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# Family Income and Low Birth Weight in Term Infants: a Nationwide Study in Israel

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## Abstract

**Objectives** To explore the influence of income on Low Birth Weight (LBW), taking into account other socio-economic measurements.

**Methods** This retrospective cohort study is based on the Israel National Insurance Institute (NII) database. The study population included 58,454 women who gave birth between 2008 and 2013 to 85,605 infants. Only singleton births at term (gestational age in weeks = 37 and later) were included. Logistic regression models with a Generalized Estimating Equation approach were used in order to assess the independent effect of income and Socio-Economic Regional Index (SERI), maternal age, family status, population group and occupational status on LBW. In addition, sibling analysis was conducted to assess the influence of a change in income on birth weight (BW) among 21,998 women.

**Results** Lower income was associated with higher odds of LBW (odds ratio (OR) = 1.266; 95% CI:1.115–1.437. Immigrants from Ethiopia, Bedouins from the Negev, the youngest, the oldest, and single mothers had higher odds for LBW newborns. Compared to women whose income quartile had not changed between the most recent and the first births, for women who experienced a deterioration of three and two quartiles in family income, significantly lower birth weight was observed at the time point with lower income: 103 g ($p = .049$) and 71 g ($p = .008$), respectively. Improvement in income revealed an almost linear increase in birth weight.

**Conclusions for Practice** In an effort to prevent LBW associated mortality and diseases, interventions should be focused first of all on women from population groups who are disadvantaged.

**Keywords** Low Birth Weight · Income · Socio-Economic Position · Population group

## Significance

What is already known about this subject:

LBW among infants who were born at term is influenced by a wide range of factors of which one is Socio-Economic Position (SEP) and it is associated with major diseases occurring during early childhood and later in life. Researchers have hypothesized that the pathway from disadvantaged SEP to LBW goes through higher stress level, living in areas with higher pollution, maternal smoking, younger maternal age, less favorable nutritional state and reduced recourse to prenatal services during pregnancy.

What this study adds:

Higher income was found to be associated with lower odds of LBW, after taking into account other SEP-related variables and population group. When the change in infant birth weight was checked for the same women, it was found that a change in family income was associated with a higher

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probability of a baby with LBW if this change was for the worse and with a lower probability of LBW if the income of the family improved**.** SERI was not associated with LBW, separately from income. Better understanding the pathway through socio-economic position to LBW may help in preventing LBW at term.

## Introduction

The World Health Organization (WHO) has defined low birth weight (LBW) as a baby's weight at birth of less than 2500 g (Cutland et al., 2017). LBW is not only associated with higher infant, child and adolescent mortality (Watkins et al., 2016), but recent research suggests that several of the major diseases occurring later in life, including coronary heart disease, hypertension and Type 2 diabetes partially originate in impaired intrauterine growth and development which is reflected by LBW (Gluckman, 2007; Kajantie et al., 2005; Lillycrop & Burdge, 2012; Lin et al., 2017; Osmond & Barker, 2000).

Low birth weight among infants who were born at term is influenced by a wide range of factors one of which is Socio-Economic Position (SEP). SEP is assessed using education, income, occupation or neighborhood socio-economic status (Lamy et al., 2019). A recent meta-analysis of 26 studies revealed that women with higher education experience have a 33% reduction in the odds of LBW compared to women with low education (OR = 0.67; 95% CI: 0.61–0.74) and literate women have 35% lower odds of giving birth to a LBW infant compared to illiterate women (OR = 0.65; 95% CI: 0.46–0.93) (Godah et al., 2021). Review of 21 studies concluded that lower SEP measured by any of socio-economic related indicators is associated with higher risk of LBW. For example, in a Canadian cohort, women whose family income was less than $12,000 were two times more likely to have a LBW baby (OR 2.06; 95% CI: 1.02- 4.15) (Campbell & Seabrook, 2016).

Researchers hypothesized that there are several pathways from disadvantaged SEP to LBW. First of all, higher stress level among women from low SEP is associated with exposure of the fetus to higher levels of cortisol, while high intrauterine cortisol exposure can inhibit fetal growth (Ae-Ngibise et al., 2019; Campbell & Seabrook, 2016; Cozzani et al., 2021; Seth et al., 2015). In addition, younger maternal age is observed among women from lower SEP, while younger maternal age is associated with LBW (Wang et al., 2020). Lower SEP is associated with a less favorable nutritional state (Hong et al., 2005; Wubetu et al., 2021). Another pathway leads from low SEP to LBW through less favorable environmental conditions of living; higher levels of outdoor air pollutants (Yitshak-Sade et al., 2016) and lower residential greenness are more common in disadvantaged SEP areas (Jacobs et al., 2017; Ricciardi & Guastadisegni, 2003). Finally, smoking and alcohol consumption (Sbrana et al., 2016) and reduced usage of antenatal health services (Oulay et al., 2018; Zhou et al., 2019) comprise behavioral trends which are more frequent among low SEP and are associated with LBW.

To the best of our knowledge none of the above mentioned studies evaluated the change in maternal income on the risk of LBW using sibling analysis which controls for observed and unobserved shared (familial) confounding (Frisell et al., 2012; Strully & Mishra, 2009; Susser et al., 2010).

Although the odds for LBW at term significantly decreased in Israel by 19% in 2014 compared to 2000, 2.6% of babies born at term still have LBW (Agay-Shay, Michael, et al., 2018; Agay-Shay, Rudolf, et al., 2018). There are inequalities and gaps between sub-populations in Israel related to health indicators in general and in birth-related outcomes in particular. The population in Israel comprises 9,291,000 residents; 6,870,000 are Jews (74% of the total population); 1,956,000 are Arabs (21%); and 456,000 are Others (4.0%) (Central Bureau of Statistics, 2021). During 2020, approximately 176,000 infants were born: 73.8% born to Jewish mothers, 23.4% to Arab mothers and 2.8% to mothers of Others (Central Bureau of Statistics, 2021).

Almost 20% of the Jewish population comprise immigrants from Russia and the other Former Soviet Union (FSU) republics who arrived after 1989 (INSS, 2021). Immigrants from the FSU areas are generally a highly educated and professionally qualified group who underwent successful integration into Israeli society (Glöckner, 2010; Khanin, 2010). In a study conducted in 2017, Jewish women from the FSU had significantly lower risk for LBW newborns compared to Israeli born mothers (Lubotzky-Gete et al., 2017).

The Ethiopian Jewish community is another unique population group living in Israel which includes approximately 100,000 immigrants who arrived in Israel from Ethiopia (Bar-Haim & Semyonov, 2015). The Ethiopian sub-population in Israel suffers from lower income, lower education and higher residential segregation than any other Jewish group. Jewish women from Ethiopia have a four times higher abortion rate compared to Israeli-born Jewish women, and their usage of preventive medicine, referral and early detection rates for cancer are lower (Dayan & Shvartzman, 2013). Ethiopian women have had about twice the incidence of extremely preterm births compared with non-Ethiopians, twice the odds for neonates who were small for gestational age and had about threefold increased risk of stillbirths (Calderon-Margalit et al., 2015).

Another major sub-population group in Israel is Israeli Arabs (21% of the population). Most of the Israeli Arabs (80%) are Muslims; another 20% are Christians (INSS, 2021). Among the Muslims, the Bedouin population of the Negev is a very unique population subgroup. This

ethnic minority includes 280,000 Bedouins who live in the Negev desert in Southern Israel. This group underwent an accelerated modernization processes, the end of nomadism, and a transition to permanent settlements which is not quite finished. A majority of the Bedouins live in 18 settled communities founded and recognized by the state. At the same time, nearly 40% of the Bedouin live outside the localities recognized by the state. This is the youngest population in Israel, with 51 percent children under 18 (Yahel & Abu-Ajaj, 2021). These unrecognized Bedouin settlements have poor sanitation lacking central waste or garbage disposal as well as lack of basic infrastructures such as water supply, electrical connections, public transportation. They have reduced access to health services (Shibli et al., 2021) and higher levels of exposure to air pollution and industrial heavy metal waste (Karakis et al., 2008; Yitshak-Sade et al., 2016). The Infant mortality rate in this population is 11/1000 (Bittles, 2019) while among other Israeli Arabs—6/1000 (Kathleen, 2016) and 2/1000 among Jewish newborns (Staff, 2016).

This study aims to reveal the influence of maternal income on LBW, taking into account other socio-economic variables such as maternal employment status, population group and SERI in a large nationwide database. In addition, the study aimed to evaluate the effect of the change in maternal income using sibling analysis.

## Methods

### Study Population

This retrospective cohort study is based on the database of the National Insurance Institute (NII) of Israel, and is merged with a file of live births obtained from the National Live Birth Registry of Ministry of Health using the identity number of the mother for merging. The National Insurance Institute (NII) of Israel is a unique authority which collects social security payments from all employed residents according to their income, and pays benefits according to specific entitlements (Savitsky et al., 2020).

Among the entire Israeli population, birth weight records were lacking for 2% of all births during the study period (2008–2013). The study population included a 10% simple random sample of 58,454 women who were Israeli citizens at the time of birth and who gave birth between 2008 and 2013. Only singleton births at term (gestational age [GA] in weeks = 37 and later) with known birth weight were included, resulting in a study population of 85,605 births during the study period.

### Study Variables

*Birth weight* was used as a categorical variable with categories of ≤ 2500 g (LBW) and ≥ 2501 g.

*Age* was considered both as a continuous variable and as a categorical variable, with categories of ≤ 20 years, 21–24 years, 25–34 years, 35–42 years and ≥ 43 years.

The *Population group* included Israeli-born Jews, immigrants from the FSU who had immigrated since 1990, immigrants from Ethiopia, Arabs (excluding Bedouins), Bedouins (Bedouins of the Negev); and Other Immigrants (OI) who were not born in Israel.

*Family status* of the mother at birth included three categories: Single; Married/In relationship; Divorced/Widowed.

*Birth order* was used as a categorical variable with categories 1, 2, 3 and 4 + .

*Family income* in New Israeli Shekels (NIS) was based on income in the year prior to birth and is categorized by quartile. Income included the annual salary of the woman and her spouse (if she was married or living in a joint household) and/or any other income such as benefits. An annual salary of less than 600 NIS for salaried workers and less than 400 NIS for freelance workers (1% among women and 0.5% among spouses) was defined as lack of income. The annual income quartiles are shown in Table 1.

*Employment status* of the woman was categorized as having been employed in the year before giving birth as either a salaried worker or freelancer. When there was a spouse, the same categorization was made; otherwise, "no spouse" was noted. Women who were not employed during the previous year were defined as housewives. In addition, the variable *employment status of the family* was created: whether a woman or her spouse was employed, or neither was employed.

*Socio-Economic Regional Index (SERI)* was defined as the classification of the women's residence according to the Israeli Central Bureau of Statistics Socio-Economic Regional Index, consisting of twenty regional clusters (1 for lowest SERI and 20 for the highest).

The association of LBW rate with SERI (Fig. 1) is inverse in nature; improved SERI was associated with decreased LBW rate (Fig. 1). SERI quartiles were defined based on the ranking clusters: 1st Quartile = SERI (1–5), 2nd Quartile = SERI (6–9), 3rd Quartile = SERI (10–12) and 4th Quartile = SERI (13–20).

### Statistical Analysis

LBW represents the dependent variable in the analysis and was defined as a dichotomous category. A logistic regression model with a Generalized Estimating Equation (GEE) approach was used for the univariate and multivariable analyses. In order to assess the independent effect of

**Table 1** Demographic characteristics of study population at the first birth during the study period, by Income Quartile

| Demographic characteristics | Annual Family Income | | | | Total N (%) |
|---|---|---|---|---|---|
| | I quartile (< 44,971 NIS) | II quartile (44,971–98,687) | III quartile (98,687–187,516) | IV quartile (187,516 +) | |
| | 14,146 (24.2) | 14,014 (24.0) | 15,179 (26.0) | 15,115 (25.9) | 58,454 (100) |
| Maternal Age, % | | | | | |
| < 20 years | 13.3 | 6.8 | 1.5 | 0.1 | 3,087 (5.3) |
| 21–24 | 31.6 | 24.0 | 11.3 | 1.9 | 9,851 (16.3) |
| 25–34 | 41.8 | 53.4 | 67.3 | 63.4 | 33,195 (56.8) |
| 35–42 | 12.5 | 14.7 | 18.9 | 33.2 | 11,715 (20.0) |
| 43 + | 0.8 | 0.9 | 1.0 | 1.4 | 606 (1.0) |
| Population Group, % | | | | | |
| Israeli born Jews | 55.5 | 49.7 | 62.4 | 77.7 | 36,026 (61.6) |
| Arabs (excluding Bedouins) | 22.6 | 30.7 | 16.1 | 5.3 | 10,734 (18.4) |
| Immigrants from FSU | 5.9 | 7.2 | 11.0 | 9.8 | 5,003 (8.6) |
| Immigrants from Ethiopia | 1.3 | 1.8 | 2.7 | 0.4 | 922 (1.6) |
| Other immigrants | 7.7 | 5.0 | 5.8 | 6.4 | 3,632 (6.2) |
| Bedouins | 7.0 | 5.6 | 2.0 | 0.4 | 2,137 (3.7) |
| Family Status at birth; % | | | | | |
| Single | 7.2 | 4.6 | 2.3 | 1.3 | 2,197 (3.8) |
| Married/In relationship | 91.4 | 92.2 | 95.4 | 96.7 | 55,047 (94.2) |
| Divorced/Widow | 1.4 | 2.5 | 2.3 | 2.1 | 1,210 (2.0) |
| Birth order, % | | | | | |
| 1 | 46.2 | 43.8 | 44.6 | 36.7 | 24,981 (42.7) |
| 2 | 15.9 | 17.9 | 21.6 | 23.8 | 11,634 (19.9) |
| 3 | 11.9 | 15.2 | 17.6 | 26.5 | 10,482 (17.9) |
| 4 and more | 26.0 | 23.1 | 16.3 | 13.1 | 11,357 (19.5) |
| Occupational status of woman, % | | | | | |
| Not employed | 50.0 | 31.1 | 10.2 | 4.9 | 13,714 (23.5) |
| Employed | 50.0 | 68.9 | 89.8 | 95.1 | 44,740 (76.5) |
| Occupational status of spouse, % | | | | | |
| No spouse | 8.3 | 5.6 | 2.6 | 1.4 | 2,566 (4.4) |
| Not employed | 59.2 | 19.7 | 4.1 | 0.9 | 11,887 (20.3) |
| Employed | 32.6 | 74.7 | 93.2 | 97.7 | 44,001 (75.3) |
| Occupational status of any family member, % | | | | | |
| Nobody employed | 30.1 | 1.7 | 0 | 0 | 4,503 (7.7) |
| Somebody Employed | 69.9 | 98.3 | 100 | 100 | 53,952 (92.3) |
| Socio-Economic Regional Index (SERI), % | | | | | |
| I quartile (1–5) | 41.8 | 36.1 | 17.1 | 5.1 | 14,330 (24.5) |
| II quartile (6–9) | 32.4 | 32.4 | 29.7 | 17.0 | 16,195 (27.7) |
| III quartile (10–12) | 17.7 | 21.5 | 33.6 | 38.4 | 16,421 (28.1) |
| IV quartile (13 +) | 8.2 | 10.0 | 19.6 | 39.5 | 11,508 (19.7) |

each variable, variables found to be significantly associated with LBW in the univariate analysis were included in the multivariable analysis. Thus association of family income with LBW was evaluated in multivariable model, adjusted for age, population group, SERI, family status at birth, and occupational status of family. In addition, six stratified GEE models were conducted in each population group separately.

The GEE method takes into account the correlation between births of the same mother. The structure of the working correlation matrix, which reflects the assumption regarding the correlation between observations from the same cluster, was defined as exchangeable. Thus, the same correlation exists between any births of the mother. The results of all multivariable regression models are presented as an adjusted OR with a 95% confidence interval (CI).

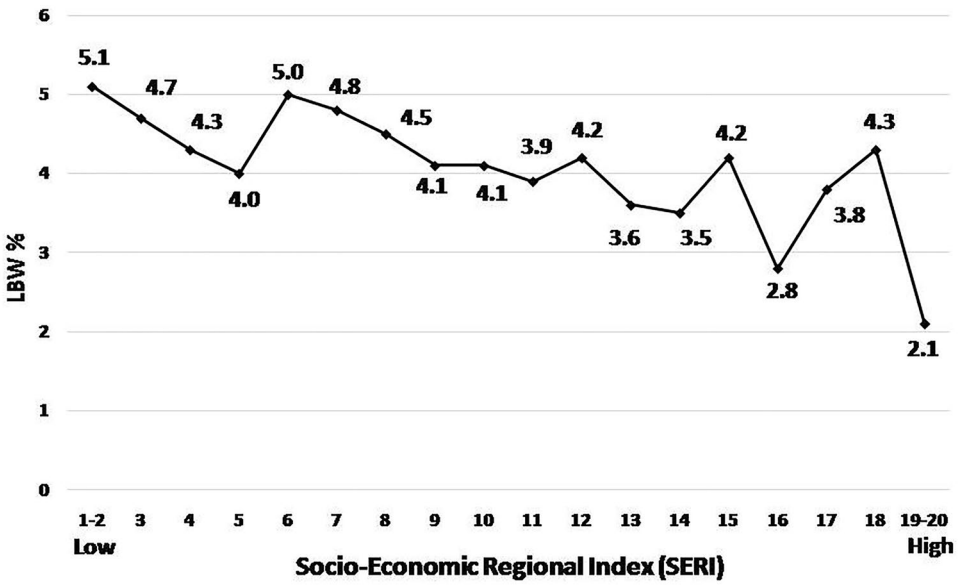


**Fig. 1** Low birth rate at term by socio-economic regional index

Before including independent variables in the multivariable analysis, correlations between variables were checked using a Kendall's Tau coefficient. The strongest correlation reached a Kendall's Tau coefficient of 0.4.

A separate sibling analysis was used to assess the influence of a change in income for the same woman on BW among 21,998 women who gave birth at least twice during the study period, using a General Linear Model. This approach assumes that there is little or no individual-level confounding and any misclassification of exposure or outcomes similar in the siblings.

A Bonferroni correction was used to assess the significance of the association. For this analysis a $p$ value of $0.05/6 = 0.008$ was accepted as statistically significant. Statistical analyses were performed with SAS statistical software version 9.2 (SAS Institute, Inc., Cary, NC) and SPSS version 25.0.

## Results

The study population of 58,454 women had 85,605 singleton births delivered at term during the study period. The mean birth weight was 3296 g (SD = 436.1). Among the newborns, 2584 babies (3%) had LBW, while the smallest baby born at term weighed 1100 g and the largest weighed 5940 g. The mean maternal age at birth was 29.5 years (SD = 5.6), while the minimal maternal age was 14 years and the maximum was 56 years.

The demographic characteristics of the women at first birth during the study period are shown in Table 1. Most of the women (almost 61.6%) were Jewish (born in Israel); Arabs (excluding Bedouins) comprised 18.4%. Arabs and Bedouins comprised 22.6% and 7.0%, respectively, among the lowest income quartile, while among the highest income quartile the proportion of Arabs and Bedouins was 5.3% and 0.4%, respectively. Among the lowest income quartile, half of women were not employed, while among the highest income quartile only 5% of women were not employed during in the year prior to the birth. SERI was positively associated with income; the proportion of women living in the lowest SERI cluster decreased from 41.8% in the lowest income quartile to 5% in the highest income quartile.

The rate of LBW among primiparas whose first birth occurred during the study period is shown in Table 2. The women's age was significantly associated with the LBW rate among primiparas, with the LBW rate in relation to age increasing from 3.8% among women aged less than 20 years to 8.1% among those aged 43 years or older ($p = 0.002$). Bedouins and immigrants from Ethiopia had the highest LBW rates (6.0% and 8.4% respectively) compared to other population groups ($p < 0.0001$). SERI was significantly associated with LBW as living in areas with low SERI (cluster 6–9) led to a 4.8% rate of LBW vs. 3.8%-4.3% in other clusters ($p = 0.038$). The women's occupations or that of their spouses or of any family member were not significantly associated with LBW rate, nor was the family income.

The results of the GEE model on the association of maternal characteristics with LBW are shown in Table 3. After adjustment, the lowest probability of having a baby with LBW observed among the women aged 25–34 years, in comparison to the probability of the mothers aged less than 20 years and of those 43 years or older, was respectively 24% and 56% higher (OR = 1.244; 95% CI: 1.024–1.511 and OR = 1.556; 95% CI: 1.103–2.195, respectively). An additional model with age as a continuous variable and its quadratic term revealed a significant U-shape association with LBW ($p$ value of quadratic term = 0.00008).

**Table 2** Rate of LBW/1,000 births by Maternal Characteristics among primiparas at the first birth during the study period (n = 24,982)

| Demographic characteristics | LBW (n) | LBW (rate/100) | Total |
|---|---|---|---|
| Age* | | | |
| < 20 years | 105 | 3.8 | 2,763 |
| 21–24 years | 305 | 4.4 | 6,932 |
| 25–34 years | 561 | 4.2 | 13,357 |
| 35–42 years | 97 | 5.8 | 1,672 |
| 43 + | 12 | 8.1 | 148 |
| Population Group* | | | |
| Israeli born Jews | 701 | 4.4 | 15,932 |
| Bedouins | 44 | 6.0 | 733 |
| Other Arabs | 183 | 4.4 | 4,159 |
| Immigrant from Ethiopia | 29 | 8.4 | 345 |
| Immigrant from FSU | 85 | 3.6 | 2,361 |
| Other immigrants | 38 | 2.7 | 1,407 |
| Socio-Economic Regional Index (SERI) * | | | |
| I quartile (1–5) | 229 | 4.3 | 5,326 |
| II quartile (6–9) | 328 | 4.8 | 6,833 |
| III quartile (10–12) | 319 | 4.3 | 7,419 |
| IV quartile (13 + ) | 204 | 3.8 | 5,368 |
| Family Status at birth | | | |
| Single | 80 | 5.0 | 1,600 |
| Married | 990 | 4.3 | 23,023 |
| Divorced/Widow | 10 | 4.2 | 238 |
| Occupational status of woman | | | |
| Not employed | 182 | 14.3 | 1,273 |
| Employed | 898 | 14.3 | 6,280 |
| Occupational status of spouse | | | |
| No spouse | 81 | 5.0 | 1,620 |
| Not employed | 217 | 4.3 | 5,047 |
| Employed | 782 | 4.3 | 18,186 |
| Occupational status of family | | | |
| Nobody employed | 54 | 4.2 | 1,286 |
| Somebody employed | 1026 | 4.3 | 23,860 |
| Annual Family Income, NIS | | | |
| < 44,971 | 287 | 4.4 | 6,523 |
| 44,971–98,687 | 282 | 4.6 | 6,130 |
| 98,687–187,516 | 292 | 4.3 | 6,791 |
| 187,516 + | 219 | 4.0 | 5,475 |

*p value of $X^2 < 0.05$

Immigrants from Ethiopia and Bedouins have the highest probability of LBW: adjusted OR = 1.510; 95% CI: 1.155–1.975 among the immigrants from Ethiopia and OR = 1.306; 95% CI: 1.065–1.602 among the Bedouins. Married mothers have the lowest risk of having babies with LBW. In comparison, single mothers have a 70% higher probability of having a baby with LBW (OR = 1.704; 95% CI: 1.398–2.076) and divorced or widowed mothers a 40% higher risk (OR = 1.404; 95% CI: 1.066–1.849).

**Table 3** Probability of LBW by Maternal Characteristics, univariate and adjusted analysis (results of GEE model), n = 85,605 births

| Demographic characteristics | Univariate | | Multivariable | |
|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI |
| Age | | | | |
| < 20 years | **1.297** | **1.076–1.562** | **1.244** | **1.024–1.511** |
| 21–24 years | **1.216** | **1.095–1.349** | **1.185** | **1.060–1.324** |
| 25–34 years | ref | ref | ref | ref |
| 35–42 years | 1.014 | 0.913–1.127 | 1.013 | 0.909–1.129 |
| 43 + | **1.672** | **1.193–2.345** | **1.556** | **1.103–2.195** |
| Population group | | | | |
| Israeli born Jews | ref | ref | ref | ref |
| Bedouins | **1.218** | **1.012–1.467** | **1.306** | **1.065–1.602** |
| Other Arabs | 0.961 | 0.860–1.074 | 0.966 | 0.851–1.097 |
| Immigrant from Ethiopia | **1.716** | **1.316–2.236** | **1.510** | **1.155–1.975** |
| Immigrant from FSU | 0.867 | 0.733–1.025 | **0.785** | **0.661–0.933** |
| Other immigrants | **0.738** | **0.607–0.899** | **0.730** | **0.599–0.889** |
| Socio-Economic Regional Index (SERI) | | | | |
| I quartile (1–5) | 1.039 | 0.914–1.182 | 0.907 | 0.776–1.060 |
| II quartile (6–9) | **1.234** | **1.089–1.398** | 1.142 | 0.985–1.346 |
| III quartile (10–12) | 1.122 | 0.988–1.273 | 1.097 | 0.939–1.282 |
| IV quartile (13 + ) | ref | ref | ref | ref |
| Family status at birth | | | | |
| Single | **1.759** | **1.456–2.125** | **1.704** | **1.398–2.076** |
| Married | ref | ref | ref | ref |
| Divorced/Widow | **1.398** | **1.068–1.830** | **1.404** | **1.066–1.849** |
| Occupational status of family | | | | |
| Nobody employed | 1.001 | 0.868–1.155 | 0.975 | 0.828–1.149 |
| Somebody employed | ref | ref | ref | ref |
| Annual Family Income, NIS | | | | |
| < 44,971 | **1.224** | **1.088–1.378** | 1.130 | 0.977–1.308 |
| 44,971–98,687 | **1.344** | **1.198–1.508** | **1.266** | **1.115–1.437** |
| 98,687–187,516 | **1.185** | **1.055–1.333** | **1.147** | **1.016–1.295** |
| 187,516 + | ref | ref | ref | ref |

The occupational status of any family member was not associated with LBW in the univariate and multivariable analyses. The mother's occupation was not associated, either (results are not presented). When the spouse's occupation was taken into account, the spouse's occupational status itself was not associated with LBW, but having no spouse in the household was significantly associated with LBW (OR = 1.613; 95% CI: 1.332–1.955) (the results are not presented in the Table).

SERI, which was found to be linked to LBW in the univariate analysis, was no longer associated with LBW in the multivariable analysis. The reason for the disappearance of the association was the adjustment for income.

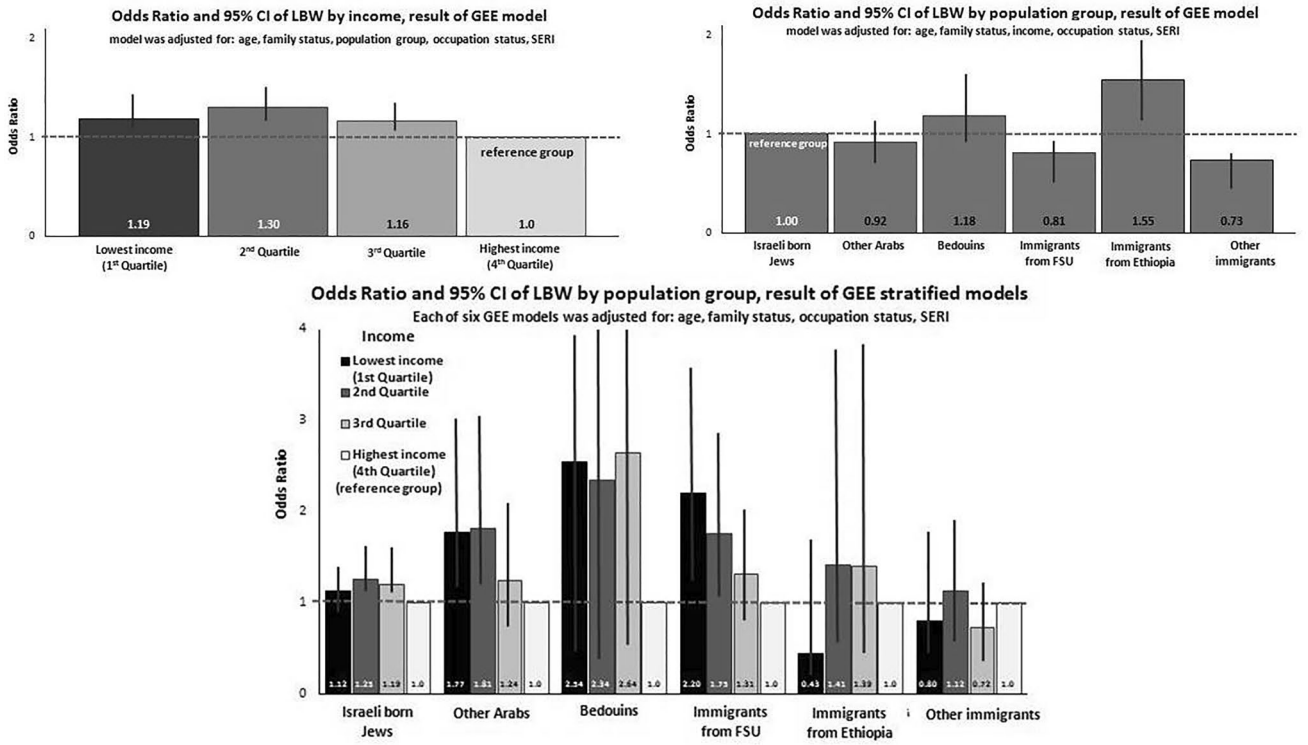


**Fig. 2** Odds Ratio and 95% CI of LBW, result of GEE models

Lower income was associated with higher probability of LBW, while in the multivariable analysis the highest probability of LBW was observed among the mothers from the second income quartile vs. the upper quartile (OR = 1.266; 95% CI: 1.115–1.437). After stratification by population group (Fig. 2), the same trend of higher odds for LBW when the income is lower vs. odds for LBW in the highest income quartile were observed among 92% of the population (Israeli born Jews, Arabs (excluding Bedouins), immigrants from FSU and Bedouins).

An additional analysis was conducted among 21,998 women who gave birth at least twice during the study period, with the mean gap between the first and the last birth in the study period being 33.1 months (SD = 13.3 months).The difference between the income quartiles at the last birth and at the first birth in the study period was calculated. The difference in infant birth weight between the last and the first birth in the study period was calculated as well. The general linear model with the difference in BW between the last and the first birth and with independent variables (change in income quartile, income quartile at the beginning of the study period and time gap between the last and the first births) was drawn up. As shown in Fig. 3, the group of women who experienced a deterioration of three and two quartiles in family income between the last and the first births had significantly smaller babies at the time point with lower income: 103 g lighter if a deterioration of three quartiles occurred (p value = 0.049) and 71 g lighter if a deterioration of two quartiles occurred (p value = 0.008), compared to the women who did not change their income quartile between the last and the first birth during the study period. Improvement in income revealed an almost linear increase in BW, but this association was not significant.

## Discussion

This study aimed to reveal the influence of income on LBW. Higher income was found to be associated with a lower probability of having a baby with LBW, after taking into account other SEP-related variables and population group. Previous studies have found a similar association between family income and LBW in Israel (Zussman et al., 2013) and other countries (Aizer & Currie, 2014). The influence of income on birth weight may be mediated by the range of factors: higher income is associated with the woman's accessibility to proper nutrition and antenatal care, lower stress level, lower exposure to harmful environmental factors such as air pollution (Aizer & Currie, 2014) and lower exposure to active and passive smoking during pregnancy (Hawsawi et al., 2015; Wojtyla et al., 2021). The mechanism of the influence of the maternal lifestyle on BW may work through

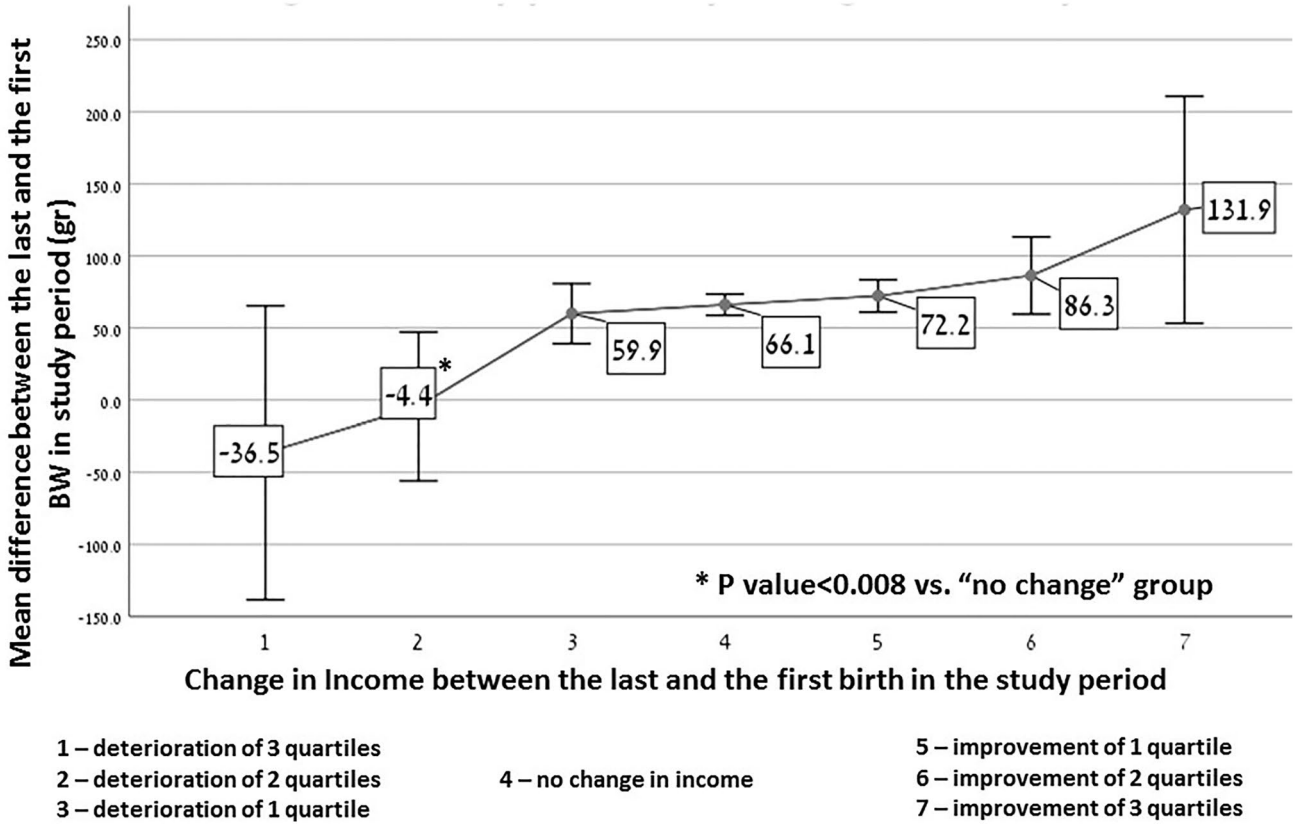


**Fig. 3** Change in mean BW between the last and the first birth during the study period by change in family income

epigenetic changes in the fetus. For example, epigenetic modifications such as DNA methylation mediates the relationship between maternal smoking and lower birth weight (Hannon et al., 2019; Tehranifar et al., 2013).

When the change in infant BW was checked for the same women, it was found that a change in family income was associated with a higher probability of a baby with LBW if this change was for the worse and with a lower probability of LBW if the income improved. A significant decrease in BW was observed among the women whose income deteriorated, with this finding pointing to the possible influence of stress on BW following the loss of the family's economic stability. The results of a meta-analysis of eight cohort studies suggested a significant association between prenatal exposure to stress and increased rates of low birth weight (OR = 1.68; 95% CI: 1.19 -2.38) (Lima et al., 2018). It has been thought that stress may be associated with a lack of oxygen to the fetus (hypoxia), which adversely affects fetal growth and is a topic worthy of further attention (Schetter, 2011). Another suggested key pathway from stress to LBW involves activation of the hypothalamic–pituitary–adrenal (HPA) axis of the mother as a result of maternal stressors (Schetter, 2011).

Income was associated with LBW after taking SERI into account. SERI was not associated with LBW separately from income, which contrasted with previous studies. SERI expresses various aspects of the environment affecting the baby's development, such as living conditions. Because of lower housing costs, families with low income are more likely to live near, and therefore to be exposed to, sources of pollution. A study of all births in five large U.S. states found that African-American women and women with less education (two correlates of economic disadvantage) were more likely to live within 200 m of hazardous waste sites or factories emitting toxic releases (Aizer & Currie, 2014). In an ecological study in the Czech Republic the prevalence of LBW was positively associated with the concentrations of two air pollutants and the crude odds ratios for 50 µg/m3 increase in SO2 and NO2 were 1.21 (CI: 1.13–1.30) and 1.14 (CI: 1.04–1.24), respectively (Bobak & Leon, 1999). The results of a systematic review of 25 studies in China showed that air pollution with SO2 was consistently associated with LBW (Chung et al., 2016). The mechanism linking air pollution to LBW is still unknown; researchers propose inflammation as a biologically plausible mechanism (Chung et al., 2016). On the other hand, a favorable environment is associated with better birth outcomes; in an Israeli study, an increase in surrounding greenness, especially during the first and second trimester, was associated with the decreased of

risk for LBW (Agay-Shay et al., 2014; Agay-Shay, Michael, et al., 2018; Agay-Shay, Rudolf, et al., 2018).

This study found no significant association between SERI and LBW, probably as a result of confounding by population group and income (the adjustment for population group and income wiped out an association between SERI and LBW). Similarly, a study conducted in Tehran did not find a statistical significant relationship between residential area (Tehran versus suburbs of Tehran) and LBW (Vahdaninia et al., 2008).

The influence of income on LBW cannot be explained by confounding by population group. Population group itself was found to be associated with LBW even after adjustment for income. The highest probability of LBW was found among the Bedouins. This association may be explained by several factors. First of all, Bedouins live either in recently-established permanent settlements (60%) or in traditional tribal settlements (40%). Like the other Israelis, all Bedouins could benefit from National Health Insurance and receive medical care in community clinics, but accessibility barriers exists for a significant number of women living in unrecognized settlements and this influences underutilization of antenatal services (Bilenko et al., 2007; Shibli et al., 2021). Thus, Bedouins living in traditional tribal settlements often have to travel considerable distances to the nearest clinic (Karakis et al., 2008), while lack of public transportation and the need to be accompanied by the husband or other male family relative makes this visit challenging. Despite some recent improvement in access to prenatal care, over 40% of the pregnant women in traditional tribal settlements still received no prenatal care (Bilenko et al., 2007; Shibli et al., 2021). Recourse to prenatal care has a known and efficient preventative influence on LWB (Khan et al., 2016).

The second reason for higher odds for LBW among the Bedouin population is consanguineous marriages (Vardi-Saliternik et al., 2002) which represent an ancient tradition in Bedouin culture (Raz & Atar, 2005). The prevalence of consanguineous marriages among the Bedouins is 44.8%, while the most common type of spousal relationship was first cousins (65.7% of all consanguineous marriages) (Na'amnih et al., 2014). Based on current evidence, consanguineous marriages increase the risk of LBW (Mumtaz et al., 2007; Poorolajal et al., 2017).

In relation to exposure to smoking, active smoking does not contribute to LBW risk in this group as smoking is not prevalent among Bedouin women; according to an Israeli survey, 17% of Jewish women smoked during the pregnancy in comparison with only 3% of Arab pregnant women) (Fisher et al., 2005). On the other hand, the prevalence of smoking among Arab men is very high (74% (Hawsawi et al., 2015)]), while 54.7% of Arab women who don't smoke are exposed to coerced smoking, compared to 26.6% of Jewish women (Khatib, 2017). The evidence on the association of passive smoking with LBW has been previously established (Hawsawi et al., 2015; Wahabi et al., 2013; Wojtyla et al., 2021).

Finally, unrecognized settlements are not connected to the basic infrastructures, lack central waste or garbage disposal and have poor sanitation conditions. Ambient air pollutants and hazardous household factors have been found to be associated with LBW in this population (Karakis et al., 2014; Yitshak-Sade et al., 2016). In addition, women living in tribal conditions are exposed to extreme temperatures, especially heat in a non-air-conditioned homes, during pregnancy which may result in reduced fetal growth, according to a new Israeli study (Basagaña et al., 2021).

A higher probability of LBW among immigrants from Ethiopia was previously reported (Calderon-Margalit et al., 2015; Lubotzky-Gete et al., 2017). Researchers suggested a lower rate of early detection of preeclampsia among immigrants from Ethiopia due to suboptimal prenatal care access (Lubotzky-Gete et al., 2017).

In addition, although pre-pregnancy BMI data were not available in this study, being underweight prior to pregnancy increases the risk of LBW in the infant (Yu et al., 2013). It is known that the body mass index of Ethiopian immigrants is still low in comparison with the rest of the population; however, information about their dietary habits is limited (Banderlei & Kalter-Leibovich, 2017) and genetic factors may also play an important role in body mass composition (Lusky et al., 1997, 2000). Moreover, Ethiopian Jewish women have 2.5-fold greater risk for gestation diabetes despite having a lower mean BMI (Jaffe et al., 2020) than other population groups, but in this study information on pregnancy related morbidity was unavailable.

Although family status is associated with income, it has an independent influence on the probability of LBW. The higher odds of unmarried mothers for LBW found in this study are similar to findings by previous studies: the meta-analysis of 21 studies found that compared to married mothers, unmarried mothers had 46% higher odds for LBW (OR = 1.46; 95% CI: 1.25–1.71); single mothers had 65% higher odds (OR = 1.65; 95% CI: 1.44–1.88) and among cohabitating mothers the OR for LBW was 1.29 (95% CI: 1.25–1.32) (Shah et al., 2011).

## Study Strengths

The current study contributed to and broadened existing knowledge about the association between income and LBW, while taking into account not only individual income data of every participant, but additional SEP characteristics such as Socio-Economic Regional Index (SERI), family status at birth, and occupational status of family. In a large sub-sample of 21,998 women who gave birth at least twice during

the study period, sibling analysis of LBW was performed and provided data on how change in income to better or to worse with the same mother was associated with the chance for the birth of infant with LBW following this change in income. The sibling analysis performed in this study is one of its major strengths and uniqueness of the current study.

In addition, this study was conducted on large unbiased sample of women whose data on income, family status and other characteristics was not collected retrospectively and was not dependent on recall as the NII collects this information from independent sources such as Ministry of the Interior and the Tax Authority. Another strength of this study is its attention to minority groups who are disadvantaged. Thus, the study has importance not only for Israel, where several sub-populations have very different health profiles and significant gaps exist between the different sub-groups, but to other countries, where different population groups suffer from disadvantaged conditions and, as a result, experience worse perinatal outcomes.

## Limitations

Despite the broad scope of the NII database, it posed certain limitations. Maternal anthropometrics (weight before pregnancy, pregnancy-related weight gain, pre-pregnancy BMI), exposure to tobacco and pregnancy-related morbidity (such as gestational diabetes) were not accessible in this study; consequently, assessing the contribution of the income in comparison with other factors was impossible. In addition, as the NII database includes only income reported to the Israeli Tax Authority, the study may have missed unreported sources of income. It is known that the gap between the income reported in surveys and the income reported to the Israeli Tax Authority is 26% among Arabs in comparison with other groups (Zarhoviz, 2018). Finally, among the Bedouin there are men who are married to a number of women (20–40% of Bedouin families are polygamous) and in most cases these women will not be registered as married in the NII database. In this case, the income of the spouse of a woman not registered as married cannot be estimated.

## Conclusion

The Developmental Origins of Health and Disease theory claims that intrauterine conditions and early life influences can alter later disease risk. Low socioeconomic position is robustly associated with adverse pregnancy outcomes including infant mortality, prematurity, low birth weight, and intrauterine growth restriction. A better understanding of the correlation between socio-economic disparities and birth weight may help public health practitioners to improve not only birth outcomes, but future health of human populations as well.

Governmental agencies should implement a key strategy for the achievement of health promotion aims—**advocacy**, which includes protection of the vulnerable population (representational advocacy) and empowerment of the disadvantaged (facilitation advocacy). The Ministry of Health should make immediate improvements in accessibility of antenatal services among minorities, especially among Bedouin women living in unrecognized settlements. In the past, a project of mobile mammography proved that bringing health services to the population eliminates health-related gaps due to accessibility problems. Mobile clinics for pregnancy follow-up may be an effective solution. An effort should be made by the Ministry of Health and by Health Maintenance Organizations among the Bedouin population and among immigrants from Ethiopia to eliminate the reasons for non-use of prenatal care relating to language barriers, lack of geographic accessibility and lack of awareness that these services exist. Special efforts should be directed toward prevention and early diagnosis of pregnancy-related conditions, which may result in adverse newborn outcomes. The Ministry of Education should implement a school programs for all Israeli teenagers, improving knowledge and contributing to positive attitudes toward pre-marital genetic counseling.

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**Authors' contributions** Dr. Bella Savitsky conceived and designed the study, planned the data analysis, analyzed the data, wrote the manuscript. Irina Radomislensky contributed to data collection, planned the data analysis, created the study files, analyzed the data, reviewed the final version of the manuscript for submission. Zhanna Frid contributed to data collection and creation of the study files, took part in the process of data analysis, reviewed the final version of the manuscript for submission. Natalia Gitelson contributed to data collection and creation of the study files, took part in the process of data analysis, reviewed the final version of the manuscript for submission. Prof. Tova Hendel conceived and designed the study, responsible for overall content, reviewed the final version of the manuscript for submission.

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**Data availability** Data sharing is not applicable to this article as the Research Center of the National Insurance Institute (NII) of Israel do not allow any files, even those without IDs, to be released out of research room of the NII, where the analysis was performed.

## Declarations

**Conflict of interest** All authors approve that they do not have any financial and personal relationships with other people, or organizations, that could inappropriately influence (bias) this research and this manuscript.

**Ethical approval** This study was approved by the Research Committee of the National Insurance Institute of Israel and it was decided that as identifying information was not available to researchers, ethical approval was not needed and no informed consent was needed.

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