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Preconception health in England: a proposal for annual reporting with core metrics.

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Background

The recent Lancet series on Preconception Health drew attention to this under-appreciated period in the life course when health, behavioural and environmental 'exposures' can have far-reaching consequences not only for pregnancy outcomes but also for health across generations [1-3]. Besides extensive media coverage, the series was discussed in the UK Government (House of Lords) debate on childhood obesity [4]. Soon afterwards, Public Health England produced a suite of resources making the case for a focus on preconception care [5]. The Preconception Partnership, a group of engaged stakeholders, convened to discuss how to translate findings into policy and practice. The Partnership proposed an 'annual report card' to describe the state of, and trends in, preconception health using routine national data sources (metrics). The report card would offer methods for continued surveillance and accountability of relevant agencies in improving the nation's preconception health. This paper describes the conceptual framework for the report, including a dual intervention strategy and a set of core metrics, with illustrated examples of how the accumulated data could best describe and monitor the national state of preconception health. Going forward, we invite suggestions for other suitable metrics to help capture the national picture.

Conceptual Framework

The conceptual framework for the annual report draws on evidence presented in the Lancet series and by Public Health England, including the mechanism whereby parental preconception 'exposures' contribute to the developmental origins of health and disease (2). It also incorporates our proposal for differing definitions of the preconception period: (1) the biological perspective (days to weeks before embryo development); the individual perspective (a conscious intention to conceive, often weeks to months before conception); and the public health perspective (months or years beforehand to address preconception risk factors such as diet and obesity).

This framework provides the basis for a dual intervention strategy operating at population level, irrespective of pregnancy planning, and at individual level for those who plan to or become pregnant. Both should work synergistically to improve health. At the level of the individual, we need to improve the identification of women or couples planning a pregnancy who would likely benefit from actions to improve health before conception. This requires reorientation of the health services and health care professionals to normalise conversations about planning for pregnancy during routine visits, e.g. for contraception, cervical screening, and for management of long term conditions such as diabetes. Since plans to conceive may not be disclosed spontaneously to health care professionals, we need to heighten awareness, among healthcare providers and the public alike, of the importance of optimising preconception health. The Preconception Partnership endorses the need for

services across this critical period of the life course to dovetail with those preceding and following, to provide a continuum of support and care [6-8].

At population level, a wider, parallel strategy is required to reduce preconception risk factors, irrespective of pregnancy planning. Key to this is recognising the importance of the wider determinants of health - poverty, education, employment and support networks - on preconception risk factors, framing preconception health as a collective agenda to reduce social inequalities in health and supporting individuals in developing health awareness. This calls for effective engagement with not only health care providers, but social care providers, social support networks, carers, educators, and policy-makers. We must also engage in advocacy for the necessary resources to promote preconception health through public and private actors. Strategies need to be tailored for different stages in the life course (3): i) children and adolescents; ii) adults with no current intention to become pregnant, and iii) adults intending to become pregnant (again).

Together, these strategies seek to increase preconception awareness, planning and preparation for pregnancy - related but distinct aspects of preconception health that can be captured through a variety of measures (Table 1). *Awareness* refers to recognition at any age that health before conception affects the chances of a healthy pregnancy and baby, as well as disease risk in later life. *Planning* implies a conscious intention to become pregnant in the near-to-medium future. *Preparation* means taking action to improve health before pregnancy. Neither awareness nor planning alone is likely to have much impact on preconception health (women can plan pregnancies around domestic circumstances without changing health behaviours), whereas preparation is impossible without planning and some awareness, combined with motivation and engagement.

A national intervention strategy with potential core metrics for preconception health.

In 2017 there were 679,106 live births and 2,873 stillbirths in England and Wales, and an estimated total fertility rate of 1.76 children per woman. Fertility rates in women in their thirties and forties have been increasing since the late 1970s, while the fertility rate in women under 20 has declined significantly this century. Just over half (52%) of all live births were to parents who were married or in a civil partnership [9]. Our analysis of the Maternity Services Data Set (see below) estimates that 35% of all pregnancies in England in 2017 were first pregnancies. Proposed intervention strategies to improve preconception health, with potential core metrics are listed in Table 1 and described briefly below.

Children and adolescents

For children and adolescents who are not intending to become pregnant for many years (if at all), the concept of preconception health needs to be integrated into a wider educational curriculum about healthy behaviours that also explains why health is something to consider before, rather than after, a pregnancy occurs. In addition to national datasets, such as the

National Child Measurement Programme, [10] which provides estimates of overweight and obesity levels in primary schools, organisations such as the Schools Health Education Unit [11] and the Association for Young People's Health [12] also collect or collate large scale data relevant to preconception health from government statistics, household and school surveys. The forthcoming introduction of mandatory Health Education alongside a reformed curriculum for Relationships and Sex Education in schools [13] presents an ideal opportunity to introduce the notion of optimal health before planning a future pregnancy, in addition to the more immediate concerns of avoiding unwanted consequences of sexual activity. The inspection framework of the Office for Standards in Education (Ofsted), the regulatory board for schools in England, is currently under review; this might provide an opportunity consider ways to assess the effectiveness of a school curriculum in which preconception health is integral to a broader health and wellbeing curriculum.

Food environment

Improving the food environment presents wide-ranging opportunities and challenges, from mandatory food fortification (e.g. fortifying flour with folic acid and other vitamins) and fiscal measures (such as minimum alcohol pricing and sugar sweetened beverage levy) to regulation of the food retail and food service industries (e.g. food labelling and marketing and promotions of unhealthy foods, location of supermarkets and fast food outlets). The UK Government has recently announced a consultation on mandatory folic acid fortification of flour to prevent fetal abnormalities. Over 80 countries around the world have already taken this important step and all studies have observed a subsequent decrease in prevalence of neural tube defects (NTD) [14] Data on the number of diagnoses and terminations with an NTD are available from congenital anomaly registers in the UK from which it is estimated that 2014 fewer NTD pregnancies would have occurred had folic acid fortification been implemented in 1998, as it was in the USA [15].

The priority that government and food industry place on developing an environment supportive of preconception health and nutrition could be monitored through content analyses of national and local government policy documents and publicly available information from national food retailers and manufacturers (corporate social responsibility statements and company websites). The findings from these analyses would provide an overview of the commitment and leadership of these organisations to optimising preconception health and could provide impetus for generating future action through competition [16, 17]. Progress on key environmental indicators can also be measured using national datasets. The Family Food datasets derive from the annual Living Costs and Food Survey which is conducted with approximately 5000 families in the UK and provides information on household food and eating out purchases [18]. Data from those of reproductive age could be used to monitor household purchasing and expenditure patterns, among those of childbearing years, on food categories that are markers of healthy or unhealthy preconception diet including fruit and vegetables, wholemeal versus white bread,

takeaway foods and sugar sweetened drinks. The Food environment assessment tool (Feat) provides data on the density of fast food outlets and supermarkets by local authority, and can be used to assess density by neighbourhood deprivation. [19] Fast food outlets are most prevalent in deprived neighbourhoods [20, 21] and monitoring using Feat could support local authority planning decisions to help improve preconception health among disadvantaged groups [22]. EuroMonitor data could be used to track sales of vitamin and mineral supplements, such as folic acid, recommended before conception by the NHS, as an indicator of increasing societal awareness of the importance of micronutrient sufficiency for a healthy pregnancy. If routine assessment of the healthfulness of the in-store environment of retail outlets were combined with environmental health food safety audits, then data on availability, variety and promotional activities for healthy and unhealthy foods could be examined.

Current public health strategies and surveys

The 'Improving Prevention' work stream of the Maternity Transformation Programme, led by Public Health England, places emphasis on improving the health of women before, during and after pregnancy. This work stream has targeted initiatives to, for example, increase the proportion of smoke free pregnancies, improve perinatal mental health and embed prevention throughout the maternity pathway. Since several risk factors during pregnancy, such as smoking and obesity, are already targets of public health strategies, we need to highlight the preconception period as one of special opportunity for intervention, based on evidence from life course epidemiology, developmental (embryo) programming around the time of conception and maternal motivation [1-3].

Routine surveys can provide useful data on nutrition, smoking, alcohol and other risk factors for pregnancy. For example, the UK National Diet and Nutrition Survey (NDNS) is a rolling programme that collects detailed, quantitative information on the food consumption, nutrient intake and nutritional status of the general population aged 1.5 years and over living in private households in the UK. The survey covers a representative sample of around 1000 people per year. Fieldwork began in 2008 and is now in its eleventh year; dietary information is collected using a four-day estimated (unweighed) diary. The NDNS is the only long-standing nationally representative survey of detailed dietary intake in the UK. Methods are robust, but under-reporting of nutrient intake is known to be a problem, particularly in women with higher BMI. The Health Survey for England, commissioned by NHS Digital, is another useful source. It provides nationally representative data on smoking, alcohol, BMI, physical activity and fruit and vegetable consumption, as well as biomarkers (blood pressure, cholesterol and glycated haemoglobin) from nearly 8000 people aged over 16. The latest report combines these data to assign a multiple risk score; the proportion of women with no risk behaviours was highest (17%) for women aged 25 and 44 years, while the most common combination of risks in women was low fruit and vegetable consumption with obesity [23].

The public health outcomes framework [24] includes several measures relevant to a report card on preconception health, including MMR vaccination coverage, rates of excess weight in children and adults, physical activity, smoking, consumption of fruit and vegetables, under 18 conceptions and breastfeeding.

Primary care databases

Primary care databases are another useful source of data on risk factors for pregnancy health [25] (Figure 1). The Clinical Practice Research Datalink (CPRD) contains computerised primary care records, including diagnoses, prescriptions, tests from primary care and referral data covering around 9% of the UK population. The Royal College of General Practitioners (RCGP) Research Surveillance Centre (RSC) includes over 400 practices (around 5% of the population of England) [26]. Both are long established, provide good quality data that is broadly representative of the population (UK or England respectively) and can be linked using pseudonymised NHS number to other large databases (e.g. hospital and cause of death data). The RCGP RSC is one of the oldest sentinel networks in Europe. It provides continuous feedback to practices about data quality, through visits now augmented by a dashboard. [27] Practices can collect samples, administer questionnaires and recruit to studies. While data quality is among the best in primary care, variation in completeness and accuracy of data brings limitations. [28] By contrast, no routine, consistent or reliable data on preconception health are collected in sexual and reproductive (family planning) or assisted reproduction (IVF) clinics. The arrival of the Maternity Services Dataset (below) provides a new opportunity to link data from primary care databases on individual women before conception to data from subsequent pregnancies and resulting offspring.

Maternity datasets and pregnancy planning

The NHS Digital Maternity Services Dataset (MSDS) is a new source of data which flows from all maternities in England [29]. It records individual data from the antenatal booking appointment, through scans and screening tests for fetal and maternal health, to delivery (method of delivery and birth complications) and outcome (gestational age, birthweight, stillbirth, live birth, Apgar scores, newborn examination). Content includes demographic and social factors (English as a second language, social support, complex social factors), health behaviours and lifestyle factors relevant to preparation for pregnancy (BMI, smoking, alcohol, folic acid supplementation), obstetric history (previous pregnancies and outcome), relevant medical history (asthma, epilepsy, diabetes, cardiovascular, mental health etc.) and medical complications developed during pregnancy (gestational diabetes, hypertension). The dataset provides a large national cohort (>600,000 records per year) which can in future support population surveillance of inequalities, trends over time, local and national benchmarking and international comparisons. Since the MSDS can link subsequent pregnancies in the same woman (figures 2 and 3), it will be possible to estimate birth interval and interconception weight change which are important risk factors for maternal

and child health. Linkage of the MSDS to other datasets such as Hospital Episode Statistics (including neonatal care) and Community Services Dataset (growth, nutrition, child development outcomes) for assessment of longer term health and development outcomes is in development. MSDS version 2 will replace earlier versions in April 2019 and is more flexible, lending itself to further data on preconception health such as glycated haemoglobin (HbA1c) at the booking visit. Since the MSDS carries financial incentives for compliance with data coverage and quality standards, completion rates are good (e.g. booking data 80-90% complete in 2017 with 1% missing for deprivation, 14% for ethnicity) and are expected to improve further.

The London Measure of Unplanned Pregnancy (LMUP) is a validated measure, composed of six simple questions, that scores (from 0 to 12) the extent of planning for a current or recent pregnancy [30]. The sixth question asks specifically about actions taken in preparation for pregnancy such as eating more healthily or seeking health advice. Extensive research shows that the LMUP is easy to complete and acceptable to women. It is sensitive enough to detect changes in the rate of unplanned pregnancy over time, across subgroups or following preconception intervention. It is currently being piloted in two large London maternity services with a view to inclusion in the Maternity Services Dataset that will enable national surveillance of unintended pregnancy rates, similar to the way that antenatal HIV tests are used for surveillance of HIV infection.

Data linkage and modelling

The ability to link big data across high quality datasets is particularly exciting; it brings new opportunities to track individual reproductive health trajectories - from preconception to first pregnancy, interconception and subsequent pregnancies – at scale. It means we can go beyond a national picture of preconception health to examine associations between preconception exposure and outcomes, spanning, for example, maternal obesity or diabetes to preterm and still births, child health and cognitive development. We can also explore evidence for the effectiveness of preconception interventions in improving such outcomes. While estimates of effectiveness from randomised trials are only just emerging [3], we can explore the feasibility of modelling the impact of preconception interventions, using evidence from the literature to estimate the relative impacts, cost-effectiveness and net benefits of different preconception interventions on a range of maternal and child outcomes, including long-term outcomes relating to health, education, earnings, welfare use and crime. Models that combine estimated intervention impacts with the routinely available data presented here could guide the investments of policy-makers and donors in this crucial and increasingly prioritised area of the life course. Conti and Heckman [31] summarise the evidence on the returns on investment for interventions to promote child well-being from conception to age 5, within an integrated developmental framework. We aim to extend this period backwards to estimate the costs and benefits of investing even earlier in the life course, that is, during the preconception period. We have previously

conceptualised a schematic overview of an economic model for nutrition interventions [3]. Here we expand on this to consider other relevant behaviours and risk factors including contraception use and other indicators of pregnancy planning, smoking, substance use, diabetes, population-level interventions and individual preconception counselling advice, and their consequences (Fig 4).

Discussion

The data sources described here illustrate the potential to describe and monitor the state of preconception health nationally using routinely collected data. The proposed metrics are generally of high quality, reflecting a long UK tradition of public health surveillance. Some data sources are restricted to England, such as the Maternity Services Data Set, and the RCGP RSC, while others are UK-wide. We have chosen to focus on England at the launch of this initiative, while acknowledging that other countries also have robust national data systems with highly developed capacity for data linkage [32].

Among women of reproductive age, irrespective of pregnancy planning, the data show impressive reductions in prevalence of smoking over time (Figure 1) but concerning rates of other preconception risk factors. In the NDNS, just over 50% of women aged 18-49 were overweight or obese, and over 70% were eating fewer than five portions of fruit or vegetables per day. Intake of iron and minerals are below the lower reference nutrient intakes (LNRIs) and therefore very likely to be inadequate for these women, particularly if they become pregnant. In the RCGP RSC, the proportion of women aged 15 to 45 who became pregnant each year was 4.0% in 2004, 6.7% in 2011 and 4.9% in 2017. Figure 1 shows a rising prevalence of common mental health problems (mostly depression and anxiety) and a persistent rate of prescribed medications that are known to be dangerous (e.g. valproate) or of doubtful safety in pregnancy (including some medications for hypertension and diabetes) among women not using contraception (Figure 1). Although pregnancy intention cannot be inferred from these data (they do not include condom use, or contraception obtained outside general practice), the anticipated inclusion of the LMUP in the MSDS will provide a new tool for surveillance of pregnancy intention at a national level. The LMUP is only applicable to women with a current or recent pregnancy, but work is underway to develop a robust measure of pregnancy intention for women who are not pregnant [33]; this could be useful in normalising discussions about planning for pregnancy in routine health care consultations.

Within the pregnant population (figures 2 and 3), there is clear clustering of social and medical risks among younger women (deprivation score, complex social factors, obesity (figure 2) and smoking (figure 3). These data indicate that early motherhood is a marker of vulnerability, emphasising the need for more effective ways of engaging with and supporting young women in high risk populations. Across all age groups, women are less likely to take folic acid supplements before conception or quit smoking for a subsequent

pregnancy than for their first pregnancy, suggesting that preconception health messages need to be continued as part of interconception health promotion.

Using data to enhance accountability

An annual report card with robust metrics on preconception health and its implications should be used to hold responsible agencies to account. Successive reports of the UK and Ireland confidential inquiries into maternal deaths and morbidity have concluded that improving preconception health is a priority for action. Indeed the latest report found it 'striking' that 'one recurring dominant theme emerges' from these inquiries, that is, the need for early planning of care for women with pre-existing conditions. [34] The CMO for England drew attention to preconception health in her 2015 annual report [8], as have international agencies [35, 36], but the necessary support to deliver strategies for better outcomes is lagging behind. The recent UK Government consultation on mandatory food fortification with folic acid is an important step in the right direction; another would be to ensure that no obesity strategy, nutrition strategy, non-communicable disease or adolescent health strategy fails to include preconception health [37]. Disappointingly, the UK Government's plan to halve childhood obesity by 2030 does not mention preconception health, even though the risk of obesity and the dietary behaviours of the children it intends to influence, who have yet to be conceived, will be significantly determined by the BMI and nutrition of their parents at the time of conception (1,2). For this reason, we propose content analysis of key documents in addition to routinely collected data, to reverse neglect of the preconception period in national health strategies. Since economic modelling of the impact of interventions can be a powerful means of leveraging resources [31], we look forward to estimates of the financial, as well as health and wellbeing, returns from investing in preconception interventions.

Key messages

- There is growing interest in preconception health as a critical period for influencing not only pregnancy outcomes, but also future maternal and child health and prevention of long term conditions.

- More and more national and international policy documents emphasise the need to improve preconception health, but resources and action have not followed.

- The preconception period (defined in biological, individual or public health terms) needs to become a focus of existing strategies that tackle obesity, smoking, nutrition, alcohol, maternal and child health, reproductive health, and non-communicable diseases.

- Preconception health can be assessed by metrics from multiple sources which will reflect awareness of preconception health, planning and preparation for pregnancy at public health and individual levels.

- An annual report card detailing these metrics should be used to hold governments and other relevant public and private agencies to account for delivering interventions to improve preconception health.

- Economic modelling of the return on investment in preconception interventions may prove useful in leveraging resources.

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References

1. Stephenson, J., et al., *Before the beginning: nutrition and lifestyle in the preconception period and its importance for future health.* Lancet, 2018. **391**(10132): p. 1830-1841.
2. Fleming, T.P., et al., *Origins of lifetime health around the time of conception: causes and consequences.* Lancet, 2018. **391**(10132): p. 1842-1852.
3. Barker, M., et al., *Intervention strategies to improve nutrition and health behaviours before conception.* Lancet, 2018. **391**(10132): p. 1853-1864.
4. House of Lords Hansard. *Children and Young People: Obesity*. 2018. 04/12/2018. https://hansard.parliament.uk/lords/2018-04-17/debates/39772C88-BA33-49ED-B4D5-C015DFA37511/ChildrenAndYoungPeopleObesity.
5. GOV.UK. *Preconception care: making the case*. 2018. 04/12/2018. https://www.gov.uk/government/publications/preconception-care-making-the-case.
6. *ACOG Committee Opinion number 313, September 2005. The importance of preconception care in the continuum of women's health care.* Obstet Gynecol, 2005. **106**(3): p. 665-6.
7. Hall, J.A., et al., *Conceptual framework for integrating 'Pregnancy Planning and Prevention' (P3).* Journal of Family Planning and Reproductive Health Care, 2016. **42**(1): p. 75-76.
8. Davies, S.C., Department of Health, *"Annual Report of the Chief Medical Officer 2014, The Health of the 51%: Women" London*. 2015. p. 167.
9. Office for National Statistics. *Live births, stillbirths and the intensity of childbearing, measured by the total fertility rate.* 2018. 04/12/2018. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/bulletins/birthsummarytablesenglandandwales/2017.

10. Digital NHS. *National Child Measurement Programme*. 04/12/2018. https://digital.nhs.uk/services/national-child-measurement-programme/.
11. The schools and students health education unit. *Health and Wellbeing surveys for Children and Young People since 1977*. 04/12/2018. https://sheu.org.uk/.
12. Hagell A, S.R., Coleman J., , *Key Data on Young People 2017.* Association for Young People's Health, 2017.
13. Department for Education. *Relationships education, relationships and sex education, and health education*. 2018. 04/12/2018. https://consult.education.gov.uk/pshe/relationships-education-rse-health-education/.
14. Wald, N.J., J.K. Morris, and C. Blakemore, *Public health failure in the prevention of neural tube defects: time to abandon the tolerable upper intake level of folate.* Public health reviews, 2018. **39**: p. 2-2.
15. Morris, J., et al., *Prevention of neural tube defects in the UK: a missed opportunity.* Archives of disease in childhood, 2016. **101**(7): p. 604-607.
16. Penn-Newman, D., et al., *How well do national and local policies in England relevant to maternal and child health meet the international standard for non-communicable disease prevention? A policy analysis.* BMJ Open, 2018. **8**(11).
17. Sacks, G., et al., *A proposed approach to monitor private-sector policies and practices related to food environments, obesity and non-communicable disease prevention.* Obes Rev, 2013. **14 Suppl 1**: p. 38-48.
18. GOV.UK. *Statistical data set: Family food datasets*. 2018. 04/12/2018. https://www.gov.uk/government/statistical-data-sets/family-food-datasets.
19. Food environment assessment tool., 04/12/2018. https://www.feat-tool.org.uk/.
20. Black, C., G. Moon, and J. Baird, *Dietary inequalities: what is the evidence for the effect of the neighbourhood food environment?* Health Place, 2014. **27**: p. 229-42.
21. Maguire, E.R., T. Burgoine, and P. Monsivais, *Area deprivation and the food environment over time: A repeated cross-sectional study on takeaway outlet density and supermarket presence in Norfolk, UK, 1990-2008.* Health Place, 2015. **33**: p. 142-7.
22. Vogel, C., et al., *The relationship between dietary quality and the local food environment differs according to level of educational attainment: A cross-sectional study.* PLoS One, 2017. **12**(8): p. e0183700.
23. Scholes S., *Health Survey for England 2017 Multiple risk factors*. 2018.
24. GOV.UK. *Public health outcomes framework: February 2018 data update*. 2018. 04/12/2018. https://www.gov.uk/government/statistics/public-health-outcomes-framework-february-2018-data-update.
25. Kousoulis, A.A., I. Rafi, and S. de Lusignan, *The CPRD and the RCGP: building on research success by enhancing benefits for patients and practices.* Br J Gen Pract, 2015. **65**(631): p. 54-5.
26. de Lusignan, S., et al., *RCGP Research and Surveillance Centre: 50 years' surveillance of influenza, infections, and respiratory conditions.* Br J Gen Pract, 2017. **67**(663): p. 440-441.
27. Pathirannehelage, S., et al., *Uptake of a Dashboard Designed to Give Realtime Feedback to a Sentinel Network About Key Data Required for Influenza Vaccine Effectiveness Studies.* Stud Health Technol Inform, 2018. **247**: p. 161-165.
28. de Lusignan, S. and C. van Weel, *The use of routinely collected computer data for research in primary care: opportunities and challenges.* Fam Pract, 2006. **23**(2): p. 253-63.
29. NHS., D. *Data sets*. 04/12/2018. https://digital.nhs.uk/data-and-information/data-collections-and-data-sets/data-sets.
30. Barrett, G., S.C. Smith, and K. Wellings, *Conceptualisation, development, and evaluation of a measure of unplanned pregnancy.* Journal of Epidemiology and Community Health, 2004. **58**(5): p. 426-433.

31. Conti, G. and J.J. Heckman, *Economics of child well-being.*, in *Handbook of child well-being*. 2014, Springer: Dordrecht. p. 363-401.
32. Health Data Research UK *Digital Innovation Hubs*. 04/12/2018. https://www.hdruk.ac.uk/.
33. Rocca CH, B.R., et al.,. *Desire to Avoid Pregnancy (DAP) Scale: A new psychometric instrument to measure prospective pregnancy preferences*. in *North American Forum on Family Plannings*. 2016.
34. Knight M, N.M., Tuffnel D, et al., , *Saving Lives, Improving Mothers' Care: Lessons learned to inform maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2013–15.* 2017.
35. WHO Policy Brief., *Preconception care: Maximizing the gains for maternal and child health*. 2013. p. 1 - 8.
36. Hanson, M.A., et al., *The International Federation of Gynecology and Obstetrics (FIGO) recommendations on adolescent, preconception, and maternal nutrition: "Think Nutrition First".* Int J Gynaecol Obstet, 2015. **131 Suppl 4**: p. S213-53.
37. Lancet. *Series from the Lancet journals*. 2018. 04/12/2018. https://www.thelancet.com/series/preconception-health.

Table 1. Systems approach to intervention to improve preconception health with potential core metrics

Population Level	**Intervention approaches**	**Potential Metrics**
	Mandatory flour fortification with folic acid	Prevalence of neural tube defects from congenital anomaly registers
Awareness	School curriculum recognizes significance of health before a future pregnancy	Schools Health Education Unit surveys Possibly Ofsted data in future
	Improving the food environment	Content analyses of government policies and food company documents Family Food datasets (Living Costs and Food Survey) – household food purchasing patterns Food environment assessment tool (FEAT) – fast food and supermarket density
	Embedding and highlighting preconception health in other public health initiatives e.g. - childhood prevention of obesity, - alcohol and smoking prevention - first 1000 days	Content analyses of government policies Public Health Outcomes Framework e.g. - Excess weight (children and adults) - Smoking - Physical activity - Under 18 conceptions UK National Diet & Nutrition Survey **(Table 2)** Health Survey for England
Individual Level		
Planning		London Measure of Unplanned Pregnancy (0-12)

	Normalising conversations about pregnancy intention e.g. during healthcare visits for - family planning, cervical screening, post-natal care and infant developmental checks; - Management of long term conditions - High risk groups	RCGP Research Surveillance Centre (**Fig 1)** e.g. - BMI - Smoking - Long term conditions e.g. - Diabetes, Hypertension - Common mental health problems - Medication not recommended in pregnancy
Preparation	Offer support for healthy behaviour change to individuals planning a pregnancy - online interactive tools, e.g. https://www.tommys.org/pregnancy-information/planning-pregnancy - referral to evidence based services including smoking cessation, weight loss (weight watchers (ref) slimmers world (ref) and bariatric surgery.	Maternity Services Dataset (MSDS) Antenatal booking visit **(Figures 2, 3)** - BMI - smoking (*did you quit before pregnancy?)* - folic acid (*did you start taking it before pregnancy?)* - alcohol - substance use - complex social factors - mental health - HbA1c in MSDS version 2 LMUP *(Question 6 did you do anything to improve your health in preparation for pregnancy?* EuroMonitor - Preconception supplement sales
	Training for health care providers to have conversations about preconception health e.g. - formal medical, health and social care staff training curricula - healthy conversation skills	Content analysis of health and social care staff professionals training curricula Uptake of training in health conversation skills

Interconception planning and preparation for next pregnancy		LMUP score (0-12)
	Encourage birth interval at least 18 months - Effective post-natal contraception	Birth interval from Hospital Episodes Statistics or Maternity Services Data Set (v 2)
	Post-partum weight management	Weight tracking across pregnancies (MSDS v 2)
	- Support breast-feeding	Breastfeeding rates, from Public Health Outcomes Framework

BMI: Body Mass Index LMUP: London Measure of Unplanned Pregnancy RCGP: Royal College of General Practitioners

Table 2 UK NDNS Y7-8

Table 2 Percentage of females of reproductive age (11-49 years old) in UK NDNS Y7-8 RP (2014/2015 to 2015/2016 N=695)[1] with dietary intakes below lower reference nutrient intakes (LRNI) or with poor health behaviours

		Age at survey (N,%)							
		Aged 11-17 (239, 15%)	Aged 18-19 (42, 6%)	Age 20-24 (49, 10%)	Aged 25-29 (79, 15%)	Aged 30-34 (65, 14%)	Aged 35-39 (62, 12%)	Aged 40-49 (159, 28%)	Total 18-49 (456)
BMI (SD)		21.9 (6.8)	24.4 (7.3)	27.5 (5.8)	26.0 (4.7)	25.8 (4.1)	25.5 (4.3)	27.9 (5.4)	26.5 (5.9)
Overweight/obese, % (95% CIs)		30 (23, 38)	23 (9,48)	60 (40, 77)	44 (31, 59)	54 (39, 69)	47 (31, 65)	63 (53, 73)	52 (46, 59)
F&V (<5 serves/day), % (95% CIs)		91 (85, 94)	72 (45, 89)	77 (57, 90)	75 (60, 86)	58 (43, 71)	77 (62, 88)	77 (67, 84)	73 (67, 78)
Current smoker, %		N/A	22 (7, 51)	20 (10, 37)	39 (25, 54)	26 (15, 40)	19 (10, 32)	19 (13, 27)	24 (19, 29)
High risk alcohol intake[2], % (95% CIs)			33 (16, 57)	16 (7, 33)	16 (9, 28)	19 (10, 33)	9 (4, 18)	19 (12, 27)	18 (14, 22)
Vitamins	LRNI[3]	% (95%CIs) of individuals in NDNS with mean dietary only intakes < LRNIs							
Vitamin A	250 µg/d	26 (19, 34)	4 (1, 11)	15 (6, 31)	12 (5, 29)	17 (8, 33)	5 (2, 14)	9 (5, 15)	11 (8, 15)
Vitamin B12	1.0µg/d[4]	4 (2, 7)	0	2 (0, 11)	5 (1, 18)	1 (0, 7)	6 (2, 22)	3 (1, 9)	3 (2, 6)
Folate	100µg/d	16 (12, 23)	3 (1, 8)	8 (3, 23)	7 (3, 18)	12 (5, 28)	3 (1, 9)	5 (2, 11)	7 (4, 10)
Riboflavin	0.8mg/d	26 (19, 34)	10 (4, 24)	14 (5, 33)	22 (12, 38)	22 (12, 39)	10 (4, 23)	15 (9, 25)	16 (12, 21)
Minerals									
Calcium	400mg/d[4]	22 (16, 30)	8 (4, 18)	8 (3, 19)	20 (10, 35)	15 (7, 29)	9 (4, 19)	12 (7, 23)	13 (9, 17)
Iodine	70µg/d[4]	26 (20, 34)	12 (5, 27)	30 (16, 48)	32 (20, 47)	27 (15, 43)	16 (8, 30)	9 (5, 16)	20 (16, 25)
Iron	8.0mg/d	56 (47, 64)	42 (19, 68)	49 (32, 67)	35 (22, 50)	33 (21, 49)	31 (19, 45)	36 (27, 46)	37 (31, 42)
Potassium	2000mg/d[4]	38 (30, 47)	28 (10, 58)	40 (25, 58)	33 (21, 48)	30 (17, 47)	25 (16, 38)	21 (14, 30)	28 (23, 33)
Selenium	40µg/d	43 (36, 51)	29 (14, 50)	61 (42, 77)	42 (29, 57)	47 (33, 62)	44 (29, 59)	46 (37, 55)	46 (40, 52)
Zinc	4mg/d[4]	28 (22, 36)	7 (3, 16)	12 (5, 26)	7 (2, 19)	18 (8, 34)	4 (1, 14)	10 (5, 20)	10 (7, 14)

N is unweighted numbers; F&V = Fruit and vegetable consumption; BMI = Body mass index (13.8% missing in aged 40-49 group. To determine overweight and obese in children the 85th & 95th centiles of the British 1990 growth reference (UK90 BMI) was used.)

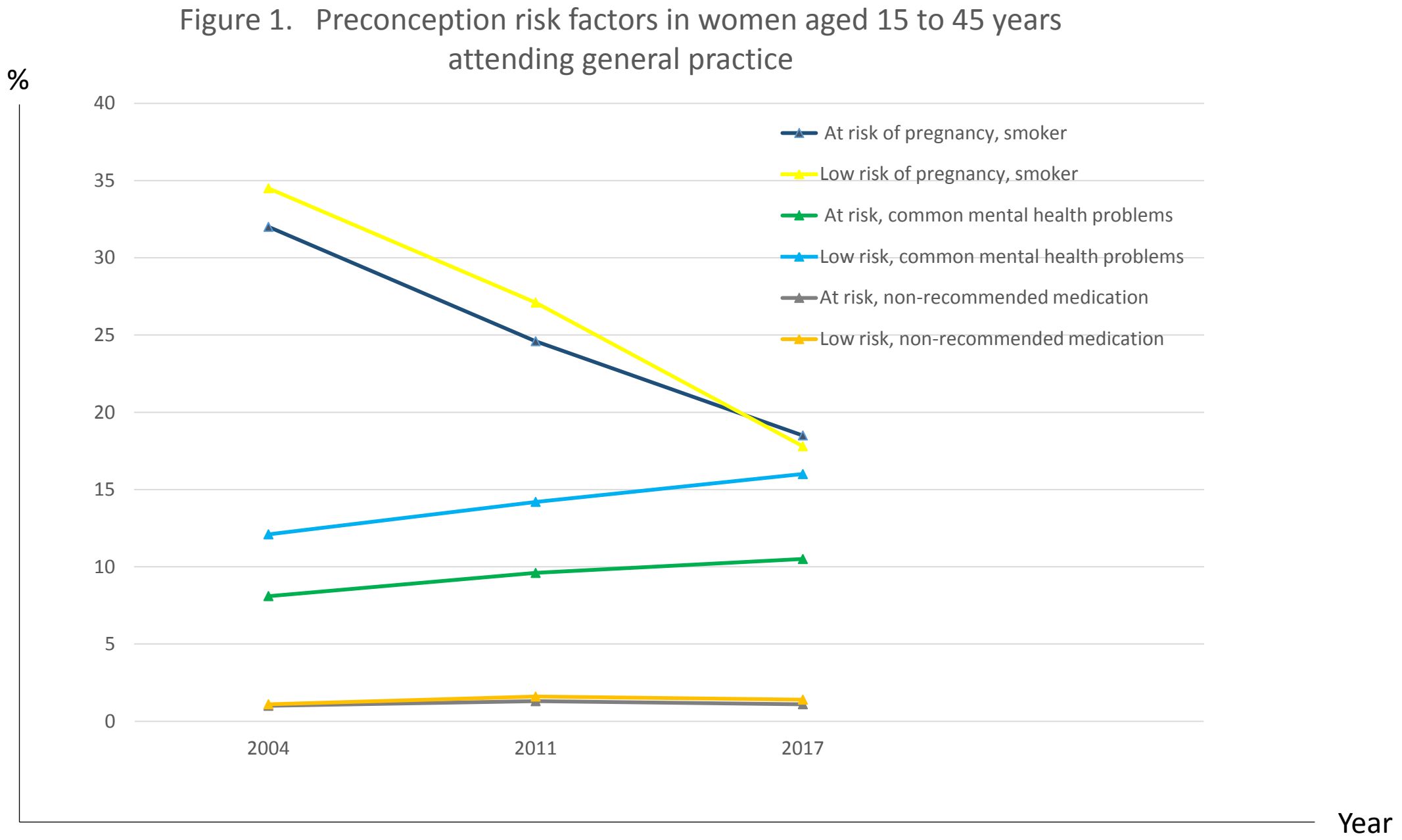
[1]UK National diet and Nutrition Survey Rolling Program (NDNS RP) Years 7-8 2014/2015 to 2015/2016. Means (SD) and percentages (95%CIs) are weighted to provide nationally representative results.

[2]Over 6 units of alcohol in one drinking occasion in the previous 7 days

[3]Micronutrient Lower Reference Nutrient Intake (LRNI) are those recommended in COMA, 1991
Intakes below the LRNI are very probably inadequate.

[4]LRNI for adolescents: Vitamin B12 for age 11-14 = 0.8µg/d; Calcium for age 11-18 = 450mg/d; Iodine for age 11-14 = 65µg/d; Potassium for age 11-14 = 1400mg; =Zinc for age 11-14 = 5.3mg.

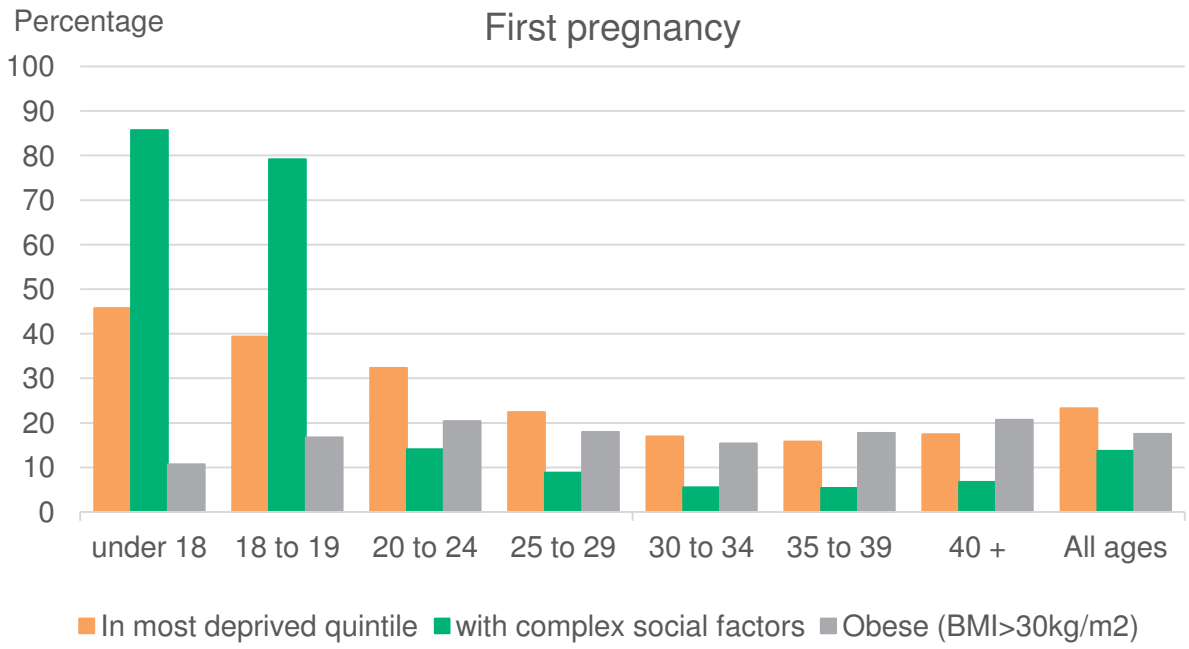
Figure 1 GP RSC data

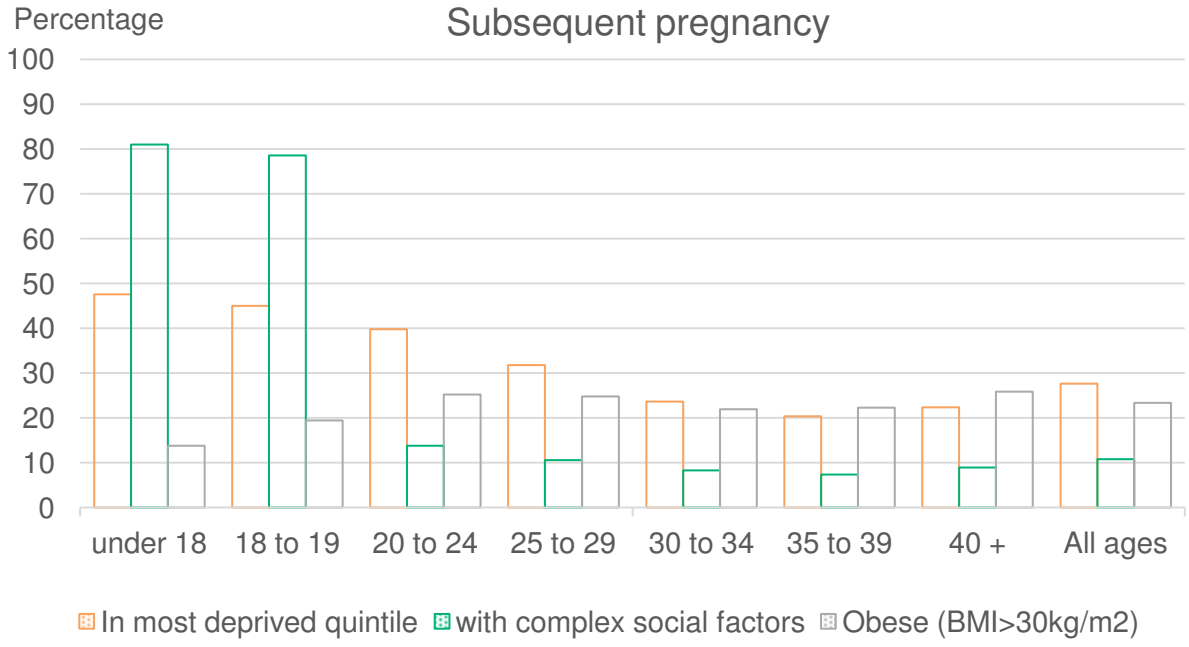


'At risk' defined by no use of contraception; 'low risk' defined by use of contraception, sterilised or infertile. Source: RCGP Research Surveillance Centre.

Figure 2-3 MSDS legend

Figure 2. Demographic and clinical factors at antenatal booking visit for first and all subsequent pregnancies. Source: Maternity Services Data Set 2017 booking episode.





Legend: Complex social factors applies to women whose pregnancies are complicated by one or more of the following: alcohol or drug misuse, recent migrant or asylum seeker status, difficulty with reading or speaking English, domestic abuse.

Figure 3. Smoking status and folic acid supplementation for first and all subsequent pregnancies. Source: Maternity Services Data Set 2017 booking episode.

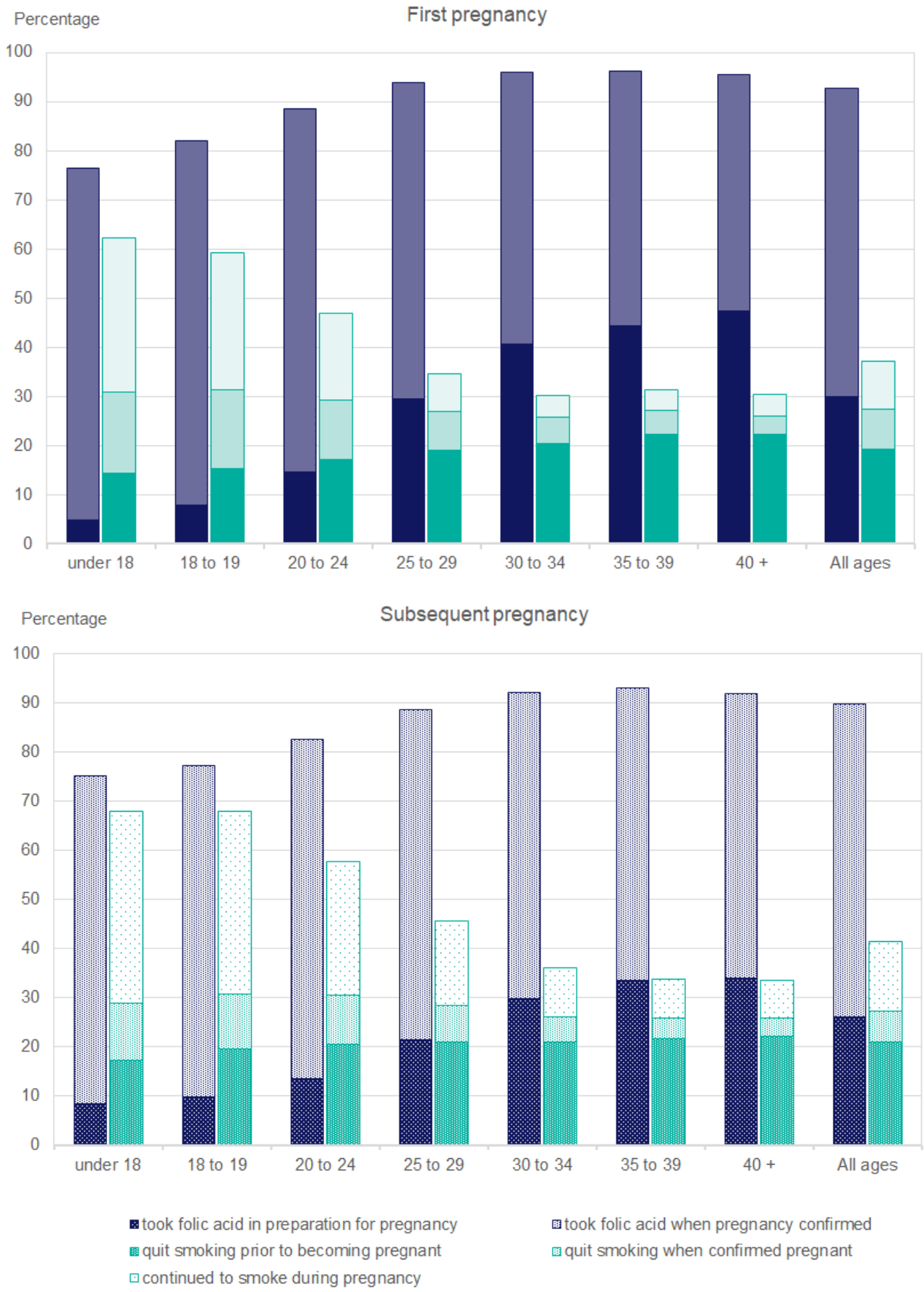
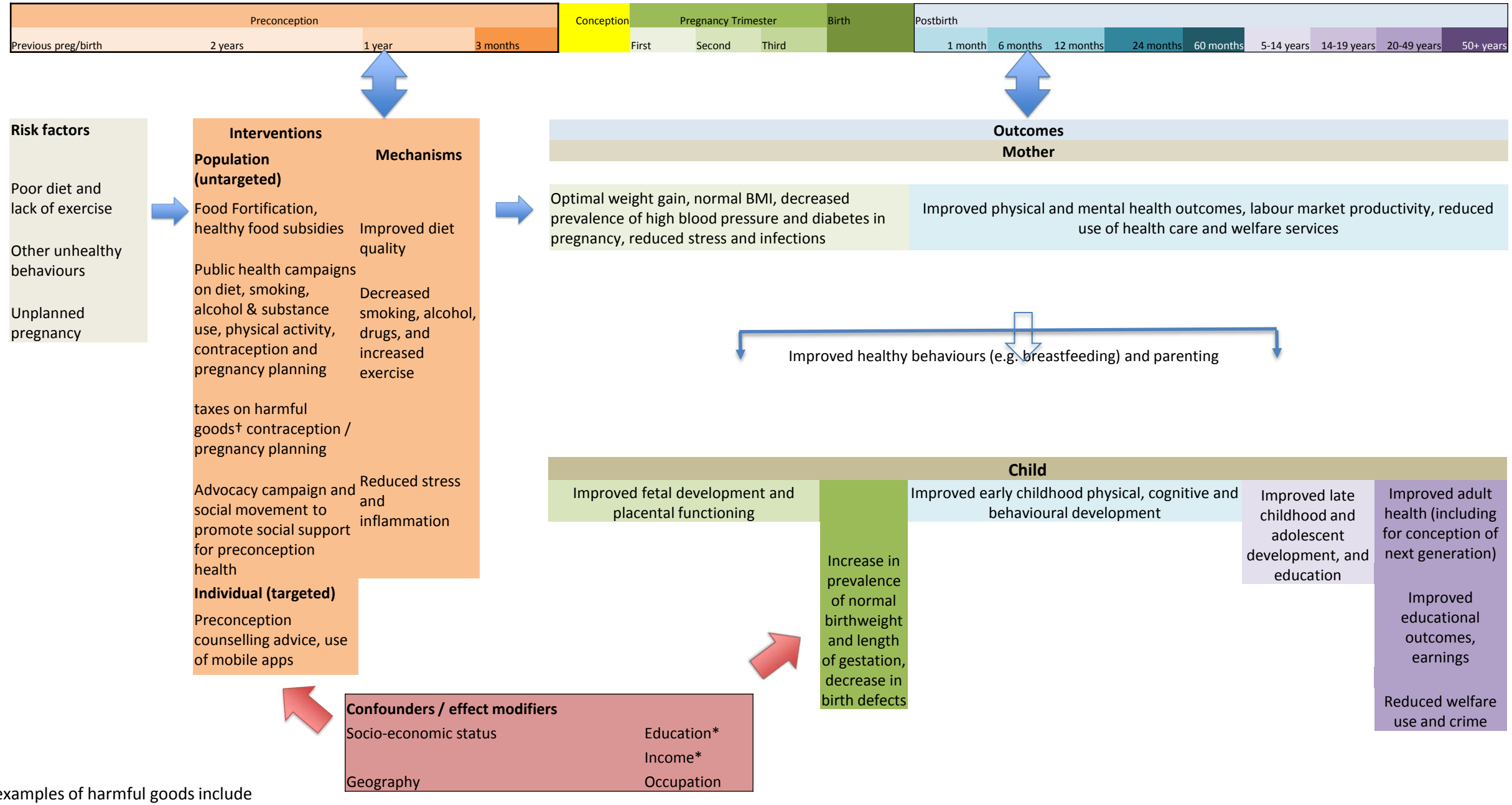


Figure 4 modelling preconception risks

Figure 4. Pathways linking preconception exposures and interventions to long term health, education and welfare outcomes.



† examples of harmful goods include tobacco, alcohol, sugar-sweetened beverages, trans-fat containing foods

* baseline/counterfactual levels i.e. not influenced by preconception interventions