RESEARCH REPORT

What happens to women's self-reported cigarette consumption and urinary cotinine levels in pregnancy?

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ABSTRACT

Aims To describe the pattern of self-reported cigarette consumption and nicotine consumption, measured by urinary cotinine concentration, in a cohort of pregnant women who did not stop smoking.

Design Cohort study.

Setting Randomly selected general practices from the West Midlands, UK.

Participants Five hundred and fifty-nine pregnant women in a clinical trial who were enrolled at booking for maternity care (about 12 weeks of gestation), who were followed up in mid and late pregnancy and 10 days post-natal and who did not stop smoking during that period.

Measurements Retrospectively collected self-reported cigarette consumption prior to pregnancy and contemporaneously collected self-reported cigarette consumption and urinary cotinine concentrations at booking for maternity care, 20 weeks of gestation, 30 weeks of gestation and 10 days post-natal.

Findings Women reported smoking a median of 10–19 cigarettes per day prior to pregnancy and a median of 5–9 cigarettes per day at booking for maternity care. At booking, women reported consuming a mean [95% confidence interval (CI)] of 6.3 (5.6–7.0) cigarettes per day. At 20 weeks of pregnancy this had risen to mean (95% CI) 11.5 (10.9–12.2), and remained at 11 cigarettes per day when measured again at 30 weeks of gestation and 10 days post-natal. Mean (95% CI) urinary cotinine levels at booking were 6.0 (5.4–6.6) μg/mL, and did not change much through pregnancy. There were statistically significant associations between urinary cotinine and reported cigarette consumption at all time points except at booking.

Conclusions Women smokers report lower cigarette consumption at booking for maternity care than they do prior to pregnancy or from mid pregnancy onwards, but cotinine data imply that their intake of toxins does not change throughout pregnancy. Reports suggesting many women reduce their smoking in pregnancy have probably been over-optimistic.

KEYWORDS Nicotine, pregnancy, smoking.

INTRODUCTION

The prevalence of smoking peaks in early adulthood [1,2], so it is not surprising that smoking is common among pregnant women in the UK and many other developed countries. Data from the Health Education Authority Tracking Survey (HEATS) show that about 25–30% of pregnant women smoke in England [3]. The UK Government made reducing smoking prevalence in pregnancy a health target, and used advertising and trained midwives in smoking cessation to try and reduce the prevalence. However, the prevalence of smoking in pregnancy did not change between 1992 and 1997 [3].

There is unequivocal evidence that smoking while pregnant reduces birth weight of the baby and increases the risk of pre-term birth [4]. There is consistent evidence

that smoking in pregnancy is associated with neurocognitive deficits in early childhood [5] (although these may subsequently resolve [6]), reduced pulmonary function [7] and reduced growth in height [8].

Many women who smoke before pregnancy either stop smoking completely or reduce their cigarette consumption in preparation for pregnancy or soon after discovering that they are pregnant [3]. Data from the HEATS showed that, on average, 10% of women reported that they stopped smoking prior to pregnancy, 18% stopped during pregnancy, 4% cut down prior to pregnancy, 32% cut down during pregnancy, leaving only 36% of smokers not changing their habit in response to pregnancy. Reducing consumption is a more commonly employed strategy than is stopping altogether. There might be some advantages for the health of the foetus and mother if women genuinely reduce their smoke intake [9].

It is possible that the apparent reduction in consumption is being overestimated because of the reliance on self-report. Generally, smokers in surveys give accurate information about whether they smoke or not, but the more intense the anti-smoking environment, the higher is the rate at which smokers falsely declare themselves non-smokers [10]. This seems to be the case in pregnancy, where up to 25% of pregnant smokers falsely declare themselves to be non-smokers [10–15]. It seems intuitively likely that if women who are current smokers deny smoking altogether because of perceived pressure to do so—perhaps from health professionals, relatives or society in general—then they may also falsely declare reduced consumption, and there is evidence that this might be so [16].

Few studies have followed women's smoking consumption throughout pregnancy. Rebagliato *et al.* obtained self-reported consumption and salivary cotinine, a marker of nicotine intake, from a cohort of Spanish smokers in the third trimester of pregnancy and 1 month after delivery [17]. During pregnancy, women reported consuming 2.9 cigarettes per day fewer than after delivery, which was supported by lower antenatal cotinine levels. This implies the volunteers in this study truly reduced their cigarette consumption while pregnant. A similar study compared women's cigarette consumption and cotinine levels in the first and third trimesters, reporting the changes in smoking prevalence and consumption [18,19]. The mean reported cigarette consumption and blood cotinine in the first and third trimesters were not given in the paper. However, this study reported that, among continuing smokers, cotinine levels showed no real change in 32%, 36% had lower levels and 32% higher levels. Most of those who reduced their cotinine concentration had a high cotinine concentration initially, while most of those reporting a low concentration initially had a higher concentration later in pregnancy. These results are compatible with regression to the mean, and the pattern is hard to interpret. No other studies that we know have tracked women's smoking through pregnancy.

METHODS

In a smoking cessation trial [20], midwives in randomly selected practices in the West Midlands, UK, were asked to recruit all smokers that booked with them for maternity care. We estimate that they recruited 42% of all smokers who booked. Full details on these women's sociodemographic and smoking habits are published in the trial report [20]. In brief, nearly all were white: almost two thirds had had a baby previously, were of mean (SD) age 26.5 (5.9) years, of average net household income of £100–200 per week; two thirds lived with partners that smoked; and women booked on average at 12 weeks of gestation. Data on women's smoking were obtained at booking (less than 20 weeks gestation), 23–25 weeks, 28–30 weeks and 10 days after delivery. Midwives gave women questionnaires and also sent off the urine that they had collected as part of routine antenatal care for cotinine analysis. Self-reported consumption was based on two questions. One question was 'how many cigarettes do you normally smoke in a day?', with responses in categories: fewer than 5; 5–9; 10–19; 20–29; 30 or more. The second question was 'how many cigarettes have you smoked in the last 24 hours?', where any number between 0 and 99 could be given in response. The mean of these two was used as daily consumption, replacing the categories in the first question by the mid category value. Urinary cotinine concentration was measured by Wolfson Laboratories (Birmingham University), using a colorimetric assay, expressing the results in μg/mL [21]. This assay measures the concentration of all compounds with a pyridine ring, which include all breakdown products of nicotine, not just cotinine, but the result is expressed as a cotinine equivalent. Because several compounds are measured together, the cotinine concentrations are about eight times those usually reported in other studies. The measured concentration adjusts for the dilution of urine, and the cut-off dividing smokers from non-smokers is 1.5 μg/mL. The colorimetric assay has been validated against a gas chromatography urinary cotinine assay [21].

Nine hundred and eighteen women were recruited to the study, of which 186 (20.3%) dropped out of the study by 30 weeks pregnancy, mainly due to the early ending of pregnancy. Fifty-nine (6.4%) women quit smoking by 30 weeks of gestation and 114 (12.4%) could not be followed up at this point. The aim of this study was to examine changes in smoking during pregnancy among

women not quitting. Quitters and those not followed up were excluded. The 559 women smokers followed up had similar baseline smoking habits to the 300 women who were not followed up. The mean (SD) baseline cotinine levels were 6.0 (4.0) and 4.5 (4.0) μg/mL among women followed up and not followed up, respectively, which were not significantly different ($P = 0.87$). Mean reported baseline daily cigarette consumption was 6.3 (5.5) and 5.6 (4.8) cigarettes per day, respectively, which were also not significantly different ($P = 0.37$). Nor were there any large or statistically significant differences between the two groups in most other characteristics: mean score on the Fagerstrom Test for Nicotine Dependence, stage of change, age, ethnicity, parity, proportion having a partner or proportion whose partner smoked. However, there was a difference in the educational level and income of those followed up and those lost to follow-up, with those lost being less well educated (40.4% versus 25.2% having no educational qualifications, Mann–Whitney *U*-test, $P = 0.038$) and poorer (61.8% versus 49.2% with a net household income less than £200 per week, Mann–Whitney *U*-test, $P < 0.001$).

Of those 559 smokers in the cohort followed up, 556 (99.5%) smokers had self-report cigarette consumption and 462 (82.6%) had cotinine concentration data at booking; 529 (94.6%) and 421 (75.3%) smokers had self-report and cotinine data at 23–25 weeks, respectively; 559 (100.0%) and 447 (80.0%) women had self-report and cotinine data at 28–30 weeks, respectively; and 511 (91.4%) and 343 (61.4%) women had self-report and cotinine data at 10 days post-natally, respectively.

The women were recruited in clusters defined by their general practice, so this was accounted for in the analysis using random effects regression in Multilevel Modelling for Windows (Multilevel Models Project, Institute of Education, London, UK). Mean cotinine and reported daily cigarette consumption was calculated for each of the four time points. These show changes in mean consumption in the population as a whole, not the mean change in consumption within individuals. To calculate this, we took the cigarettes per day at baseline from that at 28–30 weeks of gestation and at 10 days post-natal for each individual, calculating the means of these changes, accounting for clustering using random effects regression as before. We also calculated the regression coefficients for the cross-sectional associations between cotinine concentration and reported cigarette consumption at each of the four time points, and the regression coefficients for the longitudinal associations between changes in reported cigarette consumption and changes in cotinine concentration from baseline to 28–30 weeks of gestation and 10 days post-natal.

The question we raised in the Introduction was whether women reduced their cigarette consumption from their pre-pregnancy levels, as reported in other studies. We did not recruit these women until they booked for maternity care, so we had no contemporaneously collected reported cigarette consumption data nor urinary cotinine data prior to pregnancy to directly answer this question. However, we did ask women at booking, 'before you were pregnant, how many cigarettes did you normally smoke in a day?' and, 'now you are pregnant, how many cigarettes do you normally smoke in a day?', with responses in the same categories as reported earlier. To give some idea of whether women were reporting reduced consumption at booking compared with pre-pregnancy, we compared the median category response using a paired Wilcoxon test.

Because different women were available on each occasion, changes in means between time points could arise spuriously because these women may have unchanging consumption but different populations on each occasion could produce different means. In sensitivity analysis, we included only those 220 women who had full data on every occasion. These results were not different so are not reported.

RESULTS

The average cotinine level did not differ greatly across the four time points, but self-reported daily consumption nearly doubled from six to 11 cigarettes per day at 23–25 weeks, and then was fairly constant (Fig. 1). The data on change within individuals confirms this. Self-reported consumption showed a mean [95% confidence intervals (CI)] increase of 4.5 (3.8–5.1) cigarettes per day ($\chi^2 = 167.0$, df = 1, $P < 0.001$) for the difference between

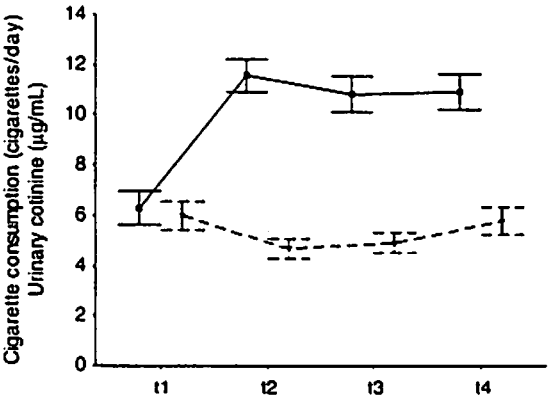

Figure 1 Mean cotinine and daily self-reported cigarette consumption levels at four time points in pregnancy. t1, booking; t2, 23–25 weeks of gestation; t3, 28–30 weeks of gestation; t4, 10 days post-natal. Cotinine = dashed lines with triangular markers; cigarette consumption = solid lines with square markers

booking and 30 weeks gestation. However, cotinine levels did not change significantly, with a mean (95% CI) increase of 0.4 (0.0–0.8) μg/mL ($\chi^2 = 3.2$, df = 1, $P = 0.072$) between booking and 30 weeks gestation. However, the pattern was slightly different for the differences between booking and 10 days post-natal. Mean reported consumption increased (95% CI) by 4.7 (3.9–5.5) ($\chi^2 = 130.6$, df = 1, $P < 0.001$), and mean cotinine showed a slight rise (95% CI) of 1.0 (0.7–1.3) μg/mL ($\chi^2 = 38.8$, df = 1, $P < 0.001$).

There was a highly statistically significant ($P < 0.001$) but not very strong association between urinary cotinine and reported consumption at 23–25 weeks, 28–30 weeks gestation and 10 days post-natal. On each occasion, for five cigarettes per day higher reported cigarette consumption, there was a 0.7 (0.4–1.0), 0.8 (0.5–1.0) and 1.0 (0.6–1.4) μg/mL higher urinary cotinine concentration at 23–25, 28–30 weeks gestation and 10 days post-natal, respectively. However, at booking, there was not a statistically significant relationship between cotinine concentration and reported cigarette consumption, with five cigarettes per day higher reported consumption being associated with a 0.3 (0.0–0.6) μg/mL higher urinary cotinine concentration ($P = 0.055$). For five cigarettes per day higher reported consumption, urinary cotinine concentrations were 0.3 (0.0–0.6) μg/mL higher. Nor were there statistically significant relationships between change in urinary cotinine concentration and change in reported cigarette consumption from baseline to 28–30 weeks gestation and 10 days post-natal. Five cigarettes per day change in consumption was associated with a 0.2 (0.0–0.4) and 0.0 (0.0–0.1) μg/mL change in urinary cotinine concentration at 30 weeks gestation and 10 days post-natal, respectively.

Five hundred and forty-seven of the 559 (97.9%) women responded to both questions on pre-pregnancy and current cigarette consumption on the booking questionnaire. The median response for pre-pregnancy consumption was 10–19 cigarettes per day, while the median response for current consumption was 5–9 cigarettes per day. In only five cases did women report consuming more at booking than before pregnancy. 136 reported identical categories of consumption and 406 reported lower consumption categories. This difference was highly significant ($z = -18.1$, $P < 0.001$).

DISCUSSION

Women report much lower cigarette consumption at booking than at other stages in pregnancy, and this increases by 23–25 weeks and is fairly stable thereafter to at least 10 days post-natally. However, mean urinary cotinine does not change much through pregnancy. Furthermore, cotinine concentration at booking was unrelated to reported consumption, unlike at other times in pregnancy, and there was no evidence that changes from booking in women's reported consumption of cigarettes were related to changes in urinary cotinine concentrations. Women retrospectively reported reduced cigarette consumption at booking for maternity care compared with their normal consumption prior to pregnancy.

Previous studies have relied on retrospectively collected self-report data alone, and found that many women smokers decrease their consumption in pregnancy. The self-reported consumption data alone from this study show data partly consistent with these previous findings. However, this is the first study to show that the reported decrease in consumption was only temporary and consumption had increased again by mid pregnancy, although we cannot know whether the reported consumption from mid pregnancy onward is still less than pre-pregnancy consumption. However, this is the first study to show that women's nicotine consumption, as measured by urinary cotinine, remained constant throughout pregnancy. The urinary cotinine data are not necessarily incompatible with these self-report data and previous studies' findings that women frequently report reduced cigarette consumption in pregnancy. Perhaps women truly smoke fewer cigarettes, but they smoke those cigarettes more intensively. Alternatively, or perhaps as well as this, women may under-report cigarette consumption as a result of those forces that also result in denying smoking altogether.

One limitation of the study is that a minority of eligible smokers were recruited. Selection bias could operate if, among those women not recruited, the smoking or cotinine pattern was different from that observed in the sample of women that were recruited. Similarly, information bias could have distorted the pattern. Just over 60% of recruited women constituted this cohort, but those who were not followed up had similar baseline smoking habits and were similar in most other measured respects to those women who were followed up, so neither of these explanations seems likely.

Another possible explanation of the findings relates to physiological changes in pregnancy that could produce spurious changes in urinary cotinine concentration. Creatinine clearance increases in pregnancy, but, as cotinine was corrected for urinary creatinine, this should not cause of the pattern we observed. Only one study has reported on nicotine metabolism in pregnant women. Dempsey and colleagues reported that, among 10 volunteers, measured nicotine consumption from freely smoked cigarettes was similar during and after pregnancy, but that serum nicotine and cotinine concentrations were lower because of these substances' shorter

half-lives during pregnancy [22]. However, renal cotinine clearance increased during pregnancy, which would increase urinary cotinine concentration, but the net effect of these changes on urinary cotinine concentrations was not reported in the paper. No data on changes occurring through pregnancy to nicotine or cotinine serum or urinary concentrations were reported. It is therefore unclear whether changes in the metabolism and excretion of nicotine products through pregnancy caused the discrepancy between self-reported cigarette consumption and urinary cotinine.

Women in this study reported smoking an average of 11 cigarettes per day at all times except booking, which is similar to that reported in other studies of pregnant women [15], and similar to that for non-pregnant women smokers in this age group (about 12 cigarettes per day) [23]. These data support our retrospective self-report data that women in this study were reporting a reduction in their normal cigarette consumption early in pregnancy and consuming cigarettes at levels similar to their non-pregnancy consumption from mid pregnancy onwards.

Efforts to help pregnant women stop smoking altogether have been disappointing [15,24], while smoking reduction benefits the foetus [9], and previous published data indicate that it is the most commonly employed strategy by women. Harm reduction by encouraging smoking reduction could therefore be seen as a useful strategy. However, these data challenge that position by implying that little might be gained because any reduction in cigarette consumption is small, temporary and does not reduce nicotine consumption. Whether there would be a greater benefit in encouraging reduction rather than total cessation could only be finally clarified by randomized controlled trials. Until such data are available, smoking cessation should remain the key goal for pregnant women.

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