Associations of Education and Income with Secondhand Smoke Exposure Among Non-smoking Pregnant Women in Japan: The Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study

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Abstract

Objectives  There is accumulating evidence that lower socioeconomic groups are more exposed to secondhand smoke (SHS) than higher ones in the general population. The objective of the study was to examine the associations of education and income with SHS exposure among non-smoking pregnant women in Japan.

Methods  We analyzed data from 11,615 non-smoking pregnant women in Japan who participated in the Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study from 2013 to 2017. SHS exposure was defined as indoor exposure to someone else’s cigarette smoke ≥ 1 day/week during pregnancy. Multiple logistic regression analyses were conducted to examine whether pregnant women’s educational attainment or equivalent household income was associated with SHS exposure, adjusting for covariates. Stratified analyses by work status were also conducted.

Results  The prevalence of SHS exposure during pregnancy was 32.6%; 27.6% among non-working women and 35.8% among working women. Lower educational attainment was associated with an increased risk of SHS exposure; the odds ratio of high school education or lower compared with university education or higher was 1.87 (95% confidence interval, 1.66–2.10). Lower equivalent household income was associated with an increased risk of SHS exposure; the odds ratio of the lowest compared with the highest level of income was 1.53 (95% confidence interval, 1.35–1.74). These associations did not differ between non-working women and working women.

Conclusions for Practice  Associations of education and income with SHS exposure imply that educational interventions and financial incentives are needed for pregnant women and their household smokers.

Significance

What is already known on this subject? Secondhand smoke exposure during pregnancy has negative consequences for pregnancy and infant outcome. Education and income have been suggested to be associated with secondhand smoke exposure during pregnancy.

What this study adds? We found that about one-third of pregnant women were exposed to secondhand smoke in Japan. Pregnant women with lower educational attainment and/or lower equivalent household income had significantly higher risks of secondhand smoke exposure than pregnant women with higher education and/or income.

Keywords  Education · Income · Japan · Pregnant women · Secondhand smoke exposure

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Introduction

There is growing evidence that secondhand smoke (SHS) exposure during pregnancy has negative consequences for pregnancy and infant outcomes; the 2006 Surgeon General’s Report concluded that the evidence is sufficient to infer a causal association between SHS exposure during pregnancy and a small reduction in birth weight (U.S. Department of Health & Human Services, 2006). More recent studies have demonstrated that SHS exposure during pregnancy is associated with increased risks of stillbirth and congenital anomalies (Leonardi-Bee et al., 2011; Salmasi et al., 2010). To design appropriate public health policies, it is important to understand which women are most affected by SHS exposure during pregnancy.

Studies examining the association of education and income with SHS exposure during pregnancy are limited (Aurrekoetxea et al., 2014; Do et al., 2018; Hawkins et al., 2014; Hikita et al., 2017; Madureira et al., 2020; Reece et al., 2019; Vardavas et al., 2010), while there is accumulating evidence that lower socioeconomic groups are more exposed to SHS than higher ones in the general population (Gan et al., 2015; Nazar et al., 2016; U.S. Department of Health & Human Services, 2006; WHO Regional Office for Europe, 2019). Although education and income reflect the central dimension of social stratification, they have different meanings in society; education is thought to capture knowledge and skills, while income measures material resources to enhance health (Galobardes et al., 2006). Existing studies among pregnant women have mainly focused on education (Aurrekoetxea et al., 2014; Do et al., 2018; Hikita et al., 2017; Madureira et al., 2020; Reece et al., 2019; Vardavas et al., 2010), and the association between income and SHS exposure have rarely been examined (Hawkins et al., 2014). To the best of our knowledge, no studies have examined the association of education and income with SHS exposure during pregnancy in Japan. Studies in Japan are needed because Japanese people have unique characteristics of tobacco use and SHS exposure. The difference in smoking prevalence between men and women is larger in Japan than in most OECD countries (OECD, 2019); the prevalence of smoking was 31.1% among men and 9.5% among women in the national survey in 2016 (Ministry of Health, Labour and Welfare, 2018). In addition, World Health Organization (WHO) report in 2015 ranked Japan the lowest among the Framework Convention on Tobacco Control ratifying countries with regard to implementing preventive measures against SHS exposure (World Health Organization, 2015).

Considering the above circumstances, we conducted the present study to examine the associations of education and income with SHS exposure among pregnant women in Japan. In addition, we also examined these associations by work status, because work status is associated with education and income (Galobardes et al., 2006).

Methods

Study Population

Data were obtained from the Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study (TMM Birth Three Cohort Study), which has been described elsewhere (Kuriyama et al., 2020). Pregnant women and their family members, including the women’s partners (the fathers of the fetuses), were contacted in obstetric clinics or hospitals when they scheduled their deliveries from 2013 to 2017. Approximately fifty obstetric clinics and hospitals in Miyagi Prefecture participated in the recruiting process. Trained genome medical research coordinators provided information on the TMM BirThree Cohort Study to potential participants and received a signed informed consent form from each participant. Of 32,968 pregnant women who were contacted, 22,493 agreed to participate in the study and 20,647 completed the questionnaires during pregnancy. Among these women, 147 with missing data on smoking status and 626 smokers were excluded. Of the remaining 19,874 non-smoking pregnant women, 8259 were excluded because of missing values in educational attainment, equivalent household income, SHS exposure, or work status during pregnancy. The remaining 11,615 non-smoking pregnant women were included in the present study. Figure 1 shows the flow diagram of the present study. The characteristics of 11,615 women included in the analysis and 8259 excluded women are shown in Supplementary Table.

Measures

Pregnant women reported their educational attainment, which were divided into three categories: high school or lower (elementary, junior high school, or senior high school), college (2-year college or special training school), and university or higher (university or graduate school). Pregnant women were asked to select their total annual household income (including taxes) from seven categories: ≤ 1.99, 2.00–3.99, 4.00–5.99, 6.00–7.99, 8.00–9.99, 10.00–11.99, and ≥ 12.00 million Japanese yen (JPY). Equivalent household income was calculated as household income divided by the square root of the number of family members (Atkinson et al., 1995), and the resulting value was categorized into four groups: ≤ 1.99, 2.00–2.99, 3.00–3.99, and ≥ 4.00 million JPY, which corresponded approximately to quartiles. Work status during pregnancy was measured by how many days
per week the women worked. The response of > 0 days was defined as working.

SHS exposure during pregnancy was measured by how often women reported being exposed to the cigarette smoke of someone else indoors. The responses were almost never, 1 day/week, 2–3 days/week, 4–6 days/week, or every day. SHS exposure was defined as 1 day/week or more. This categorization was based on the idea that there is no safe amount of SHS and that breathing even a little SHS can be dangerous (U.S. Department of Health & Human Services, 2006). Age was categorized into five groups: ≤ 24, 25–29, 30–34, 35–39, and ≥ 40 years. Women’s smoking history was categorized as never smoked, quit before becoming aware of the pregnancy, and quit after becoming aware of the pregnancy. If the women’s partners participated in the TMM BirThree Cohort Study, they reported their educational attainment on the questionnaire at the time of enrollment. This variable was categorized into the same three groups used to categorize the women’s educational attainment.

Statistical Analysis

Multiple logistic regression analyses were conducted to examine the associations of education and income with SHS exposure during pregnancy. We calculated the odds ratios (ORs) and 95% confidence intervals (CIs) for education and income, adjusted for women’s age (model 1), as well as for work status during pregnancy, smoking history, and partner’s education (model 2a for education and model 2b for income). We then included income and education simultaneously in the same model (model 3). Variance inflation factors for education and income were within acceptable limits (< 2.0), indicating no serious problems of collinearity. We also stratified our models by work status, and examined whether this modified the association by including interaction terms in the models.

All analyses were conducted with SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). For all analyses, a two-tailed P value < 0.05 was considered statistically significant.

Results

Table 1 shows the characteristics of non-smoking pregnant women. Prevalence of SHS exposure during pregnancy was 32.6%. A total of 61.0% was working during pregnancy. Working women were higher educated, had higher equivalent household income, were more likely to be exposed to SHS and more likely to be never smokers than non-working women.

Table 2 presents the prevalence, ORs and 95% CIs for SHS exposure during pregnancy. Lower educational attainment was associated with an increased risk of SHS exposure after adjusting for age (model 1) and after additionally adjusting for women’s work status, smoking history, and partner’s educational attainment (model 2a); the adjusted ORs of high school education or lower compared with university education or higher were 2.53 (95% CI, 2.28–2.81), and 2.07 (95% CI, 1.85–2.32), respectively. After further adjustments for equivalent household income,
this association was somewhat attenuated but did not disappear; the corresponding OR was 1.87 (95% CI, 1.66–2.10). Lower equivalent household income was associated with an increased risk of SHS exposure after adjusting for age (model 1) and after additionally adjusting for women’s work status, smoking history, and partners’ educational attainment (model 2b); the adjusted ORs of ≤ 1.99 million JPY compared with ≥ 4.00 million JPY income were 1.89 (95% CI, 1.68–2.11), and 1.80 (95% CI, 1.60–2.04), respectively. After further adjustments for women’s educational attainment, this association was somewhat attenuated but did not disappear; the corresponding OR was 1.53 (95% CI, 1.35–1.74). Younger age and working during pregnancy were associated with increased risks of SHS exposure. Women who had quit smoking before pregnancy awareness and women who had quit smoking after pregnancy awareness had increased risks of SHS exposure compared with women who had never smoked: the adjusted ORs were 1.34 (95% CI, 1.22–1.48) and 3.05 (95% CI, 2.69–3.46), respectively. Having a partner with lower education was associated with an increased risk of SHS exposure; the adjusted OR of high school education or lower compared with university education or higher was 1.52 (95% CI, 1.30–1.78).

Table 3 presents the results of the analyses stratified by work status. Lower educational attainment was associated with an increased risk of SHS exposure both among non-working women and working women; the adjusted ORs of high school education or lower compared with university education or higher were 1.52 (95% CI, 1.30–1.78). No significant interaction was found between work status and educational attainment (P = 0.58). Lower equivalent household income

| Table 1 | Characteristics of non-smoking pregnant women: the TMM BirThree Cohort Study |
|---|---|---|---|
| | Total (N = 11,615) | Work status | P-value* |
| | | Not working (n = 4526) | Working (n = 7089) |
| Educational attainment |  |  | < 0.001 |
| University or higher | 3487 (30.0) | 1150 (25.4) | 2337 (33.0) |
| College | 4546 (39.2) | 1729 (38.2) | 2817 (39.7) |
| High school or lower | 3582 (30.8) | 1647 (36.4) | 1935 (27.3) |
| Equivalent household income (/year) |  | < 0.001 |  |
| ≥ 4.00 million Japanese yen | 3125 (26.9) | 757 (16.7) | 2368 (33.4) |
| 3.00–3.99 million Japanese yen | 2187 (18.8) | 719 (15.9) | 1468 (20.7) |
| 2.00–2.99 million Japanese yen | 3678 (31.7) | 1700 (37.6) | 1978 (27.9) |
| ≤ 1.99 million Japanese yen | 2625 (22.6) | 1350 (29.8) | 1275 (18.0) |
| Secondhand smoke exposure |  | < 0.001 |  |
| Almost never | 7828 (67.4) | 3275 (72.4) | 4553 (64.2) |
| 1 day/week or more | 3787 (32.6) | 1251 (27.6) | 2536 (35.8) |
| Age |  | < 0.001 |  |
| ≤ 24 years | 668 (5.7) | 321 (7.1) | 347 (4.9) |
| 25–29 years | 2977 (25.6) | 1120 (24.7) | 1857 (26.2) |
| 30–34 years | 4445 (38.3) | 1683 (37.2) | 2762 (39.0) |
| 35–39 years | 2864 (24.7) | 1117 (24.7) | 1747 (24.6) |
| ≥ 40 years | 661 (5.7) | 285 (6.3) | 376 (5.3) |
| Smoking history |  | < 0.001 |  |
| Never smoked | 7467 (64.3) | 2813 (62.2) | 4654 (65.6) |
| Quit before pregnancy awareness | 2829 (24.3) | 1177 (26.0) | 1652 (23.3) |
| Quit after pregnancy awareness | 1319 (11.4) | 536 (11.8) | 783 (11.1) |
| Partner’s educational attainment |  |  | 0.011 |
| University or higher | 1945 (16.7) | 775 (17.1) | 1170 (16.5) |
| College | 949 (8.2) | 324 (7.2) | 625 (8.8) |
| High school or lower | 1669 (14.4) | 640 (14.1) | 1029 (14.5) |
| Missing | 7052 (60.7) | 2787 (61.6) | 4265 (60.2) |

TMM BirThree Cohort Study, Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study

*Obtained using the chi-squared test, comparing work status categories
was associated with an increased risk of SHS exposure both among non-working women and working women; the adjusted ORs of ≤ 1.99 million JPY compared with ≥ 4.00 million JPY income were 1.28 (95% CI, 1.02–1.60), and 1.66 (95% CI, 1.42–1.94), respectively (model 3). No significant interaction was found between work status and equivalent household income \( (\text{P}=0.18) \).

### Discussion

The present study examined the associations of education and income with SHS exposure among pregnant women in Japan. About one-third of pregnant women reported being exposed to SHS. Pregnant women with lower education and/or lower equivalent household income had significantly higher risks of SHS exposure than pregnant women with higher education and/or income. These associations did not differ between non-working women and working women.

Lower education was associated with an increased risk of SHS exposure during pregnancy, independent of equivalent household income. There are several possible explanations for this association. First, education conveys factual health-related knowledge (Glymour et al., 2014), and lower educated people working jobs offering few opportunities for learning may have limited knowledge of the harmful effects of unhealthy behaviors (Pampel et al., 2010). WHO guidelines recommend that health care providers should provide pregnant women with advice and information about the risks...
of SHS exposure (World Health Organization, 2013), reflecting the importance of knowledge of the risks of SHS exposure among pregnant women. Second, education raises cognitive skills that foster health-promoting decisions (Cutler & Lleras-Muney, 2010; Glymour et al., 2014). Hence, education may increase individuals’ understanding of the negative effects of SHS exposure and build their capacity to manage their own SHS exposure (Pampel et al., 2010). Women’s capacity to manage their SHS exposure is affected by the intersecting influences of gender roles and power (Greaves & Hemsing, 2009). A small number of clinical interventions have suggested that providing brief advice or counseling to non-smoking pregnant women may reduce their SHS exposure (Tong et al., 2015). Third, education increases the chances of having a well-educated partner (Glymour et al., 2014). Men with lower education have been found to have a higher risk of current smoking, especially among the young population, in Japan (Tabuchi & Kondo, 2017), and SHS from partners is a major source of exposure for non-smoking women (Aurrekoetxea et al., 2014). We previously reported that lower levels of education were associated with an increased risk of indoor smoking among the partners of non-smoking pregnant women (Murakami et al., 2021). However, the present study showed that women’s education was associated with SHS exposure after adjusting for partner’s education. Fourth, social networks, which combine individuals’ resources with those of others (Berkman & Krishna, 2014), may also partially explain the observed association. Having a higher level of education increases the chances of associating with other highly educated individuals, and social networks made up of such individuals communicate health-promoting behaviors, thus widening disparities by educational attainment (Berkman & Krishna, 2014; Glymour et al., 2014; Pampel et al., 2010). Higher levels of education also correspond to a greater likelihood of friends emulating each other’s smoking behavior (Christakis & Fowler, 2008), which could lead to an association between education and SHS exposure.

We also found that lower equivalent household income was associated with an increased risk of SHS exposure during pregnancy, independent of education. This association was observed among non-working women as well as among working women. This result suggests that the partners and other household members of pregnant women with lower

| Table 3 | Associations of education and income with SHS exposure by work status among non-smoking pregnant women |
|---------|----------------------------------------|--------|-----------|--------|-----------|
|         | SHS exposure/participants (%)          | Model 1 | Model 2a  | Model 2b | Model 3  |
|         | OR (95% CI)                            | OR (95% CI) | OR (95% CI) | OR (95% CI)  |
| Educational attainment | Not working (n=4526) | | | | |
| University or higher | 205/1150 (17.8) | 1.00 | 1.00 | 1.00 |
| College | 413/1729 (23.9) | 1.45 (1.20–1.75) | 1.29 (1.07–1.57) | 1.26 (1.04–1.53) |
| High school or lower | 633/1647 (38.4) | 2.63 (2.19–3.16) | 1.99 (1.64–2.42) | 1.90 (1.56–2.31) |
| Working (n=7089) | | | | |
| University or higher | 582/2337 (24.9) | 1.00 | 1.00 | 1.00 |
| College | 1011/2817 (35.9) | 1.67 (1.48–1.89) | 1.43 (1.26–1.62) | 1.32 (1.16–1.50) |
| High school or lower | 943/1935 (48.7) | 2.73 (2.39–3.11) | 2.11 (1.83–2.42) | 1.83 (1.58–2.12) |
| Equivalent household income (/year) | Not working (n=4526) | | | | |
| ≥ 4.00 million Japanese yen | 157/757 (20.7) | 1.00 | 1.00 | 1.00 |
| 3.00–3.99 million Japanese yen | 157/719 (21.8) | 1.02 (0.79–1.31) | 0.95 (0.73–1.23) | 0.93 (0.72–1.21) |
| 2.00–2.99 million Japanese yen | 470/1700 (27.7) | 1.36 (1.10–1.68) | 1.19 (0.96–1.48) | 1.13 (0.91–1.41) |
| ≤ 1.99 million Japanese yen | 467/1350 (34.6) | 1.77 (1.43–2.20) | 1.44 (1.15–1.80) | 1.28 (1.02–1.60) |
| Working (n=7089) | | | | |
| ≥ 4.00 million Japanese yen | 642/2368 (27.1) | 1.00 | 1.00 | 1.00 |
| 3.00–3.99 million Japanese yen | 487/1468 (33.2) | 1.29 (1.12–1.49) | 1.21 (1.05–1.40) | 1.13 (0.97–1.31) |
| 2.00–2.99 million Japanese yen | 788/1978 (39.8) | 1.72 (1.51–1.96) | 1.51 (1.32–1.73) | 1.35 (1.18–1.55) |
| ≤ 1.99 million Japanese yen | 619/1275 (48.6) | 2.45 (2.12–2.83) | 1.98 (1.71–2.30) | 1.66 (1.42–1.94) |

CI: confidence interval; OR: odds ratio; SHS: secondhand smoke
Model 1: adjusted for age
Model 2a (for education) and 2b (for income): model 1 + adjusted for smoking history and partner’s educational attainment
Model 3: model 2 + adjusted for equivalent household income/educational attainment
equivalent household income might be more likely to smoke, compared with those with higher equivalent household income. The association between lower income and smoking has been consistently shown (Casetta et al., 2017), including among community-dwelling people in Japan (Fukuda et al., 2005). One possible mechanism by which lower income has been hypothesized to be associated with smoking is that people with lower income are more susceptible to the tobacco industry’s marketing strategy of glamorizing smoking by associating it with wealth and success (Casetta et al., 2017). Banning advertising that gives the impression that smoking is attractive might be useful, although the impact of advertising bans on socioeconomic inequalities in smoking has not been demonstrated (Hill et al., 2014). A higher prevalence of smoking among lower-income individuals may also be explained by several other factors such as the frequent normalization of smoking and earlier smoking initiation, less concern about harm caused by smoking, poorer access to smoking cessation resources, and more difficulty with successfully quitting among this group (Casetta et al., 2017; Hill et al., 2014). Adopting many health behaviors does not require money (Glymour et al., 2014), but paying for smoking cessation aids such as individual counseling and medications can help individuals to realize their desire to quit (Pampel et al., 2010). According to WHO guidelines, health care providers should give partners and other household members advice and information about the risks to pregnant women from SHS exposure and, if possible, also provide them with cessation support (World Health Organization, 2013). Effective interventions to create smoke-free homes alongside smoking cessation for them, perhaps involving financial incentives, need to be developed (Dherani et al., 2017; Nwosu et al., 2020). On the other hand, we also found that working women, who had higher equivalent household income, were more likely to be exposed to SHS than were non-working women. This suggests that measures against SHS exposure at work, such as totally smoke-free workplace policies, should also be implemented (Fichtenberg and Glantz 2002). Smoke-free policies tend to focus on enclosed public and workplaces but tend not to tackle home and car settings (Semple et al., 2022). However, there is a need for further international attention on SHS exposure for workers not currently protected by existing smoke-free laws such as home health and community care workers whose jobs involve providing care and assistance in domestic settings (Angus & Semple, 2019).

To our knowledge, this is the first study to demonstrate the associations of education and income with SHS exposure during pregnancy in Japan. By examining education and income simultaneously, we showed independent associations between SHS exposure and both education and income, which have different meanings in society (Galobardes et al., 2006). Although Japan lagged behind Western countries in terms of preventive measures against SHS exposure (World Health Organization, 2015), the Health Promotion Act, which was partially revised in July 2018 and came into full force in April 2020, prohibits smoking in public facilities other than designated smoking areas in those facilities. This measure is expected to be beneficial for reducing SHS exposure for non-smoking pregnant women (Schechter et al., 2018). Nevertheless, the association of education and income with SHS exposure in Japan should continue to be monitored after the introduction of this national smoking ban, because smaller magnitudes of declines in SHS exposure for lower socioeconomic groups than for higher socioeconomic groups have been found to increase the disparity in SHS exposure between these groups in the United States (Gan et al., 2015).

The present study has several limitations. First, we were able to analyze data from approximately half of the pregnant women who agreed to participate in the TMM BirThree Cohort Study. The women who were excluded from the analysis were less educated, had lower equivalent household income, and were more likely to be exposed to SHS, compared with the women who were analyzed (Supplementary Table), leading to an underestimation of the associations of education and income with SHS exposure. Second, this study was conducted at one of 47 prefectures in Japan; therefore, the generalizability of the present study is limited. However, there is little difference between the prevalence of smoking in Miyagi Prefecture and that reported in a national survey in 2016: 33.4% among men and 9.7% among women in Miyagi Prefecture and 31.1% among men and 9.5% among women (Ministry of Health, Labour and Welfare, 2018). Finally, SHS exposure was self-reported. It is possible that some women underreported active smoking and also SHS exposure because smoking has become more socially unacceptable (Nishihama et al., 2020; Shipton et al., 2009).

Conclusion

Women with lower education and/or lower income had higher risks of SHS exposure during pregnancy in Japan. These associations did not differ between non-working women and working women. These findings imply that educational interventions and financial incentives are needed for pregnant women and their household smokers in helping to reduce SHS exposure among non-smoking pregnant women.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10995-023-03648-x.

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Author Contributions KM was responsible for the study conception, design, analysis, interpretation of the data, and the drafting of the manuscript. TO, MI, FU, AN contributed to data collection and provided critical feedback. SK provided advice regarding critically important intellectual content and helped to draft the manuscript. All authors have read and approved the final manuscript.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval The TMM BirThree Cohort Study protocol was reviewed and approved by the Ethics Committee of Tohoku University Tohoku Medical Megabank Organization (2013–1–103–1).

Consent to Participate Participants gave informed consent prior to participation.

Consent to Publish Not applicable.

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