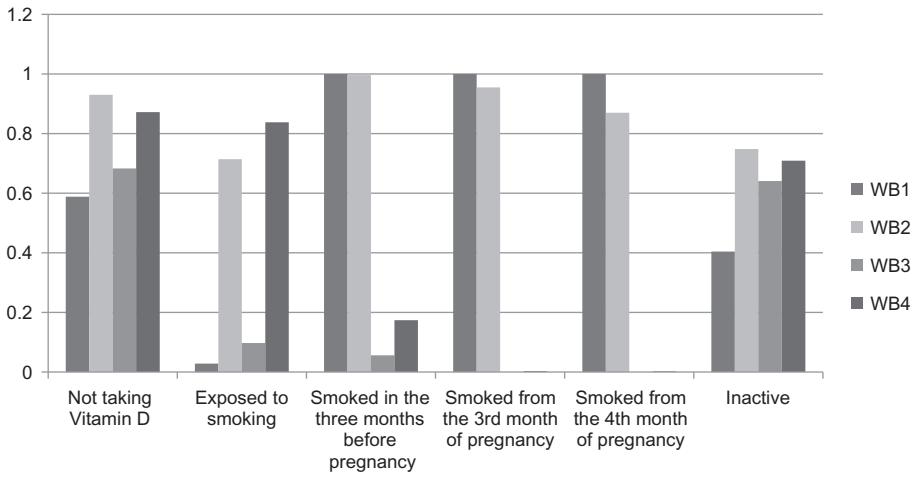

Fig. 2 Posterior probabilities of health behaviours by latent class group, WB.

Discussion

Main findings

Women of different ethnic backgrounds reported different health behaviours during pregnancy, with Pakistani mothers less likely to smoke but more likely than their WB peers to be physically inactive (76% versus 42%). Despite these compositional differences in health behaviours by ethnicity, women that were most likely to undertake multiple negative health behaviours were more likely to be unmarried, and

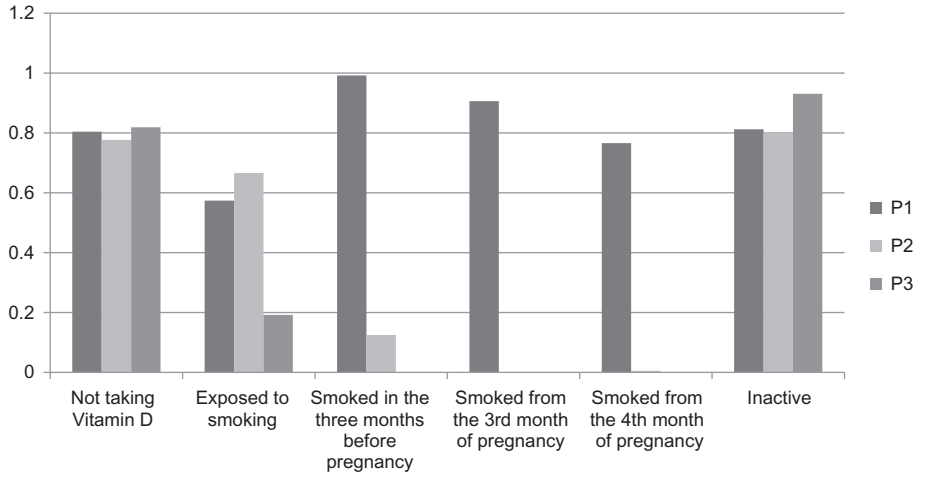

Fig. 3 Posterior probabilities of health behaviours by latent class group, Pakistani.

Table 2 Relationship between latent class group and mean birthweight (grams)

	Unadjusted (Mean difference, 95% C.I.)	*Adjusted*[a] (Mean difference, 95% C.I.)	*Adjusted*[b] (Mean difference, 95% C.I.)
Latent class group			
WB			
1 Non smoke exposed smokers (WB1)	−74.9 (−200.7, 50.9)	−112.3 (−217.9, −6.6)*	−67.2 (−192.3, 57.9)
2 Most unhealthy (WB2)	−273.4 (−315.4, −231.4)****	−255.4 (−290.5, −220.2)***	−242.0 (−290.5, −193.6)**
3 Mostly healthy but inactive (WB3)	ref.	ref.	ref.
4 Smoke exposed and inactive (WB4)	−44.5 (−94.4, 5.3)	−45.6 (−87.0, 4.3)	−31.2 (−82.1, 19.8)
Pakistani			
1 Smokers (P1)	−99.8 (−186.3, −13.3)	−53.9 (−128.2, 20.5)	−47.0 (−135.9, 41.9)
2 Smoked exposed and inactive (P2)	−17.2 (−72.2, 37.9)	−15.2 (−61.9, 31.5)	6.6 (−48.7, 61.8)
3 Mostly healthy but inactive (P3)	ref.	ref.	ref.

[a]Birth related factors comprising type of delivery (vaginal versus caesarean), babies sex, gestational diabetes, hypertensive disorders of pregnancy, length of gestation and parity.

[b]As above plus marital and cohabitation status, mother education, father education, IMD 2010, means tested benefits, housing tenure, booking BMI, subjective poverty, consanguinity.

*$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$, ****$P \leq 0.0001$.

have lower levels of education irrespective of ethnic background. For Pakistani mothers, later age at migration, being in a consanguineous union and non-participation in the workforce were all shown to reduce the risk of partaking in multiple negative health behaviours.

WB who were members of the 'Unhealthiest' WB2 group, had lighter babies than their healthier peers. For Pakistani mothers no association was observed between health behaviour group membership and resultant birthweight of offspring. Preterm birth was shown be associated with membership of the 'Inactive smokers' P1 class for Pakistani mothers only.

What is already known

Our results are consistent with previous research findings showing that women who continue to smoke throughout pregnancy have a more adverse socio-demographic profile as evidenced by the higher risk of being in the unhealthiest behavioural classes for each ethnic group, 'Unhealthiest' or the 'Inactive smokers' for the WB and Pakistani mothers, respectively.[19,20] These results provide further evidence of the insidious relationship between social disadvantage and negative health behaviours, finding that given similar social circumstances, ethnic differences in health behaviours diminish, particularly for smoking, concurring with earlier findings

Table 3 Relationship between latent class grouping and odds of preterm birth

	Unadjusted (OR 95% CI)	*Adjusted[a] (OR 95% CI)*	*Adjusted[b] (OR 95% CI)*
Latent class group			
WB			
1 Non smoke exposed smokers (WB1)	0.89 (0.30, 2.66)	0.95 (0.30, 3.00)	0.84 (0.26–2.75)
2 Most unhealthy (WB2)	1.45 (1.05, 1.99)*	1.67 (1.20, 2.36)**	1.45 (0.96–2.18)
3 Mostly healthy but inactive (WB3)	1	1	1
4 Smoke exposed and inactive (WB4)	1.07 (0.72, 1.61)	1.16 (0.76–1.78)	0.99 (0.62–1.58)
Pakistani			
1 Smokers (P1)	2.27 (1.33–3.89)	2.53 (1.42–4.50)	2.63 (1.43–4.80)
2 Smoked exposed and inactive (P2)	0.91 (0.55–1.49)	0.88 (0.52–1.50)	0.80 (0.46–1.41)
3 Mostly healthy but inactive (p3)	1	1	1

[a]Birth related factors comprising type of delivery (vaginal vs caesarean), babies sex, gestational diabetes, hypertensive disorders of pregnancy, consanguinity and parity.

[b]As above plus marital and cohabitation status, mother education, father education, IMD 2010, means tested benefits, housing tenure, booking BMI and subjective poverty.

*$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$, ****$P \leq 0.0001$.

from studies conducted in UK and Scottish multi-ethnic samples.[21,22] Our results are consistent with earlier findings showing acculturation of health behaviours of ethnic minority groups and some protective health behaviours in consanguineous women.[23] Our findings of higher rates of inactivity in Pakistani mothers during pregnancy have previously been confirmed in studies that have objectively measured physical activity.[24] However, in contrast to previous results our findings do not show strong relationships with negative health behaviours and area level deprivation.[25–27] Our cohort is however highly geographically clustered in the most deprived areas, with over 84% of the cohort living in the two most deprived IMD 2010 quintiles nationally. We therefore may have not observed a social gradient in health behaviours should one exist. Our findings linking negative health behaviours to birthweight reductions in the WB groups are consistent with previous research findings.[28] Our findings, not showing an association between smoking and preterm birth in the WB group and birthweight in the Pakistani group, must be interpreted with caution. Although we have adjusted for BMI in our models of preterm birth there is some evidence that women with overweight or obese BMIs may have a reduced risk of preterm birth, which in our cohort were more likely to be WB than Pakistani.[29] Furthermore, previous research has shown that offspring of consanguineous couples, who were more likely to be in the 'healthy but inactive' group of Pakistani origin, may have lower birthweight compared to non-consanguineous offspring which may confound birthweight differences by smoking status, particularly as consanguineous mothers are much less likely to report smoking compared with their non-consanguineous Pakistani contemporaries.[23,30]

Limitations

The results of this study are based on self-reported health behaviours of pregnant women which may underestimate health behaviours, as women may fail to report behaviours deemed to be socially unacceptable. Although we have been able to evaluate the clustering of many health behaviours that impact on pregnancy we have not been able to adjust for all behaviours, notably we do not have data to evaluate the influence of diet during pregnancy.

What this study adds

This study shows that health behaviours do cluster during pregnancy, although the composition of clusters varies according to social, cultural and ethnic background of mothers. Despite compositional differences in the health behaviour clusters, this work confirms the insidious relationship between negative health behaviours and low social support, with mothers of both ethnic groups who were single at the time of study registration had the highest probability of engaging in multiple negative health behaviours compared to those that were married. This study confirms that many recommendations produced by bodies such as NICE, particularly regarding intake of vitamin D and exercise have very low uptake and may particularly impact on Pakistani women who are known to be at particular risk for vitamin D

deficiency and gestational diabetes which may confer additional health risks both to themselves and their offspring beyond those evaluated in this study.[31,32] We also found that behavioural clusters may also predict some negative birth outcomes, although smoking is likely the dominant behavioural risk factor linked to the birth outcomes investigated.

This study has demonstrated that social patterning of health behaviours occurs during pregnancy, although not necessarily in the same direction or with the same behaviours for different ethnic groups, clearly necessitating culturally appropriate behaviour change programmes to be implemented in this population.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

Acknowledgements

Born in Bradford is only possible because of the enthusiasm and commitment of the children and parents in BiB. We are grateful to all the participants, health professionals and researchers who have made Born in Bradford happen.

Funding

BiB receives core infrastructure funding from the Wellcome Trust (WT101597MA).

References

1 Crozier SR, Robinson SM, Borland SE *et al*. Do women change their health behaviours in pregnancy? Findings from the Southampton Women's Survey. *Paediatr Perinat Epidemiol* 2009;**23**:446–53. doi:10.1111/j.1365-3016.2009.01036.x.

2 Cooper DL, Petherick ES, Wright J. Lifestyle related risk factors in a multi-ethnic cohort of pregnant women: preliminary results from the Born in Bradford study. *Public Health* 2013;**127**:1034–7. doi:10.1016/j.puhe.2013.07.009.

3 NICE. Behaviour change: the principles for effective interventions. National Institute for Health and Care Excellence 2007.

4 Norman P, Conner M, Bell R. The theory of planned behavior and smoking cessation. *Health Psychol* 1999;**18**:89–94.

5 Hashim HA, Jawis MN, Wahat A *et al*. Children's exercise behavior: the moderating role of habit processes within the theory of planned behavior. *Psychol Health Med* 2014;**19**:335–43. doi:10.1080/13548506.2013.808751.

6 Noar SM, Chabot M, Zimmerman RS. Applying health behavior theory to multiple behavior change: considerations and approaches. *Prev Med (Baltim)* 2008;**46**:275–80. doi:10.1016/j.ypmed.2007.08.001.

7 Buck D, Frosini F. Clustering of unhealthy behaviours over time. 2012.

8 Prochaska JJ, Spring B, Nigg CR. Multiple health behavior change research: an introduction and overview. *Prev Med* 2008;**46**:181–8. doi:10.1016/j.ypmed.2008.02.001.

9 Wright J, Small N, Raynor P *et al*. Cohort profile: the born in bradford multi-ethnic family cohort study. *Int J Epidemiol* 2013;**42**:978–91. doi:10.1093/ije/dys112.

10 Acock AC. Working with missing values. *J Marriage Fam* 2005;**67**:1012–28. doi:10.1111/j.1741-3737.2005.00191.x.

11 Enders CK. A primer on maximum likelihood algorithms available for use with missing data. *Struct Equ Model A Multidiscip J* 2001;**8**:128–41. doi:10.1207/S15328007SEM0801_7.

12 Department of Health. The General Practice Physical Activity Questionnaire (GPPAQ). 2009.

13 Dziak JJ, Lanza ST, Tan X. Effect size, statistical power and sample size requirements for the bootstrap likelihood ratio test in latent class analysis. *Struct Equ Modeling* 2014;**21**:534–52. doi:10.1080/10705511.2014.919819.

14 Sheridan E, Wright J, Small N *et al*. Risk factors for congenital anomaly in a multiethnic birth cohort: an analysis of the Born in Bradford study. *Lancet* 2013;**382**:1350–9. doi:10.1016/S0140-6736(13)61132-0.

15 Bradshaw J, Holmes J, Percy A. Family poverty assessed at three years old. Centre for Longitudinal Studies, Institute of Education, University of London 2008.

16 West J, Lawlor DA, Fairley L *et al*. Differences in socioeconomic position, lifestyle and health-related pregnancy characteristics between Pakistani and White British women in the Born in Bradford prospective cohort study: the influence of the woman's, her partner's and their parents' place. *BMJ Open* 2014;**4**:e004805. doi:10.1136/bmjopen-2014-004805.

17 Hagenaars J, McCtcheeon A *Applied Latent Class Analysis*. Cambridge: Cambridge University Press, 2002.

18 Jones R. RUNMPLUS: Stata module to run Mplus from Stata. 2010.

19 Graham H, Hawkins SS, Law C. Lifecourse influences on women's smoking before, during and after pregnancy. *Soc Sci Med* 2010;**70**:582–7. doi:10.1016/j.socscimed.2009.10.041.

20 Pickett KE, Wilkinson RG, Wakschlag LS. The psychosocial context of pregnancy smoking and quitting in the Millennium Cohort Study. *J Epidemiol Community Health* 2009;**63**:474–80. doi:10.1136/jech.2008.082594.

21 Bansal N, Chalmers JWT, Fischbacher CM *et al*. Ethnicity and first birth: age, smoking, delivery, gestation, weight and feeding: Scottish Health and Ethnicity Linkage Study. *Eur J Public Health* 2014;**24**:911–6. doi:10.1093/eurpub/cku059.

22 Hawkins SS, Lamb K, Cole TJ *et al*. Influence of moving to the UK on maternal health behaviours: prospective cohort study. *BMJ* 2008;**336**:1052–5. doi:10.1136/bmj.39532.688877.25.

23 Bhopal RS, Petherick ES, Wright J *et al*. Potential social, economic and general health benefits of consanguineous marriage: results from the Born in Bradford cohort study. *Eur J Public Health* 2014;**24**:862–9. doi:10.1093/eurpub/ckt166.

24 Berntsen S, Richardsen KR, Mørkrid K *et al*. Objectively recorded physical activity in early pregnancy: a multiethnic population-based study. *Scand J Med Sci Sports* 2014;**24**:594–601. doi:10.1111/sms.12034.

25 Lakshman R, McConville A, How S *et al*. Association between area-level socioeconomic deprivation and a cluster of behavioural risk factors: cross-sectional, population-based study. *J Public Health (Oxf)* 2011;**33**:234–45. doi:10.1093/pubmed/fdq072.

26 Kleinschmidt I, Hills M, Elliott P. Smoking behaviour can be predicted by neighbourhood deprivation measures. *J Epidemiol Community Health* 1995;**49(Suppl 2)**:S72–7.

27 Erskine S, Maheswaran R, Pearson T *et al*. Socioeconomic deprivation, urban-rural location and alcohol-related mortality in England and Wales. *BMC Public Health* 2010;**10**:99. doi:10.1186/1471-2458-10-99.

28 Royal College of Physicians. Passive smoking and children-a report by the Tobacco Advisory Group of the Royal College of Physicians. 2010.

29 Torloni MR, Betrán AP, Daher S *et al*. Maternal BMI and preterm birth: a systematic review of the literature with meta-analysis. *J Matern Fetal Neonatal Med* 2009;**22**:957–70. doi:10.3109/14767050903042561.

30 Abbas HA, Yunis K. The effect of consanguinity on neonatal outcomes and health. *Hum Hered* 2014;**77**:87–92. doi:10.1159/000362125.

31 Colberg SR, Castorino K, Jovanovič L. Prescribing physical activity to prevent and manage gestational diabetes. *World J Diabetes* 2013;**4**:256–62. doi:10.4239/wjd.v4.i6.256.

32 NICE. NICE guidelines Antenatal care [CG-62]. National Institute for Health and Care Excellence 2008.