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ORIGINAL ARTICLE *Infertility*

Pre-pregnancy fast food and fruit intake is associated with time to pregnancy

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STUDY QUESTION: Is preconception dietary intake associated with reduced fecundity as measured by a longer time to pregnancy (TTP)?

SUMMARY ANSWER: Lower intake of fruit and higher intake of fast food in the preconception period were both associated with a longer TTP.

WHAT IS KNOWN ALREADY: Several lifestyle factors, such as smoking and obesity, have consistently been associated with a longer TTP or infertility, but the role of preconception diet in women remains poorly studied. Healthier foods or dietary patterns have been associated with improved fertility, however, these studies focused on women already diagnosed with or receiving treatments for infertility, rather than in the general population.

STUDY DESIGN, SIZE, DURATION: This was a multi-center pregnancy-based cohort study of 5628 nulliparous women with low-risk singleton pregnancies who participated in the Screening for Pregnancy Endpoints (SCOPE) study.

PARTICIPANTS/MATERIALS, SETTING, METHODS: A total of 5598 women were included. Data on retrospectively reported TTP and preconception dietary intake were collected during the first antenatal study visit (14–16 weeks' gestation). Dietary information for the 1 month prior to conception was obtained from food frequency questions for fruit, green leafy vegetables, fish and fast foods, by a research midwife. Use of any fertility treatments associated with the current pregnancy was documented (yes, $n = 340$, no, $n = 5258$). Accelerated failure time models with log normal distribution were conducted to estimate time ratios (TR) and 95% CIs. The impact of differences in dietary intake on infertility (TTP >12 months) was compared using a generalized linear model (Poisson distribution) with robust variance estimates, with resulting relative risks (RR) and 95% CIs. All analyses were controlled for a range of maternal and paternal confounders. Sensitivity analyses were conducted to explore potential biases common to TTP studies.

MAIN RESULTS AND THE ROLE OF CHANCE: Lower intakes of fruit and higher intakes of fast food were both associated with modest increases in TTP and infertility. Absolute differences between the lowest and highest categories of intake for fruit and fast food were

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in the order of 0.6–0.9 months for TTP and 4–8% for infertility. Compared with women who consumed fruit ≥3 times/day, the adjusted effects of consuming fruit ≥1–<3 times/day (TR = 1.06, 95% CI: 0.97–1.15), 1–6 times/week (TR = 1.11, 95% CI: 1.01–1.22) or <1–3 times/month (TR = 1.19, 95% CI: 1.03–1.36), corresponded to 6, 11 and 19% increases in the median TTP (P_{trend} = 0.007). Similarly, compared with women who consumed fast food ≥4 times/week, the adjusted effects of consuming fast food ≥2–<4 times/week (TR = 0.89, 95% CI: 0.81–0.98), >0–<2 times/week (TR 0.79, 95% CI 0.69–0.89) or no fast food (TR = 0.76, 95% CI: 0.61–0.95), corresponded to an 11, 21 and 24% reduction in the median TTP (P_{trend} <0.001). For infertility, compared with women who consumed fruit ≥3 times/day, the adjusted effects of consuming fruit ≥1–<3 times/day, 1–6 times/week or <1–3 times/month corresponded to a 7, 18 and 29% increase in risk of infertility (P_{trend} = 0.043). Similarly, compared with women who consumed fast food ≥4 times/week, the adjusted effects of consuming fast food ≥2–<4 times/week, >0–<2 times/week, or no fast food, corresponded to an 18, 34 and 41% reduced risk of infertility (P_{trend} <0.001). Pre-pregnancy intake of green leafy vegetables or fish were not associated with TTP or infertility. Estimates remained stable across a range of sensitivity analyses.

LIMITATIONS, REASONS FOR CAUTION: Collection of dietary data relied on retrospective recall and evaluated a limited range of foods. Paternal dietary data was not collected and the potential for residual confounding cannot be eliminated. Compared to prospective TTP studies, retrospective TTP studies are prone to a number of potential sources of bias.

WIDER IMPLICATIONS OF THE FINDINGS: These findings underscore the importance of considering preconception diet for fecundity outcomes and preconception guidance. Further research is needed assessing a broader range of foods and food groups in the preconception period.

STUDY FUNDING/COMPETING INTEREST(S): The SCOPE database is provided and maintained by MedSciNet AB (http://medscinet.com). The Australian SCOPE study was funded by the Premier's Science and Research Fund, South Australian Government (http://www.dfeest.sa.gov.au/science-research/premiers-research-and-industry-fund). The New Zealand SCOPE study was funded by the New Enterprise Research Fund, Foundation for Research Science and Technology; Health Research Council (04/198); Evelyn Bond Fund, Auckland District Health Board Charitable Trust. The Irish SCOPE study was funded by the Health Research Board of Ireland (CSA/2007/2; http://www.hrb.ie). The UK SCOPE study was funded by National Health Service NEAT Grant (Neat Grant FSD025), Biotechnology and Biological Sciences Research council (www.bbsrc.ac.uk/funding; GT084) and University of Manchester Proof of Concept Funding (University of Manchester); Guy's and St. Thomas' Charity (King's College London) and Tommy's charity (http://www.tommys.org/; King's College London and University of Manchester); and Cerebra UK (www.cerebra.org.uk; University of Leeds). L.E.G. is supported by an Australian National Health and Medical Research Council (NHMRC) Early Career Fellowship (ID 1070421). L.J.M. is supported by a SACVRDP Fellowship; a program collaboratively funded by the National Heart Foundation, the South Australian Department of Health and the South Australian Health and Medical Research Institute. L.C.K. is supported by a Science Foundation Ireland Program Grant for INFANT (12/RC/2272). C.T.R. was supported by a National Health and Medical Research Council (NHMRC) Senior Research Fellowship (GNT1020749). There are no conflicts of interest to declare.

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Key words: dietary intake / fast food intake / fruit intake / food groups / time to pregnancy / fertility / retrospective study

Introduction

Infertility, defined as the lack of a clinically detectable pregnancy over 12 months, affects millions of couples worldwide and is associated with significant emotional and economic burden (World Health Organisation, 2015). Numerous maternal and paternal lifestyle factors have been associated with reductions in fertility including smoking (Hassan and Killick, 2004; Harlev et al., 2015), excessive alcohol consumption (Hassan and Killick, 2004; Mikkelsen et al., 2016), use of recreational drugs (Alvarez, 2015), as well as maternal (Sim et al., 2014) and paternal (Campbell et al., 2015) obesity.

While many of these lifestyle factors may be linked with diet, the specific impacts of preconception maternal diet on fertility remain poorly studied. Previous studies have focused on the role of diet on fertility outcomes among women diagnosed with or receiving treatments for infertility, rather than in the general population. In these studies, greater adherence to the Mediterranean dietary pattern, which includes a higher intake of fruits, vegetables and fish, was associated with fewer couples consulting a physician for difficulties conceiving (Toledo et al., 2011) and higher probability of achieving pregnancy in couples undergoing IVF (Vujkovic et al., 2010). Similarly, women with a higher dietary score, based on meeting dietary recommendations for core food groups in the Netherlands (i.e. fruits, vegetables, meat, fish, whole wheat products and fats), had a greater chance of ongoing pregnancy following fertility treatment (Twigt et al., 2012). In contrast, greater consumption of foods with high glycemic index (Chavarro et al., 2009) and a higher intake of energy from trans fats (Chavarro et al., 2007) were associated with an increased risk of ovulatory infertility. Overall, these studies indicate healthier foods or dietary patterns are associated with improved fertility. Given diet is a recognized modifiable factor for a range of health outcomes, the identification of food groups that are associated with infertility would be important to assist women in improving pregnancy success.

The objective of this study was to examine the impact of preconception diet on time to pregnancy (TTP) and infertility. We hypothesized that a higher intake of healthier foods, such as fruits, vegetables and fish, and a lower intake of discretionary foods (fast foods) is associated with a shorter TTP and a lower rate of infertility.

Materials and Methods

Study population

The Screening for Pregnancy Endpoints (SCOPE) study is a multi-center prospective cohort study of 5628 pregnancies recruited from November 2004 to February 2011 in Adelaide (Australia), Auckland (New Zealand), Cork (Ireland), and Leeds, London and Manchester (UK). Detailed descriptions of the study have been published previously (McCowan *et al.*, 2009). Briefly, data were collected by a research midwife at 14–16 and 19–21 weeks' gestation. Data for this study were taken from the interview at 14–16 weeks. Couples were excluded from the current analysis if they conceived following use of ART for male infertility ($n = 19$).

Ethical approval was obtained from New Zealand AKX/02/00/364, Australia REC 1712/5/2008, London, Leeds and Manchester 06/MRE01/98 and Cork ECM5 (10) 05/02/08 and all participants provided written informed consent.

Assessment of dietary variables

At 15 ± 1 weeks' gestation, women were asked to recall dietary intake in the 1 month immediately preceding conception using single item questions of specific foods. The use of single item questions has been shown to be useful to assess gross level estimates and rank individuals on intakes, rather than precise levels of intake (Yaroch *et al.*, 2012). Number of servings of foods was reported to the midwife for fruit (fresh fruit and fruit juice), green leafy vegetables (vegetables high in folate such as spinach, cabbage, lettuce, broccoli), fish (with prompts of fish such as salmon, trout, sardines, shellfish and shrimp) and key discretionary foods reported to be consumed from take-away or fast food outlets (i.e. frequency of intake of burgers, fried chicken, pizza and hot chips were totaled as 'fast food'). Frequency of fruit was categorized as ≥3 times/day (reference), ≥1–<3 times/day, 1–6 times/week and <1–3 times/month. Frequency of green leafy vegetables was categorized as ≥1 times/day (reference), 3–6 times/week, 1–2 times/week and <1–3 times/month. Frequency of fish was categorized as ≥1 time/week (reference), 1–3 times/month and never. Frequency of fast food was categorized as never, >0–<2 times/week, ≥2–<4 times/week and ≥4 times/week (reference). Dietary intake categories were established *a priori* following previously published data for the SCOPE cohort (McCowan *et al.*, 2010; North *et al.*, 2011).

Assessment of outcome

Estimates of retrospectively reported TTP were derived from the following question 'duration of sex without contraception before conception with father of baby'. Values, in months, were recorded in a continuous fashion and used to define TTP. Infertility was defined as having a TTP of more than 12 months.

Assessment of covariates

Information in each recruitment site was collected on demographics, smoking, family, medical and gynecological history, diet and supplement use, as well as anthropometric variables, such as height and weight, to determine BMI. Maternal ethnicity was self-reported and binary coded as Caucasian or other (90% were Caucasian). The socioeconomic index was developed in New Zealand and is a measure of the individual's socio-economic status derived from a specific occupation (Davis *et al.*, 1997). It provides a value of 10–90 with a higher score indicating higher socio-economic status (Galbraith *et al.*, 1996). Self-reported polycystic ovary syndrome (PCOS) was categorized as yes (confirmed by a scan and/or blood test) or no/unsure. Women who had ≥1 of any previous miscarriage at ≤10 weeks' gestation or >10 weeks' gestation were binary coded as yes/no for previous miscarriage. Cigarette use in the 3 months pre-pregnancy was binary coded as yes or no, as quitting smoking prior to pregnancy is recommended (World Health Organisation. 2010). Units of alcohol per week in the 3 months pre-pregnancy was binary coded as yes or no, based on official guidelines in several countries recommending no alcohol intake for pregnant women and women trying to conceive (International Alliance for Responsible Drinking (2016)). Women also reported if the current conception was associated with the use of any fertility treatments (e.g. IVF, ICSI, ovulation induction). Information collected from the biological father included paternal age, and paternal height and weight (to calculate BMI).

Statistical analyses

Frequencies and descriptive statistics for all women were expressed as *n* (%) or as mean (SD). Median [inter-quartile range, IQR] was reported when continuous variables were not normally distributed.

The impact of differences in dietary intake on TTP was investigated using accelerated failure time models. Such models have been used in recent studies investigating factors associated with fecundity and are preferred due to improvements in interpretability and translation of risk estimates (Gaskins *et al.*, 2015). We utilized accelerated failure time models with log normal distribution to estimate time ratios (TR) and 95% CIs. Alternative distributions were investigated but the log normal distribution was selected based on providing the lowest −2log likelihood and Akaike information criterion value. These TRs can be interpreted as the ratios of the median values of the duration of pregnancy attempts between the compared groups. A TR above 1 implies that a given exposure is associated with longer TTP, whereas a TR below 1 indicates a shorter TTP.

The impact of differences in dietary intake on infertility (TTP >12 months) was compared using a generalized linear model (Poisson distribution) with robust variance estimates, with resulting relative risks (RR) and 95% CIs.

Tests for linear trend across categories of dietary intake were conducted by including the dietary intake groups as ordinal variables into respective models. We used causal diagrams (directed acyclic graphs) to guide selection of potential covariates for which to control, based on *a priori* selection of covariates considered to impact dietary behavior and fertility.

Sensitivity analyses were performed to evaluate the robustness of the results, which were selected based on key potential sources of bias in retrospective TTP studies (Joffe *et al.*, 2005). Firstly, we investigated medical intervention bias by restricting the analysis to couples who conceived without the assistance of fertility treatments ($n = 5258$). Secondly, possible truncation bias was corrected for by restricting the analysis to those with a starting time between the second year and penultimate year of participant recruitment at each site ($n = 3645$) to account for left and right truncation bias, respectively (Joffe *et al.*, 2005). Thirdly, we investigated the potential for planning bias by restricting the analysis to couples who reported TTP of >1 month ($n = 3054$).

Statistical significance was defined as a two-sided *P*-value of <0.05. All statistical analyses were undertaken using STATA IC 14 (Stata, College Station, TX, USA).

Results

Characteristics of study participants

Characteristics for all 5598 women are shown in Table 1 and Supplementary Fig. SI shows the participant flow. The majority of women conceived without the assistance of fertility treatments ($n = 5258$; 94%),

Table I Maternal and paternal characteristics of the study population.

Maternal characteristics (*n* = 5598)	Natural conception (*n* = 5258)	Assisted conception (*n* = 340)
Age (years)[a]	28.4 (5.4)	33.1 (4.5)
BMI (kg/m^2)[a]	25.3 (4.9)	25.8 (5.4)
Socioeconomic index[a]	41.4 (16.5)	47.7 (16.4)
Ethnicity *n* (%)		
Caucasian	4717 (89.7)	314 (92.4)
Other	541 (10.3)	26 (7.7)
Fruit intake *n* (%)		
≥3x/day	1165 (22.2)	87 (25.6)
≥1–<3x/day	2002 (38.1)	147 (43.2)
1–6x/week	1609 (30.6)	92 (27.1)
<1–3x/month	482 (9.2)	14 (4.1)
Green leafy vegetable intake *n* (%)		
≥1x/day	1895 (36.0)	147 (43.2)
3–6x/week	1739 (33.1)	118 (34.7)
1–2x/week	1117 (21.2)	56 (16.5)
<1–3x/month	507 (9.6)	19 (5.6)
Fish intake *n* (%)		
≥1x/week	2775 (52.8)	194 (57.1)
1–3x/month	1806 (34.4)	105 (30.9)
Never	677 (12.9)	41 (12.1)
Fast food intake *n* (%)		
Never	146 (3.5)	16 (6.2)
>0–<2x/week	917 (22.2)	63 (24.3)
≥2–<4x/week	2067 (50.0)	147 (56.8)
≥4x/week	1008 (24.4)	33 (12.7)
Polycystic ovary syndrome *n* (%)	259 (4.9)	93 (27.4)
Previous miscarriage *n* (%)		
Yes	704 (13.4)	65 (19.1)
Smoking status *n* (%)		
Non-smoker	3819 (72.6)	313 (92.1)
Alcohol intake *n* (%)		
None	1169 (22.2)	122 (35.9)
Frequency of sexual intercourse per month[a]	12.8 (11.3)	9.1 (5.6)
Multivitamin pre-pregnancy *n* (%)		
Yes	1314 (25.0)	142 (41.8)
Country *n* (%)		
Australia	1104 (21.0)	53 (15.4)
New Zealand	1847 (35.1)	171 (50.3)
UK	620 (11.8)	35 (10.3)
Ireland	1687 (32.1)	81 (23.8)
Paternal characteristics (*n* = 4369)		
Age (years)[a]	30.7 (5.9)	35.4 (5.8)
BMI (kg/m^2)[a]	26.8 (4.2)	27.7 (4.1)

[a]Mean (SD).

reporting a median [IQR] TTP of 2.0 [1, 6] months. In total, 468 (8%) couples took >12 months to conceive and 2204 (39%) reported a TTP of 1 month or less.

Table 1 provides an overview of maternal and paternal characteristics of the study population, separated by type of conception. The mean (SD) age of women and men in the natural conception cohort was ~5 years younger than the assisted conception cohort, whereas maternal and paternal BMI were similar. Couples requiring assisted conception did not have a materially different frequency of intake for any of the food groups; however, there was a higher percentage of women with PCOS, previous miscarriage, multivitamin intake, and non-smokers, and a higher percentage of women not consuming alcohol.

Pre-pregnancy diet and TTP

The relationship between pre-pregnancy diet and TTP is presented in Fig. 1 and Supplementary Table S1. Compared to women consuming fruit ≥3 times/day, the fully adjusted TRs (95% CIs) were 1.06 (0.97–1.15) for intake ≥1–<3 times/day, 1.11 (1.01–1.22) for intake 1–6 times/week and 1.19 (1.03–1.36) for intake <1–3 times/month (P_{trend} = 0.007). Compared to women consuming fast food ≥4 times/week, the fully adjusted TRs (95% CIs) were 0.89 (0.81–0.98) for intake ≥2–<4 times/week, 0.79 (0.69–0.89) for intake >0–<2 times/week and 0.76 (0.61–0.95) for no fast food (P_{trend} = 0.001). No association was observed between intake of green leafy vegetables or fish and TTP.

Marginal estimates for median TTP according to each category of food intake are presented in Fig. 2. The adjusted difference in median TTP was 0.2–0.6 months longer with decreasing levels of fruit intake and 0.4–0.9 months shorter for decreasing levels of fast food intake.

In sensitivity analyses (Supplementary Table S1), risk estimates remained stable following the exclusion of women with assisted conception as well as following truncation. When restricting the analysis to women reporting a TTP >1 month, risk estimates for fruit intake became slightly attenuated, but not for the other food groups.

Pre-pregnancy diet and infertility

The relationship between pre-pregnancy diet and infertility is presented in Fig. 3 and Supplementary Table S2. Compared to women consuming fruit ≥3 times/day, the RR (95% CI) of infertility was 1.07 (0.88–1.29) for women consuming fruit ≥1–<3 times/day, 1.18 (0.97–1.44) for intake 1–6 times/week, and 1.29 (0.95–1.74) for intake <1–3 times/month (P_{trend} = 0.043). Compared to women consuming fast food ≥4 times/week, the fully adjusted RR of infertility were 0.82 (0.67–1.00) for women consuming fast food ≥2–<4 times/week, 0.66 (0.51–0.85) for intake >0–<2 times/week, and 0.59 (0.37–0.94) for no fast food (P_{trend} = 0.001). No association was observed between intake of green leafy vegetables or fish and infertility.

Marginal probability estimates for infertility according to each category of food intake are presented in Fig. 4. For the entire cohort, estimated probabilities of infertility based on multivariate adjusted models corresponded to an absolute increase of 1–4% with decreasing levels of fruit intake, and an absolute reduction of 3–8% for decreasing levels of fast food intake.

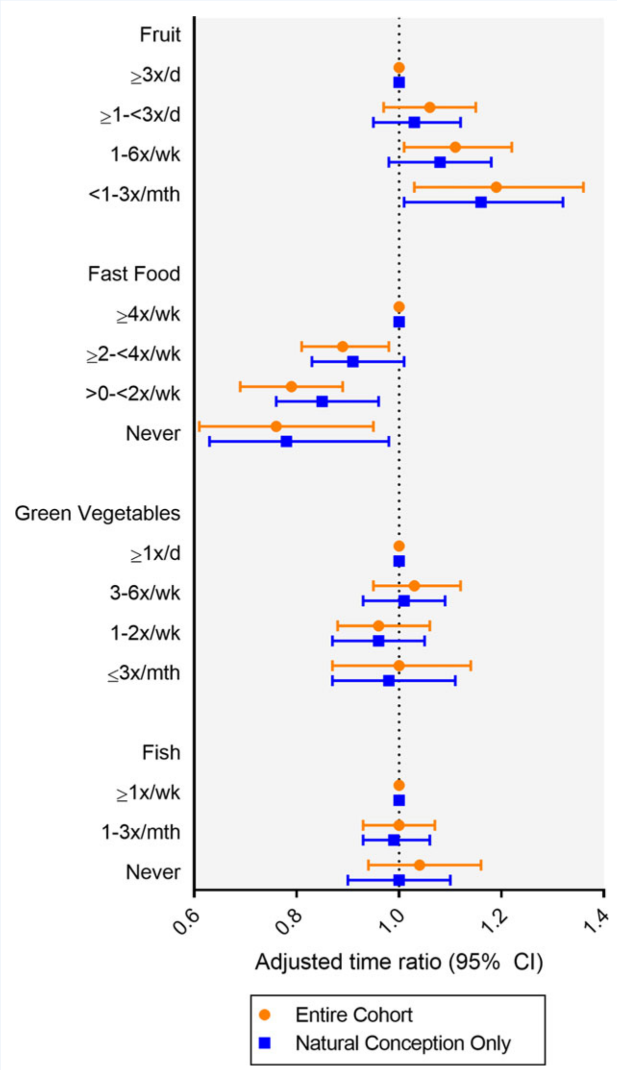

Figure 1 Association between pre-pregnancy dietary intake and time to pregnancy. Accelerated failure time models were used to estimate the time ratios and 95% CIs. All models are adjusted for maternal BMI, maternal age, socioeconomic index, recruitment site, ethnicity, polycystic ovary syndrome, previous miscarriage, smoking status, alcohol intake, multivitamin use prior to conception, frequency of sexual intercourse, paternal BMI, paternal age.

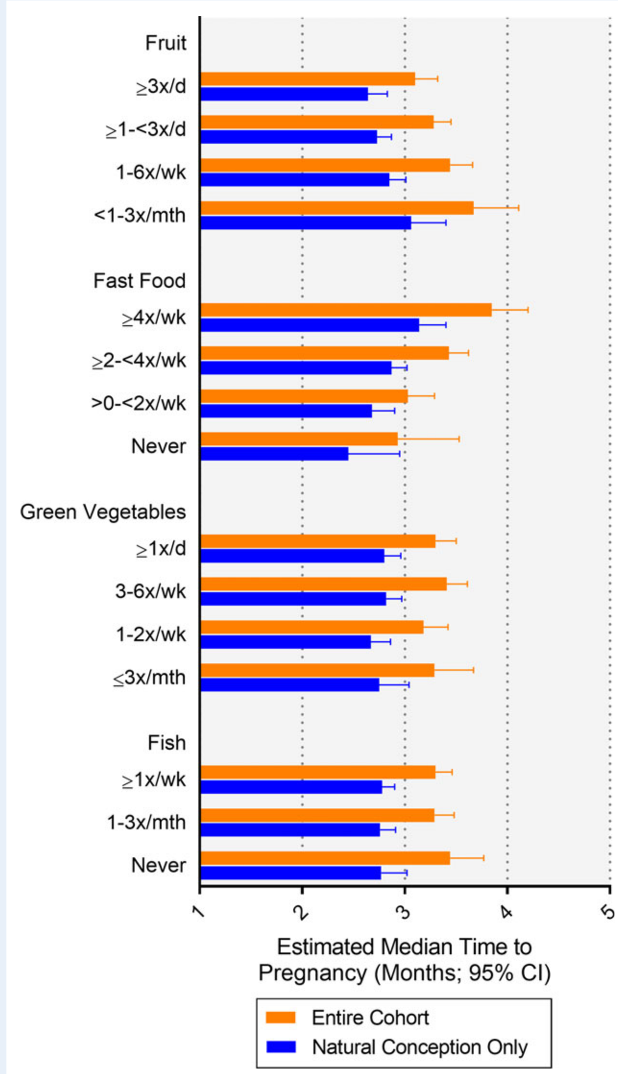

Figure 2 Estimated median time to pregnancy according to pre-pregnancy dietary intake. All models are adjusted for maternal BMI, maternal age, socioeconomic index, recruitment site, ethnicity, polycystic ovary syndrome, previous miscarriage, smoking status, alcohol intake, multivitamin use prior to conception, frequency of sexual intercourse, paternal BMI, paternal age.

In sensitivity analyses (presented in Supplementary Table S2), the exclusion of women with assisted conception resulted in larger effect estimates for both fruit and fast food intake, as did truncating the cohort. In contrast, estimates remained stable when restricting the analysis to women reporting a TTP >1 month, providing evidence against planning bias.

Discussion

In this pregnancy cohort, a lower intake of fruit and higher intake of fast food were both associated with modest increases in TTP and infertility. Absolute differences between the lowest and highest categories of intake for fruit and fast food were in the order of 0.6–0.9 months for TTP and 4–8% for infertility.

Research in pre-pregnancy diet and TTP in humans is sparse. Factors that have been identified have generally been in couples undergoing fertility treatment, demonstrating a protective role with a healthy dietary pattern or a Mediterranean dietary pattern, which includes fruits, vegetables and fish (Chavarro *et al.*, 2007; Vujkovic *et al.*, 2010; Twigt *et al.*, 2012). This supports our findings of a protective effect of fruit, but we did not find an association with green leafy vegetable or fish. Fruits and vegetables contain a range of antioxidants and phytochemicals, and these may beneficially impact fertility. As we only asked about green leafy vegetables and did not ask about orange or other types of vegetables, we did not capture total vegetable intake, potentially limiting the impact they may have on fertility.

The specific dietary components of fast food and their relationship to fertility have not been studied in human pregnancies. Fast foods are

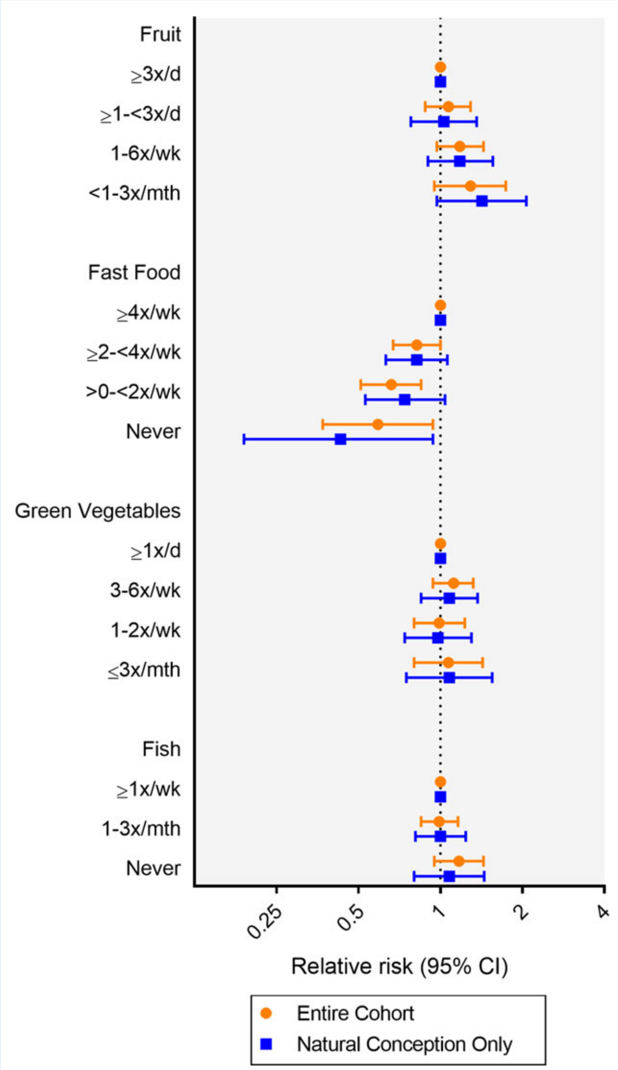

Figure 3 Association between pre-pregnancy dietary intake and infertility (TTP >12 months). Generalized linear models were used to estimate relative risks and 95% CIs. All models are adjusted for maternal BMI, maternal age, socioeconomic index, recruitment site, ethnicity, polycystic ovary syndrome, previous miscarriage, smoking status, alcohol intake, multivitamin use prior to conception, frequency of sexual intercourse, paternal BMI, paternal age.

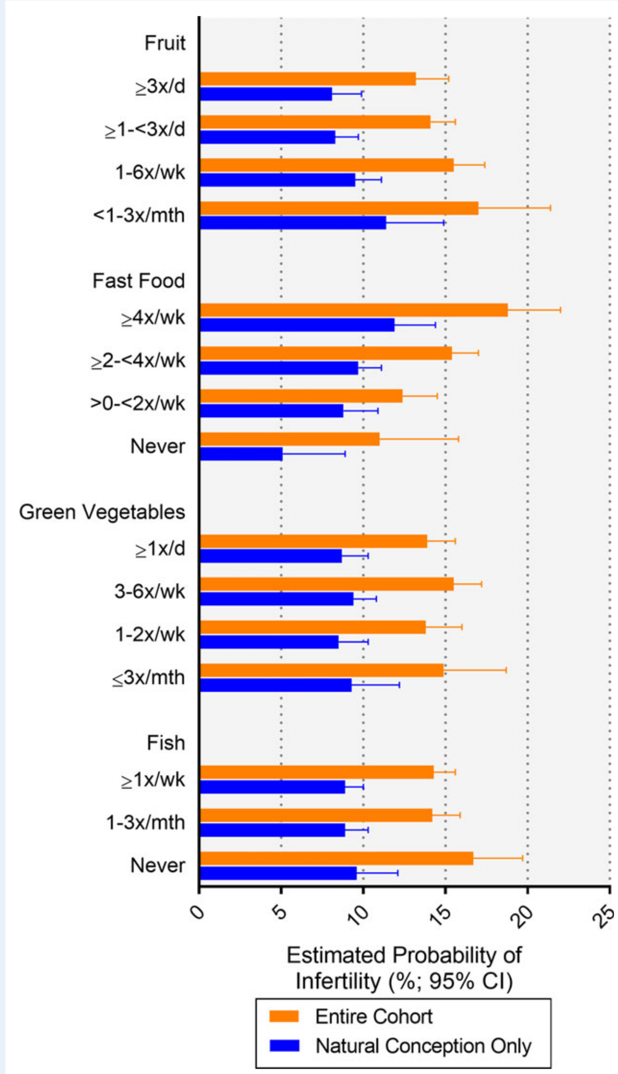

Figure 4 Estimated probabilities of prolonged time to pregnancy (>12 months to conceive) according to pre-pregnancy dietary intake. All models are adjusted for maternal BMI, maternal age, socioeconomic index, recruitment site, ethnicity, polycystic ovary syndrome, previous miscarriage, smoking status, alcohol intake, multivitamin use prior to conception, frequency of sexual intercourse, paternal BMI, paternal age.

energy dense with high amounts of saturated fat, sodium and sugar. One study showed saturated fats contribute 79% of the fatty acid composition in oocytes of women undergoing IVF (Matorras et al., 1998), while a higher concentration of saturated fatty acids or a higher ratio of saturated to polyunsaturated fats in ovarian follicular fluid was associated with reduced numbers of mature oocytes (Shaaker et al., 2012). Studies in mice have shown that excess dietary fat intake increased lipid content, and induced lipotoxicity and apoptosis in ovarian cells (Wu et al., 2010). We speculate that a high intake of fast food may be one factor mediating infertility through altered circulating and oocyte follicular fluid metabolic markers, namely lipoproteins.

We acknowledge several strengths and limitations to this retrospective study. In general, retrospective TTP studies are complementary to prospective TTP studies. Their major strength is their ability to achieve a sample that is representative of the target population; that is, in comparison to prospective TTP studies that require recruitment of highly motivated couples, introducing the potential for response and planning bias, retrospective TTP studies have the advantage of providing greater representativeness of the study sample to the target population (women planning pregnancy), improving generalizability of study findings (Joffe et al., 2005). Importantly, the use of retrospective self-reported TTP has been shown to be a valid and reliable marker for TTP and has good agreement to prospective recall (Joffe et al., 1993; Jukic et al., 2016). A major strength of this study includes the large sample size, detailed collection of maternal and paternal factors, and information on method of conception. Specific limitations include lack of information on menstrual cycle length, simple assessment of dietary intake, and the possibility of residual confounding. TTP is considered easier to remember in retrospective studies than cycle length (Olsen *et al.*, 1997), and previous studies have demonstrated that correcting for menstrual patterns had no impact on effect estimates (Hassan and Killick, 2004).

Other limitations include that dietary intake was based on retrospective recall using a limited number of questions, thus some foods may be misreported or missed. However, the practicality of using single item questions, particularly fruit and vegetable intake, has been demonstrated to be useful to assess gross level estimates and rank individuals on intakes, rather than precise levels of intake (Yaroch *et al.*, 2012). Previous studies have also reported on fast food consumption by single questions (French *et al.*, 2000; Satia *et al.*, 2004; Jeffery *et al.*, 2006; Dave *et al.*, 2009), supporting the ability for such a measure to adequately capture frequency of fast food intake. Nevertheless, the reported intake of fast food is likely an underestimate as we only captured intake at take-away restaurants and not at home. Lastly, we did not collect dietary information from the male partner, thus, we cannot determine the impact of paternal dietary intake on the couple's fertility leaving the possibility of residual confounding. A recent review on male diet and fertility markers indicated that higher intake of fruits and vegetables was associated with increased sperm motility whereas a higher intake of fat-rich foods and sweets may decrease semen quality (Giahi *et al.*, 2016); but further investigation is required due to the small number of studies.

Further limitations are those inherent to retrospective TTP studies and include the possibility of planning bias, medical intervention bias, truncation bias and behavior change bias. These were all estimated to bias risk estimates towards the null if they were present and our estimates remained relatively stable across a number of sensitivity analyses. A more detailed description of these limitations and their potential impacts on study results is provided in Supplemental Data.

Finally, the SCOPE cohort utilized in this study comprised healthy, nulliparous women, specifically chosen for their low risk of pregnancy complications. As such they were particularly fertile, with a reported median TTP of 2 months. This is similar to some (Axmon *et al.*, 2006; Gesink Law *et al.*, 2007; McKinnon *et al.*, 2016), but shorter than other (Gnoth *et al.*, 2003; Ford *et al.*, 2008) studies. The overall prevalence of infertility was 8% which is comparable to the reported median prevalence of 9% in developed and developing nations (Boivin *et al.*, 2007). Intake of the assessed food groups is also comparable to other cohorts (Olsen and Secher, 2002; Murrin *et al.*, 2007; Blumfield *et al.*, 2011), although it is difficult to precisely compare due to differences in reporting of food intakes or grams of specific foods and/or food groups. The study results are generalizable and have important implications for women of child bearing age who have a low intake of fruit and a high intake of fast foods.

In conclusion, in a nulliparous population of women, a lower intake of fruit and a higher intake of fast food in the preconception period were both associated with a longer TTP and increased risk for infertility. Small modifications in dietary intake may have benefits for improving fertility and should be encouraged both population-wide and in couples seeking conception. Further research is needed assessing a broader range of foods and food groups prior to pregnancy.

Supplementary data

Supplementary data are available at *Human Reproduction* online.

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Authors' roles

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