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Parental cigarette smoking before and during pregnancy in a cohort of 21 472 pregnancies

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Abstract

Smoking during pregnancy is one of the leading causes for adverse pregnancy outcomes. We studied parental smoking both before and during pregnancy in a retrospective cohort of 21 472 singleton pregnancies. Although most smoking women (74%) ceased tobacco use, there was possible gestational exposure to maternal cigarette smoking in every fifth pregnancy. Continued smoking throughout pregnancy was more prevalent in the partners (22%) than in the pregnant women (7%). The smoking behaviour of the women, especially the number of cigarettes smoked per day (CPD), before and in early pregnancy predicted the continuation of smoking throughout the pregnancy and could be used in identifying high risk groups. In addition, their partner's smoking habits both before and during pregnancy, were associated with the likelihood that the woman would continue to smoke during her pregnancy ($r_s \approx 0.4$). Furthermore, continued smoking of both parents were associated with decreased birth weight, head circumference and Apgar score, and increased duration of hospital stay and need for special care after birth. Consequently, addressing the lifestyles of both parents in the health care and maternity clinics could help in reducing maternal cigarette smoking during pregnancy and the adverse pregnancy outcomes associated with smoking.

KEYWORDS
alcohol, cigarettes, partner, pregnancy, smoking cessation

1 | INTRODUCTION

Smoking during pregnancy is one of the primary, preventable causes for poor maternal health and adverse pregnancy outcomes.[1,2] Acute effects of maternal smoking include an increased risk of miscarriage, stillbirth, preterm birth, low birth weight, reduced head circumference and femur length, and sudden infant death syndrome.[3,4] The long-term effects associated with maternal smoking during pregnancy include an increased risk for asthma and obesity of the child.[4,5] In addition, smoking during the periconception period is associated with delays in embryonic morphological development.[6]

Recently, Lange et al (2018) estimated the global prevalence of during-pregnancy smoking to be 1.7%.[7] However, this estimate varies between countries and regions, and is affected by maternal age. Europe has the highest prevalence of smoking, as approximately 8% of

women smoke while pregnant.[7] In addition, although the overall smoking rates in early pregnancy have decreased over the years, the smoking among the adolescent and young pregnant women have increased.[7–15]

Several factors have been claimed to explain why women continue to smoke during pregnancy, that is, lower maternal age and education level, use of alcohol before pregnancy, being single, and/or living with a partner who also smokes.[8,12,16–19] Living with a smoking partner not only decreases the likelihood that the woman will quit smoking during pregnancy but also increases her likelihood of a postpartum smoking relapse.[8,18,20] However, although the partner's lifestyle is known to affect a woman's success in smoking cessation, it is still not screened systematically as a part of reproductive health care. Moreover, although, the commonly used nicotine-dependency tests like the Heaviness of Smoking Index (HSI) and The Fagerström Test for Nicotine Dependence (FTND) have been validated also during pregnancy, there is little evidence that they can predict whether a woman will continue to smoke while pregnant.[21]

Therefore, our aims were a) to describe the smoking behaviours of women and their partners both before and during pregnancy in different age groups, b) to estimate whether the smoking behaviours of women and their partners were correlated, c) to assess how useful the HSI is for estimating smoking cessation and continued smoking during pregnancy, and d) to estimate whether the smoking behaviours of women and their partners were correlated to the health of the born baby. We used a Finnish birth cohort of 21 472 singleton pregnancies to answer these questions.[22]

2 | MATERIALS AND METHODS

The cohort consisted of 21 472 singleton pregnancies which had lasted at least 22 full gestational weeks (GWs). These pregnancies were from 14 822 women who gave birth in Kuopio University Hospital in North-Savo, Finland, between January 1st, 2009 and May 31st, 2018. The data gathering methods, compilation of the cohort, and the description of the parents' demographic data and birth outcomes have already been published elsewhere.[22] Briefly, the information of parental tobacco and alcohol use were gathered from the women via an electronic questionnaire during their pregnancy. This information was recorded into an electronic database (called PikkuHaikara) that we merged with a second database (called Haikara) housing the birth outcomes reported by health care professionals in the maternity hospital. This study is a part of Kuopio Birth Cohort study (KuBiCo, www.kubico.fi),[23] which has received research approval from the Research Ethics Committee of Hospital District of Central Finland. The study was conducted in accordance with the Basic & Clinical Pharmacology & Toxicology policy for experimental and clinical studies.[24]

To able the comparison of smoking behaviour in different ages, the parents were divided into five age groups (≤ 20; 21–24; 25–29; 30–34; and ≥ 35 years). Although smaller than the other groups, a separate group for those ≤ 20 years of age was created because previous studies have indicated that this group differs substantially from the older groups.[11–13,15] All the other age groups of women had about an equal number of pregnancies per group.

The smoking behaviour of the parents was assessed with the HSI and several binary statement variables (Supporting Information, Methods). The HSI is a shortened version of the FTND and has two questions evaluating nicotine dependency: 1) How many cigarettes do you smoke per day? (i.e., cigarettes per day, CPD) and 2) How soon after you wake up do you smoke your first cigarette? (i.e., time to first cigarette, TTFC).[25,26] Parental alcohol use was assessed as previously described.[22] In brief, the Alcohol Use Disorders Identification Test (AUDIT) was used to screen drinking one year prior to the pregnancy and 'average weekly alcohol dose before pregnancy' and 'average weekly alcohol dose during pregnancy' were also asked.

The variables were validated to minimize the amounts of discordant and missing information and we conducted multiple imputation (MI) to account for remaining missing data (Supporting Information, Methods). MI is a method that utilizes all the collected data and takes into account the uncertainty of the imputed values.[27,28] In brief, we exploited a Multiple Imputation by Chained Equation with Predictive Mean Matching (PMM) method in item score level (m = 40, k = 5). PMM utilizes regression analysis to find a pool of cases (k-nearest values) with a valid value resembling a case with a missing value.[29–31] From that k-pool of cases, it randomly selects one case whose value it imputes in place of the missing value. MI is appropriate for reporting estimates (mean and standard deviation) and correlations. However, MI is not suited for describing frequencies[27] and, therefore, the frequencies reported here are from the original dataset. We exploited Rubin's Rules to combine the parameter estimates from the multiple imputed datasets.[32]

Because the HSI is the most used screening test for tobacco in the Finnish maternity clinics, we compared the levels of nicotine-dependency (HSI) and number-of-daily-cigarettes (CPD) in age-grouped parents, who had been smoking at some time point. We calculated the multiple imputed mean estimates and 95% confidence

intervals for before and during pregnancy HSI and CPD for each group. In addition, to test whether the parents' 'Smoking status during pregnancy' variables were independent, we conducted a chi-square test. Correlations of the parents' smoking variables were analysed using the Spearman's rho bivariate nonparametric method. Multiple testing was accounted for by Bonferroni's method, that is, *p*-value less than the corrected α (0.0002 = α [0.05] /the number of correlations [253]) were considered statistically significant. Also, the associations between the categories of the 'Smoking status during pregnancy' variable and the birth outcomes, such as birth weight, head circumference, Apgar, duration of the pregnancy, duration of the hospital stay and the need for specialized treatments after birth, were investigated.

We analysed the sensitivity of our results in four ways. First, we evaluated whether the non-independence of the pregnancy cases in the original cohort (n = 21 472) had influenced our results. Secondly, we compared the means and correlation coefficients of the available cases in the original data with the estimates and coefficients of the MI data. Thirdly, we evaluated the robustness of the item score level MI by comparing its results with those obtained by the total score level MI. Fourth, we assessed if the women's relationship status had an impact on our whole cohort MI estimates. We used IBM SPSS Statistics

TABLE 1 Parents' characteristics in the cohort of 21 472 pregnancies.

Characteristics	Valid n[a]	% of all cases	% of valid cases
Women	14 822[c]	100.0	
Age (years)[b]	21 472	100.0	
≤20	731	3.4	
21–25	4004	18.6	
26–29	5945	27.7	
30–33	5632	26.2	
≥ 34	5160	24.0	
Gravidity	21 472	100.0	
Parity	21 472	100.0	
Nulliparous	9037	42.1	
Primiparous	6835	31.8	
Multiparous	5600	26.1	
Number of births[c]			
1	9337	63.0[c]	
2 or more	5485	37.0[c]	
Used assisted reproductive technology	1009	4.7	
Marital status[d]	21 338	99.4	
In a relationship[e]	17 564	81.8	
Single[f]	3774	17.6	
Partners			
Age (years)[b]	17 535	81.7	100.0
≤ 20	359	1.7	2.0
21–25	2597	12.1	14.8
26–29	4149	19.3	23.7
30–33	4635	21.6	26.4
≥ 34	5795	27.0	33.0
Unknown	3937	18.3	

[a]Number of pregnancies with a valid value in the variables.
[b]Age during the pregnancy.
[c]Individual women in the cohort and number of births per women during the cohort time period.
[d]At the time of the childbirth.
[e]Married, engaged or living with a partner; and.
[f]Single, widowed, or not living with a partner.

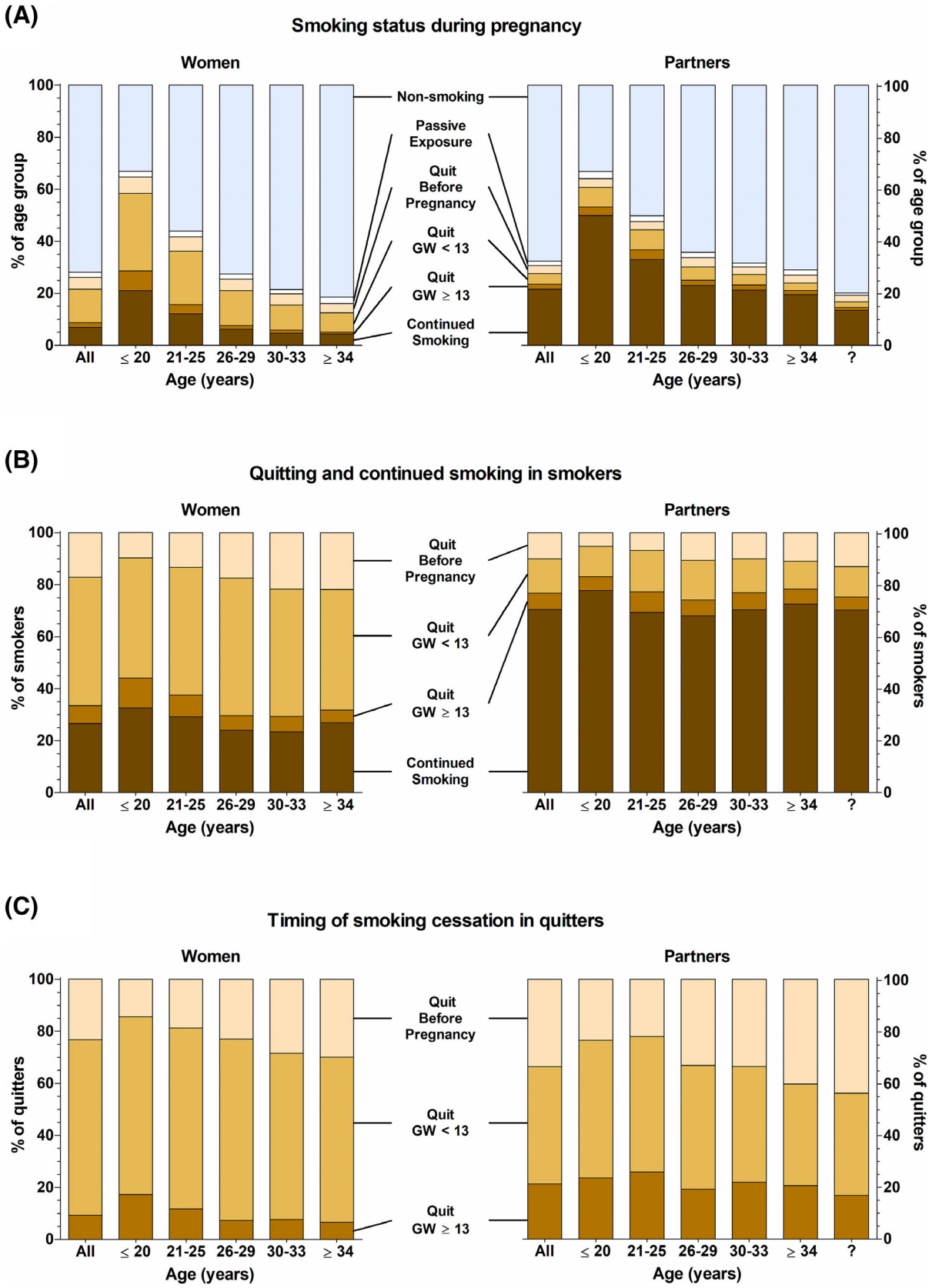


FIGURE 1 Legend on next page.

Software (v. 27.0.1.0) for all data management and statistical analyses.

3 | RESULTS

The demographics of this cohort have been previously described,[22] but key parameters are collected in Table 1. In brief, the cohort consisted of 21 472 singleton pregnancies lasting at least 22 full GWs; the majority of the 14 822 women in the cohort gave birth only once.

The variable validation by combining data from both databases reduced the level of missing and discordant data. For example, after validation there were no missing values in the women's or their partners' 'Smoking status during pregnancy' variables (Supporting Information, Table S1).

About every fourth woman smoked before pregnancy, and in every fifth pregnancy, the foetus was exposed to tobacco because of maternal smoking during pregnancy (Figure 1A). The during-pregnancy smoking included both those who quit smoking at some point during their pregnancy and those who continued to smoke. Most (73.4%) smoking women ceased tobacco use; most frequently early in their pregnancies (GW < 13). The proportion of women quitting before pregnancy increased with their ascending age (Figure 1B, C). In 6.9% of the pregnancies, the women continued smoking throughout the pregnancy (Figure 1B). In about every third pregnancy, the woman's partner was a smoker before she became pregnant (Figure 1A) and less than one third of them quit before or during pregnancy (Figure 1B).

In both parents, the prevalence of smoking in the two youngest age groups was substantially higher than among the older groups (Figure 1A). In addition, the younger women were less likely to quit smoking, or if they did quit, they ceased smoking later in the pregnancy (GW ≥ 13) (Figure 1B, C). When speaking about the percentages of pregnancy cases, most the ≤ 20-year-old women (64.7%) and partners (64.1%) were smoking before pregnancy (Figure 1A). In over a half (58.4%) the foetuses of the ≤ 20-year-old women were exposed to maternal cigarette smoking at least at some time-point during their gestation. Moreover, in every fifth pregnancy (21.1%) the ≤ 20-year-old women continued to smoke throughout their pregnancy (Figure 1A). In the 21–25-year-old parents, the women were smoking in 41.7% and the partners in 47.7% before pregnancy (Figure 1A). In one third (36.2%) the foetuses of the women aged 21–25 years were exposed to maternal cigarette smoking, in fact, 12.2% these women continued to smoke throughout their pregnancy (Figure 1A).

Higher HSIs and CPDs before pregnancy were associated with the likelihood that smoking would continue during pregnancy (Figure 2). However, these effects were more pronounced for the CPD variable where the number of daily smoked cigarettes before pregnancy was clearly able to separate those who would quit smoking before or early in pregnancy (GW < 13) from those who only quit later (GW ≥ 13) or continued to smoke throughout their pregnancy (Figure 2C). The chi-square statistics showed that the parents' 'Smoking status during pregnancy' variables were associated with each other (Chi-Square statistics value 13447.6; df = 25; $p < 0.0001$; Cramer's V 0.35), and compared with their partners, the women smoked less as indicated by CPD and significantly reduced their smoking during pregnancy (Figure 2C, D).

There were positive correlations between the smoking behaviours of both parents (Figure 3); their before-pregnancy values were strongly positively associated with their during-pregnancy smoking (all correlation coefficients > 0.8). For example, the women's and their partners' 'Smoking status during pregnancy' and their 'HSI before pregnancy' variables had $r_s = 0.91$ ($p < 0.0001$) in women almost the same as the value in their partners $r_s = 0.94$ ($p < 0.0001$).

In addition, the smoking behaviours of the women and their partners were positively associated with each other, that is, all smoking variables were positively, moderately ($r_s \approx 0.4$) associated with one another. For example, the correlation between pregnant women's and their

FIGURE 1 The prevalences of women's and their partners' smoking behaviours and smoking cessation. (A) 'Smoking status during pregnancy' categories of women and partners in the N = 21 472 pregnancies. In 18.3% (n = 3937) of the pregnancies, the age of the partner was unknown. Smoking during pregnancy was most common in the youngest (≤ 20 years) women and their partners, as 58.4% and 60.7% had been smoking at some time point during the pregnancy, and 21.1% and 49.9% continued to smoke throughout the pregnancy, respectively. (B) the proportion of quitters and continued smokers among women and partners who had been smoking before the woman became pregnant. Compared to the partners, the pregnant women ceased smoking more frequently. Altogether, in 73.4% of the pregnancies, the women ceased smoking, whereas only 29.5% the partners gave up smoking. Smoking cessation was least prevalent among the youngest (≤ 20 years) age group. (C) the timing of the smoking cessation in women and partners who gave up smoking. In both parents, it was more prevalent to cease smoking during the pregnancy, and most quitters discontinued smoking <13th gestation week. However, in partners, a larger proportion of quitters ceased smoking already before pregnancy when compared to women. Abbreviations: GW: gestation week; ?: age of the partner unknown.

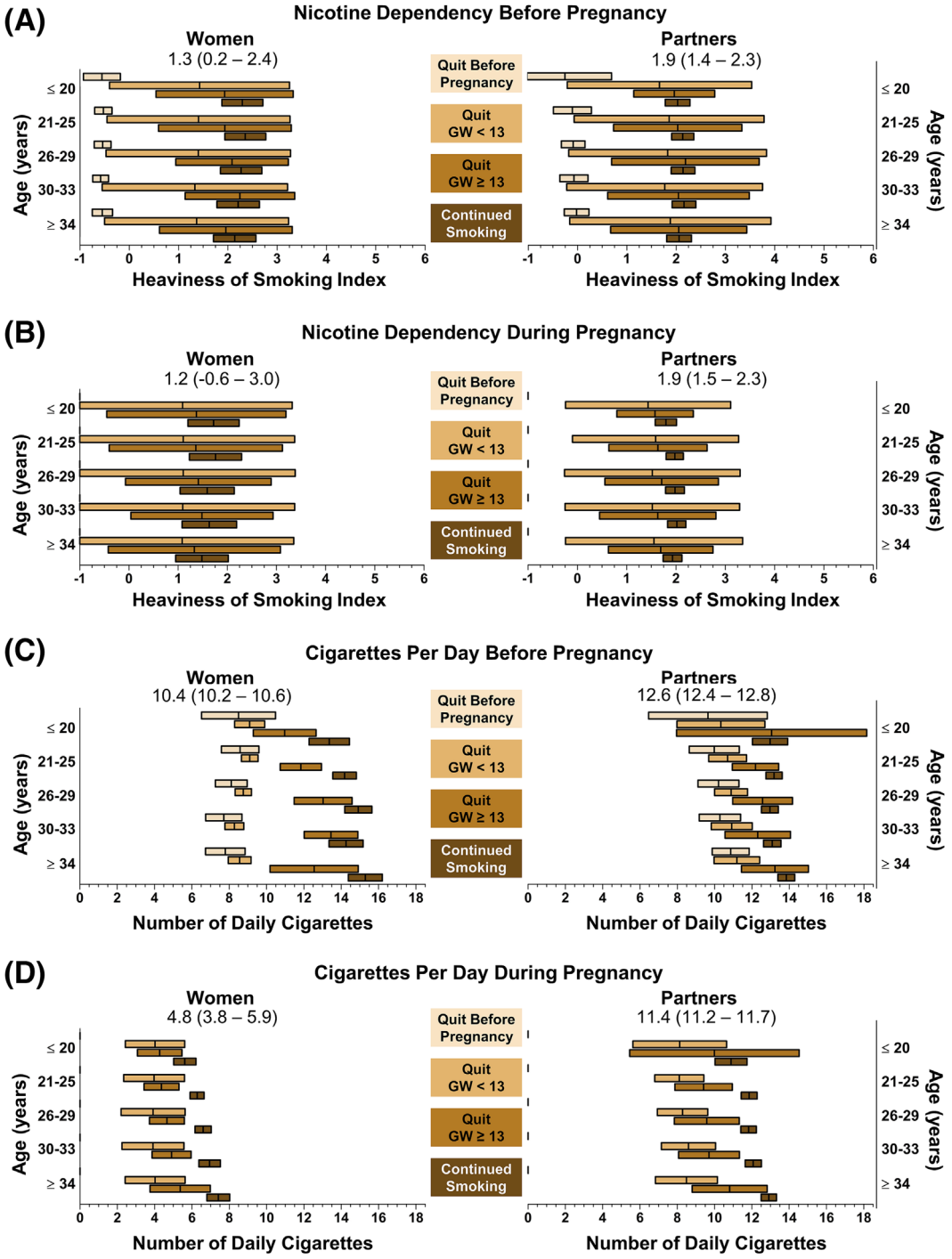


FIGURE 2 Nicotine dependencies and cigarettes per day before and during pregnancy for those who had been smoking. Multiple imputed estimates (mean and 95% CI) of the nicotine dependencies, that is, heaviness of smoking index (HSI) before (A) and during pregnancy (B), and the cigarettes per day before (C) and during pregnancy. (D) these are presented for the age grouped women and partners who according to their 'Smoking status during pregnancy' variable had been smoking before or during pregnancy. Overall, in both parents, a higher HSI (A & B) and a higher number of daily smoked cigarettes (C & D) were associated with later smoking cessation and continued smoking throughout pregnancy. This effect was clearer for the number of cigarettes per day. The HSI can have values −1 (non-smoking), 0–2 (low nicotine dependency), or 3–6 (high nicotine dependency). Note, that because these are MI estimates, there is no 'unknown' age category for partners, and that the variation in the estimates of the youngest (< 20 years) parents was high due to the smaller group sizes.

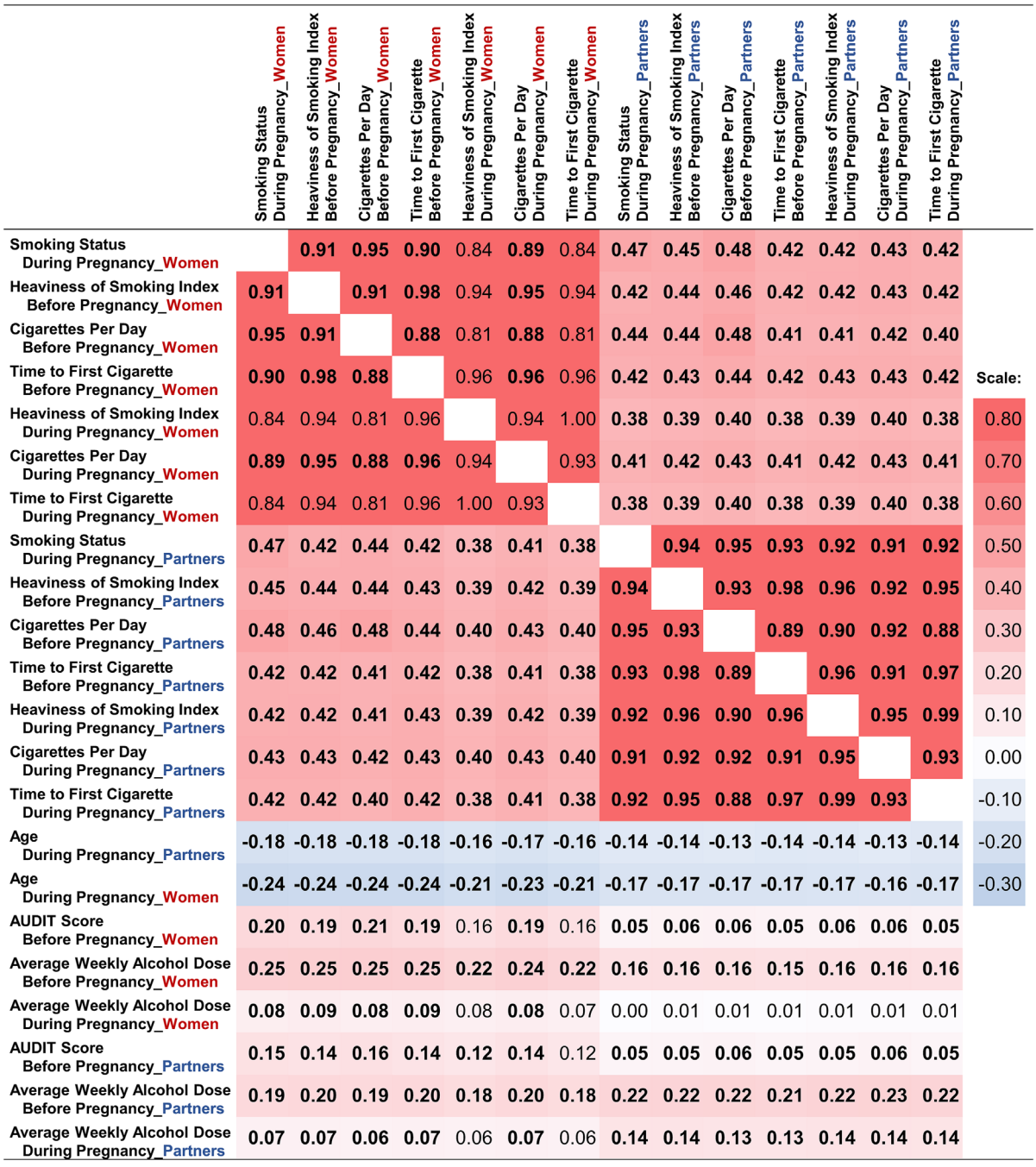
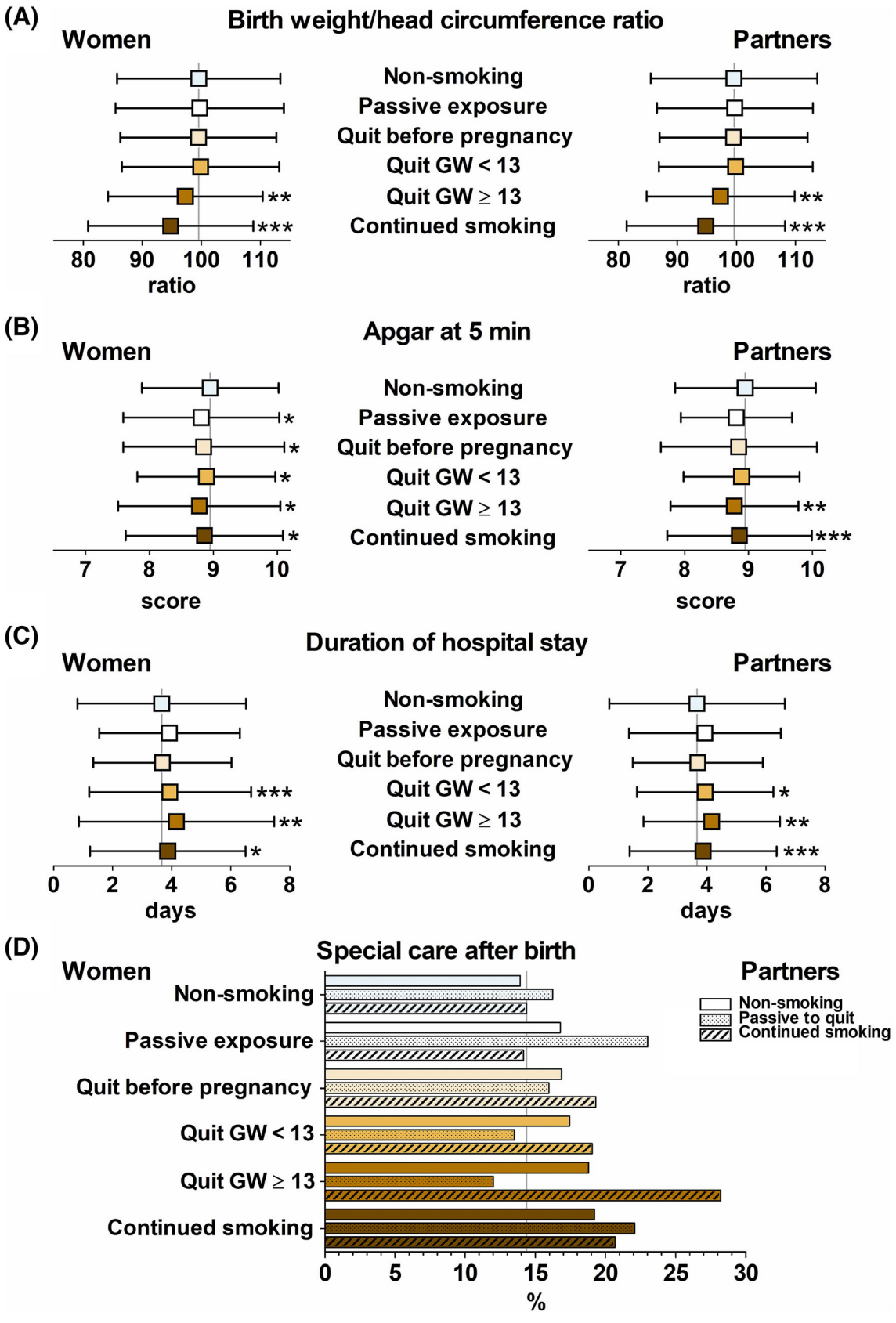


FIGURE 3 Correlations in parental smoking and alcohol use in the multiple imputed data. Spearman rho correlation coefficients between women and their partners' smoking and alcohol use variables in the multiple imputed data with the item score level predictive mean matching method. Due to the multiple imputation, the n in every cell is 21 472. P-values less than multiple testing corrected alpha level ($p < 0.0002$) were considered statistically significant and are indicated in bold. Partners' smoking habits and alcohol use were associated with women's smoking during pregnancy. There were positive correlations between the smoking behaviour of women and their partners both before and during pregnancy ($r_s = 0.38 - .48$), and weak positive correlations between partners' alcohol use before pregnancy and women's smoking before and during pregnancy ($r_s = 0.12 - .20$).

partners' 'Smoking status during pregnancy' variable was 0.47 ($p < 0.0001$) and the partner's CPD before pregnancy correlated with the women's during-pregnancy CPD ($r_s = 0.43$, $p < 0.0001$).

Furthermore, smoking behaviour of the parents was weakly but positively associated with their drinking habits. In women, there were weak positive correlations between their smoking and 'AUDIT score before



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pregnancy' and their 'Average weekly alcohol dose before pregnancy' variables (r_s, 0.19–0.25). In contrast, in their partners, smoking correlated most with their 'Average weekly alcohol dose before pregnancy' ($r_s \approx 0.20$) and 'Average weekly alcohol dose during pregnancy' ($r_s \approx 0.15$) variables. Moreover, the partners' alcohol consumption before pregnancy was positively associated with women's before- and during-pregnancy smoking (r_s, 0.12–0.20).

There were differences in the birth outcomes according to the categories of the 'Smoking status during pregnancy' variable in both women and their partners (Figure 4). Smoking of both parents was associated with reduced birth weight and birth weight/head circumference ratio (Figure 4A). Parental smoking was also negatively associated with the Apgar score at 5 min (Figure 4B) and prolonged the duration of the hospital stay after birth (Figure 4C). Moreover, maternal smoking increased the likelihood of a need of special care of the baby, and this was more pronounced when either the woman or both parents were smokers (Figure 4D).

The results of the sensitivity analyses were in line with the main analyses (Supporting Information, Figure S1, Figure S2, Figure S3, Figure S4, Figure S5 and Figure S6). This indicates that the nonindependence of the pregnancy cases and the MI did not introduce bias to the results.

4 | DISCUSSION

We observed that there is gestational exposure to tobacco in one out of five pregnancies and in 6.9% of the pregnancies the women continued to smoke throughout their pregnancy. The smoking prevalence was inversely correlated with the age of the parents, and the smoking behaviours of women and their partners were positively correlated to each other both before and during pregnancy. Furthermore, the CPD was more useful in estimating the likelihood that the parents would cease to smoke when the woman became pregnant rather than the evaluation of their nicotine dependence with HSI. Smoking status of both parents was associated with adverse birth outcomes.

In our study, the youngest women (≤ 20 years) were most likely to smoke and least likely to quit smoking during pregnancy, in line with previous studies.[8,10–13,15,33] However, even this smoking rate might be an underestimation, since younger women more often tend not to disclose their smoking behaviour.[34] The reasons for more prevalent smoking and continued smoking among the youngest age group may be mental health issues or stress[35] as well as lower education and socioeconomic levels.[36–38] However, it is probable that these young pregnant individuals do not reflect the general ≤ 20 years old Finnish female population since it is rare in Finland to have a child at a young age.[39]

As many as one out of every four women reported smoking before their pregnancy and in more than one fifth of the pregnancies there was gestational exposure to maternal cigarette smoking at some point during the pregnancy. This is in line with a previous global systematic review and meta-analysis[7] and European studies.[19,36] Furthermore, in the present study, in 8.7% of the pregnancies, the women either continued to smoke throughout their pregnancy or stopped smoking only after the 1st trimester. This proportion is close to that reported (8.5%) when smoking was confirmed with the nicotine biomarker cotinine in final trimester blood samples from the same population,[23] and it is also in line with previous European studies.[15,19,40] In contrast to Europe, women in US generally smoke less, as about 10–18% of women smoke before pregnancy and only 4–8% during pregnancy.[7,37,41] The proportion of women smokers quitting smoking (73.4%) here resembled the rate observed in other European studies.[15,18]

We observed strong positive correlations between the smoking behaviour of women and their partners both before and during pregnancy. This is consistent with several studies reporting that partners' smoking is associated with women's continued smoking during their pregnancy.[8,17,18,20,42] In comparison with the women, the partners were more often smokers and less likely to quit smoking. Our proportions of partners smoking, and quitting, are in line with other European studies.[10,18,36,43,44] Furthermore, similarly to a previous study,[44] in our cohort, it was more frequent that partners would cease smoking than quit drinking during the pregnancy.[22]

FIGURE 4 The associations of women's and their partners' smoking behaviours to birth outcomes. The mean and standard deviation of the (A) birthweight/head circumference ratio; (B) Apgar at 5 min; and (C) duration of hospital stay after birth in 'Smoking status during pregnancy' in multiple imputed data (n = 21 472). The one-way Anova was used to compare the groups to the non-smokers and *p*-values < 0.05 (*) were considered statistically significant (** $p < 0.01$, *** $p < 0.0001$). (D) Parental smoking was associated with increased need of specialized treatments (i.e., resuscitation and/or assistance in breathing, treatment for hypoglycaemia, antibiotics, phototherapy and/or other types of intensive care) to the baby either during its birth, in the ward, or in the neonatal intensive care unit.

Moreover, we observed that parental alcohol use before pregnancy was positively correlated with their smoking patterns during pregnancy, and that the partners' alcohol use was positively associated with the women's smoking behaviour during pregnancy. These results are in line with several previous reports,[17,20,45] although there are also conflicting results on how women's drinking is associated with their smoking behaviour during pregnancy.[42] In our previous report from the same cohort, we showed that women's and their partners' alcohol consumptions were positively associated.[22]

Our results indicate the importance of screening the smoking and alcohol use behaviours of both women and their partners which means that the reproductive health and maternity care services should focus more attention on the pregnant women's partners. By evaluating the smoking behaviour of the partners, it might help to identify those women at risk of continuing to smoke cigarettes during their pregnancy, as well as those families who would need more support and counselling on lifestyle changes. Likewise, since it has been demonstrated that if the partner can kick the smoking habit, this increases the woman's success in smoking cessation,[8,18,20] it should be stressed that it is important that the partner should stop, or at least reduce the number of cigarettes smoked, already before pregnancy. Furthermore, partners' smoking cessation during the pregnancy has been independently associated with a reduced risk of their child becoming asthmatic.[10]

Although in our cohort the maternal smoking did not affect the duration of the pregnancy (data not shown), smoking behaviours of both parents were associated with reduced birth weight and decreased birth weight/head circumference ratio. This is in line with studies reporting smoking during pregnancy affects foetal growth.[3,46] Parental smoking was also associated with reduced early health of the new-born as seen in lower Apgar scores, and increased duration of hospital stay and need for special care after birth. Previously, maternal cigarette smoking has been linked with increased need for maternal hospital treatment during pregnancy.[47] In contrast, quitting early has been shown to decrease the risks of adverse birth effects to the levels seen in non-smokers.[3,4] However, in our study, only quitting before pregnancy reduced the risk of negative effects to the birth outcomes to the levels observed in non-smoking pregnancies.

Finally, in agreement with several other reports, we observed that the CPD before pregnancy was a strong predictor for smoking cessation during pregnancy.[11,37,38,48–50] There may be several reasons why the HSI itself was not a good predictor in our study even though it has previously been shown to be a predictor for abstinence.[17] For example, in the HSI, the CPD is a categorical variable which reduces variability.[50] Thus, although, the HSI test is valid for measuring nicotine dependency during pregnancy,[21,51] the total HSI score does not seem to be the best predictor for smoking cessation,[49,52] since CPD as a continuous variable seems to outperform it. Moreover, the majority of the parents in this study were < 40 years old who often do not smoke inside their homes,[53,54] which can affect the time to first cigarette (TTFC) item and the usefulness of the HSI test in this population.

Our study had some limitations. First, the data on smoking relied on women's self-reporting. Second, we had no information on how many individual partners there were in the cohort. In addition, because the education level of the parents or whether smoking was a daily practice was not addressed in the questionnaires, we could not analyse their effects on the smoking behaviour. Third, examining dose–response associations with parental smoking and adverse birth outcomes was not possible since evaluating gestational exposure in other than categories of 'Smoking status during pregnancy' variable would have been unreliable with the available data.

Our study has several strengths. First, our cohort was large, depicting 95% of all childbirths in the area during the timeframe studied, and it had information on the smoking patterns of both parents before and during pregnancy. Second, an electronic questionnaire was used to reduce the social desirability bias. Furthermore, there were multiple questions in the questionnaire screening parental smoking before and during pregnancy, which enabled data validation. Third, we used MI that utilizes all the collected data, takes into account the doubt in imputed values, and produces less biased estimates.

In conclusion, addressing the smoking behaviour of both parents in the health care and maternity clinics could help in reducing maternal cigarette smoking during pregnancy. We believe that it would be important that smoking partners should be informed on how smoking cessation will improve their own health as well as their baby's. Furthermore, the number of cigarettes smoked per day before pregnancy seems to outperform HSI when assessing the likelihood of smoking cessation.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Because of confidentiality of the data and materials they are available only for authorized personnel and cannot be publicly distributed.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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