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Environmental risk factors associated with low birth weight: The case study of the Haifa Bay Area in Israel

Alina Svechkina[a], Jonathan Dubnov[b], Boris A. Portnov[a,*]

[a] Department of Natural Resources and Environmental Management, Faculty of Management, University of Haifa, Mount Carmel, Haifa 3498838, Israel
[b] School of Public Health, Faculty of Welfare and Health Sciences, University of Haifa, Mount Carmel, Haifa 3498838, Israel

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ABSTRACT

Background: Low birth weight (LBW) is known to be associated with infant mortality and postnatal health complications. Previous studies revealed strong relationships between LBW rate and several socio-demographic factors, including ethnicity, maternal age, and family income. However, studies of association between LBW rate and environmental risk factors remain infrequent.
Study methods: We retrieved a geo-referenced data set, containing 7216 individual records of children born in 2015 in the Haifa Bay Area in Israel. Using this dataset, we analysed factors affecting LBW prevalence by applying two alternative techniques: analysis of LBW rates in small census area (SCAs) and more recently developed double kernel density (DKD) relative risk (RR) estimates.
Results: In the SCA models, LBW rate was found to be associated with proximity to petrochemical industries (B = −0.26, 95%CI = −0.30, −0.22), road density (B = 0.05, 95%CI = 0.02, 0.08), distance to the seashore (B = 0.17, 95%CI = 0.14, 0.22), $PM_{2.5}$ (B = 0.06, 95%CI = 0.04, 0.09) and NO_x (B = 0.10, 95%CI = 0.06, 0.13) exposure estimates. Although similar factors emerged in the DKD models as well, in most cases, the effects of these factors in the latter models were found to be stronger: proximity to petrochemical industries (B = −0.48, 95%CI = −0.51, −0.30), road density (B = 0.05, 95%CI = 0.02, 0.08), distance to the seashore (B = 0.24, 95%CI = 0.21, 0.27), $PM_{2.5}$ (B = 0.08, 95%CI = 0.05, 0.10) and NO_x (B = 0.20, 95%CI = 0.17, 0.23) exposure estimates. In addition, elevation above the sea level was found to be statistically significant in spatial dependence models estimated for both DKD and SCA rates ($P < 0.01$).
Conclusion: The analysis revealed an excess LBW rate in residential areas located close to petrochemical industries and a protective effect of seashore proximity and elevation above the sea level on the LBW rate. We attribute the latter finding to the moderating effect of elevated seashore locations on outdoor temperatures during the hot summer season.

1. Introduction

Low birth weight (LBW) is defined by the World Health Organization (WHO) as weight at birth of less than 2500 g (WHO, 2016). Preterm births and LBW are leading causes of infant mortality, considered to be responsible for about 30% of all neonatal deaths (WHO, 2016; UNICEF, 2016). LBW is also a leading cause of death under the age of five (Swamy, 2012; Lundgren et al., 2014, WHO, 2016).

LBW may have long-term implications for postnatal development, by increasing the risk of respiratory distress, infection, hypoglycaemia, polycythaemia, intellectual disabilities, celebre palsy, vision and hearing loss, feeding and digestion problems (Hack et al., 1995; Bhutta et al., 2002; Eliyahu et al., 2002; Wen et al., 2004; Norris et al., 2012; Hannam et al., 2014). Later in life, LBW can lead to the development of cardiovascular disorders, hypertension and diabetes (Hack et al., 1995; Bhutta et al., 2002; Wen et al., 2004; Norris et al., 2012, Hutchinson et al., 2013).

LBW is known to be influenced by genetic, demographic, and socio-economic factors (WHO, 2017; CDC, 2017; Blumenshine et al., 2010). Individual level factors associated with LBW incidence include race (Urquia et al., 2010), maternal age and health (Sørbye et al., 2016; Hannam et al., 2014; Yadav and Lee, 2013), and family's socio-economic status (CDC, 2017).

Several environmental factors are also known to increase the risk of LBW. These factors include exposure to air pollution (Llop et al., 2010, Gehring et al., 2011; Gehring et al., 2014; Steib et al., 2012; Bertin et al., 2015; Kampa et al., 2011; Morello-Frosch et al., 2010), exposure to water pollutants, pesticides (Steib et al., 2012; Ferguson et al., 2013;

* Corresponding author.
E-mail address: portnov@research.haifa.ac.il (B.A. Portnov).

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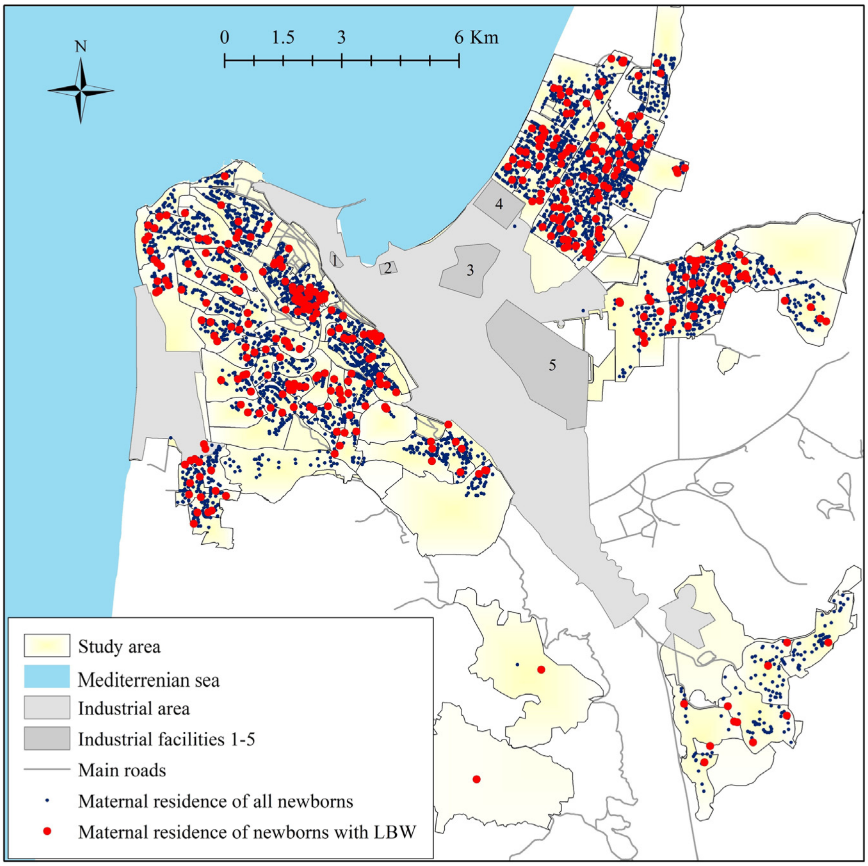

Fig. 1. Residential locations of the newborns covered by the analysis, including residential locations of children with low birth weight (< 2500 g). *Note:* The study cohort covers 6809 normal weight singleton births and 407 low birth weight (LBW) singleton births selected according to the applied inclusion criteria (see text for explanations).

Backes et al., 2013; Hannam et al., 2014), and proximity of maternal residences to different environmental hazards, such as highways, gas drilling sites, etc. (Lin et al., 2001; Maisonet et al., 2004; Adela et al., 2013; Ahern et al., 2011; Dadvand et al., 2014; Di Salvo et al., 2015).

The association between LBW and maternal exposure to air pollution was first reported in the 1970's by Williams et al. (1977), who found that traffic-related pollution in Los Angeles affected human reproduction. More recently, Gray et al. (2014) examined the joint effects of air pollution exposure and socio-economic status on pregnancy outcomes in North Carolina. Using multilevel Bayesian models and applying them to birth data for the 2002–2006 period, the researchers analysed the association between pregnancy-averaged $PM_{2.5}$ and O_3 exposure estimates and birth outcomes. The study revealed that O_3 exposure during the entire gestational period reduced birth weight by 7.4 g (95%CI = 5.2, 9.5) while $PM_{2.5}$ exposure reduced birth weight by about 3.1 g (95%CI = 3.0, 3.2).

It should be noted, however, that most previous studies of environmental factors affecting LBW rates were primarily focused on commonly monitored air pollutants, such as gases (NO_x, SO_2, CO, and O_3) and particulate matter (PM_{10} and $PM_{2.5}$). Concurrently, studies of other environmental determinants of LBW have been infrequent (Ghosh et al., 2013; Ezziane, 2013; McKenzie et al., 2014; Llop et al., 2010; Gehring et al., 2011; Gehring et al., 2014; Steib et al., 2012; Bertin et al., 2015; Alderman et al., 1987; Bernstein et al., 2004; Chen et al., 2013; Arroyo et al., 2016; Dadvand et al., 2013; Olsson et al., 2013; Rappozzo et al., 2014; Romero-Lankao et al., 2013).

In this study of LBW risk factors, we focus on both routinely measured air pollutants and not routinely monitored ones, by using various location proxies to capture their effects, and applying two different investigation techniques – the analysis of zonal rates and analysis of DKD relative risk estimates. We apply these two methods to the same database, and then mutually compare the results. The study uses birth cohort data from the newly computerized nation-wide database which was established in Israel in 2014.

Applying different investigation techniques to a study of the same health phenomenon may be justified by the fact that risk assessments provided by different estimation methods may differ due to information loss associated with data aggregation and processing (Jarup, 2004; Jerrett et al., 2005, Portnov et al., 2012; Wong, 2004; Portnov et al., 2007). Thus, morbidity risk estimates, based on pre-established statistical divisions (such as census blocks, small census areas and census tracts) are commonly used in epidemiological studies (Zusman et al., 2012; Lavigne et al., 2016; Gotway and Young, 2002; Openshow, 1984), including studies of adverse birth effects (Luo et al., 2006; Simonet et al., 2011). However, the way, in which the boundaries of geographical units are demarcated, can result in the modifiable areal units problem (MAUP), according to which the choice of areal units used for data aggregation may lead to different results and affect hypothesis testing (Wong, 2004; Portnov et al., 2007; Wong and Fotheringthem, 1991).

An alternative technique for the analysis of adverse health outcomes is based on data smoothing into continuous surfaces, differentiating between areas of different relative risk of a disease (Bithell, 1990; Shi, 2010; Zusman, 2012; Anderson, 2009; Svechkina et al., 2017). Advantages of this approach, compared to zonal estimates, are that the former method does not require an *a priori* delineation of areal units for data aggregation (Kloog et al, 2009; Portnov et al., 2007). According to several studies (cf. inter alia, Grubesic and Matisziw, 2005; Beale et al., 2008; Zusman et al., 2012), this approach is especially effective if the number of geographic units available for data aggregation and analysis is small.

2. Materials and methods

2.1. Study area

The Haifa Bay Area (HBA), data for which were used in our study, consists of the City of Haifa (280,000 residents, as of 2015) and its several suburbs - Krayot, Tirat Carmel, Nesher, and Kiryat Tiv'on (see Fig. 1). The