The Effects of Artificial Light Pollution on Human Health

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Abstract

Exposure to artificial light pollution on adult human beings is directly linked with negative health effects such as disrupted circadian rhythms, insomnia, diabetes, mood disorders, and even cancer. However, the studies that focus on artificial lights' negative effects towards infant life and health are limited. This paper extends from the literature by examining the amount of light an infant is exposed to during their mother's pregnancy and then if they are more likely to be born with adverse health defects as a result of it. I use health data from the CDC Wonder and VIIRS nighttime light data and employ two-way fixed effect regressions in my model for the period 2012-2020. The subsequent results align with the literature as infants born in more urban zip codes with higher exposure to artificial light at night are more likely to be born with a low birth weight or have a shortened gestational length than those born in less urbanized places.

KEYWORDS: Light Pollution, Skyglow, Infant, Health
JEL CODES: C33, I10, Q52

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Signature

Sergio Hernandez

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INTRODUCTION

Exposure to artificial light at night is directly correlated with a number of negative health effects on adults including insomnia, diabetes, depression, and even cancer. Light pollution disrupts the human circadian rhythms and biological clock by suppressing the production of the melatonin, responsible for the regulation of the sleep-wake cycle (Wang et al., 2021). The adoption of artificial light at night is revolutionizing human life, allowing for increased productivity and extended waking hours irrespective of the natural day and night light cycles. However, this advancement comes at a cost as it negatively impacts adult health. The presence of artificial light in our nocturnal environment causes adults who live in more populated, lit up areas such as cities to be more likely to suffer from health effects due to light pollution than adults in darker and more rural places. In this research paper, I target pregnant mothers across dense and rural counties in The United States to analyze if their exposure to light pollution passes down health problems to their infants once they are born, as current literature on light pollution affecting infant health is limited.

For this research, I use multiple two-way fixed effect regression models to find a correlation between infants born with negative health effects and their mother's exposure to light pollution. I use this method of regression analysis since I am working with panel data and collect information over time and varying places, thus requiring fixed effects for county and year. I collect birth data from the CDC, annual light data from VIIRS, use two independent light data variables (Annual Average Light, Annual Median Light) and two health related dependent variables across my regressions to analyze the results and any possible correlation.

The results show strong evidence for a relationship between the data on artificial light exposure and the infants born with one of my two dependent health variables, having a low birthweight or having a shortened gestational length, which is the period of time between conception and birth. For infants born with a low birthweight, using annual average light, my results produced an adjusted R-squared value of 0.7891, meaning that 78.91% of the variability in my dependent variable can be explained by the independent light variables in my regression. The significant coefficient and low p-value of 0.000 add to the validity of this claim. As for infants born with a shortened gestational length, I calculate an adjusted R-Squared value of 0.4526 that shows that 45.26% of the variance in my dependent variable is explained by my independent light variable. With a significant coefficient and a low p-value of 0.012, my results are indicative of statistical significance, especially at the 5% level.

For infants born with a low birthweight, using annual median light, my results produced an adjusted R-squared value of 0.7608. 76.08% of the variability in my dependent variable can be explained by the independent light variable in my regression. The significant coefficient and low p-value of 0.000 reject the null hypothesis which states that there isn't a correlation. As for infants born with a shortened gestational length, now using annual median light, I got an adjusted R-Squared value of 0.4506 that shows that 45.06% of the variance in my dependent variable is explained by my independent light variable. With a significant coefficient and a low p-value of 0.012, my results are indicative of statistical significance, especially at the 5% level.

My findings are indeed consistent with the reference literature collected for this research. Argys et al. (2021) examines the fetal health impact of light pollution using skyglow, an important aspect of light pollution. Using Walker's Law as an instrumental variable to address potential endogeneity, they find evidence of reduced birthweights and shortened gestational lengths as a result of increased nighttime brightness. In particular, they categorize increased nighttime brightness as the ability to only see one-fourth to one-third of the total stars that *should* be visible to the naked human eye in the natural, unpolluted sky. They associate this increase in nighttime brightness with an increase of 1.48 percentage points in the likelihood of pregnant mothers having a preterm birth, which aligns with my results that state that a significant portion of the variability in my shortened gestational length and low birthweight dependent variables can be explained by my annual light pollution data.

LITERATURE REVIEW

Literature on the negative effects of artificial light exposure on human health is plentiful, but few narrow in on its effects on infant life. Given this information, and by synthesizing diverse studies and perspectives, the following literature review shows the various ways in which light pollution compromises our physical and mental health, during all ages of life, urging an understanding for the connection between light and well-being in our modern, illuminated world.

People exposed to light pollution are at an increased risk of suffering from health effects as this exposure impacts the human circadian clock and rhythm. The five types of light pollution being light trespass, over-illumination, glare, light clutter, and skyglow (DarkSky International, 2023). Disturbing the circadian clock in humans interferes with hormone production, cell regulation, and other biologic activities, with a direct link existing between these disturbances and several medical disorders in humans including depression, insomnia, obesity, diabetes, mood disorders, and even cancer (Wang et al., 2021). This literature review looks at numerous studies to better understand the human health consequences of exposure to light pollution.

Boslett et at. (2021) finds a correlation between rural light pollution from shale gas drilling and insufficient sleep and poor mental and physical health. Evidence shows that the shale oil and gas boom significantly increase light pollution in these rural areas of the United States. Although this development produces positive economic changes at both local and regional levels, drilling-related light pollution in previously low light pollution areas becomes a new concern as counties with more than 100 wells drilled see increased incidences of sleeping less than 7 hours in the last 24 hours (6 percentage points) and insufficient sleep (2.5 percentage points). The incidence of poor mental and physical health also increases by between 1 and 1.5 percentage points, depending on the number of wells drilled. Exposure to light pollution alters the natural melatonin levels in our bodies, and this study backs up this claim as now these people close in proximity to the drilling sights are losing more and more sleep.

Jun Su (2022) writes about the economic and legislative side of light pollution, all while stating the negative health effects it comes with. In addition to proposing methods to quantify the economic cost of light pollution and market solutions to reduce it, they reaffirm that residents' mental and physical health are negatively influenced and that observing our stars is becoming increasingly more difficult. At the very least, people suffer from insomnia since light pollution disorders circadian rhythm. At most, since this process reduces melatonin, people have a poorer quality of sleep and become more prone to cancer. Additionally, they suggest increasing the electricity price in order to regulate against light pollution and that the range of increased price should vary among cities with diverse income levels.

Garcia-Saenz et al. (2020) publishes an impressive research article supporting the previously made claims that exposure to light pollution causes cancer. Night-shift work, exposure to ALAN, and circadian disruption increases the risk of breast, prostate, and colon cancer. Outdoor blue light spectrum exposure, which is increasingly more prevalent, is associated with colorectal cancer; even after adjusting for socioeconomic status, diet patterns, smoking habits, and family history. This is based on 661 cases from Spain from 2007-2013, meaning there is very likely much more proof of this correlation once expanding into other countries over more recent years as light pollution has only increased since.

Miao Cao et al. (2022) reviews research advances in health threats as a cause of light pollution exposure. Human obesity is found to be positively correlated to both indoor and outdoor artificial light, with a stronger correlation existing for women. Depression is also commonly found to arise as a result of ALAN exposure as confirmed by multiple studies from South Korea, Japan, and the Netherlands. When investigating the possible association of outdoor ALAN and mental disorders among US adolescents, the results show high odds for bipolar disorder, specific phobias, and major depressive disorder. Bedroom ALAN has also been causally related to various diseases, two of the more common ones being incident diabetes and carotid atherosclerosis.

Argys et al. (2021) suggests that as a direct result of their mother's artificial light exposure, newborn infants are proven to have reduced birth weights, a shortened gestational length, and an increase in preterm births. The link between these adverse effects on infant births come specifically from the measurement of skyglow: the artificial brightening of the night sky in a built-up area such as a city. Increased skyglow, demonstrated by being able to see only one fourth to one third of the total number of stars that should be visible to the naked human eye, is associated with an increase in 1.48 percentage points with the likelihood of a preterm birth. Given that adults face the risk of health effects due to their exposure to artificial light, more studies have sought after examining how the artificial light affects pregnant mothers specifically, and if those negative health effects can be passed down to their infant at their time of birth.

Liset et al. (2021) publishes a research article where they conduct a study that looks at women during their third trimester of pregnancy and observes changes to their stress and sleep by looking at their evening white light exposure. As a result, the prevalence of insomnia and a shorter sleep duration among pregnant women is increased when their exposure to light is higher than the participants who aren't. Sleep disturbances are common as it is during pregnancy, but these findings show that they can be even worse when the mothers are exposed to more artificial light at night. These results may only conclude in less sleep for these women, but literature from other articles would suggest that insomnia is the bare minimum health effect one could face, meaning this could just be the start of a more serious health effect that could not potentially affect their children too.

The literature reviewed presents plentiful evidence over the correlation between exposure to artificial light at night and the adverse health implications it causes to humans. Although the negative health effects of air pollution are studied in surplus, *light* pollution in particular comes as an initially less evident concern despite having many of the same negative externalities on humans. Given that exposure to artificial light at night alters hormone and melatonin levels, the spiral of effects that have the potential to stem from that and alter human health are abundant and detrimental. Ranging everywhere from insomnia to cancer, there are a plethora of reasons why humans should push to conserve their dark skies, look after their health and safety, and take political action when light pollution policy isn't being regulated. The implications extend beyond just getting poor sleep, and emerging evidence highlights that infants and babies are not immune to the impacts of light pollution, even prior to their own birth. Addressing light pollution starts with recognizing the issue and placing urgency on its lack of awareness; understanding the implications is essential as we attempt to promote a healthier environment for all humans, across every stage of life.

DATA

To better analyze the correlation between increased light pollution from urbanization and the consequent negative health effects on infants that arise as a result, I use the CDC Wonder page to collect data on how US counties across the country compare with each other in this regard.

I collect data in terms of a county's total number of births for the years 2012-2020, and then their subsequent number of births that are classified as either being low birth weight or having a shortened gestational length– two of the most studied negative health effects in infants due to light pollution. Any infant whose birthweight is less than 2500 grams counts as a low birth weight, and any gestational length less than 37 weeks long counts as shortened. Using the CDC's birth tracking data sets allows for the findings of the percentage of births that are affected by one of the two dependent variables used for this study, which are later used in the regression models. I then organize this information from the CDC as a panel data set through an excel spreadsheet where year, state, county, total births, affected births, and percentage of affected births are recorded. I gather a total of 781 rows of individual sets of data to make up my complete sample size of 84 counties across 32 US states. The following states are included in the model: Alabama, Arizona, California, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maryland, Minnesota, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, Utah, Washington, and Wisconsin. Given the geographic and population differences between these states, we get a mix of both highly urbanized counties and more rural ones to better examine if their differences in amounts of artificial light emitted directly correlate with the number of infants born with health issues.

To constitute for the light pollution as the independent variable, I collect two sets of annual light data from the Visible and Infrared Imaging Suite (VIIRS) titled "annual average light" and "annual median light." VIIRS is a consistently processed time series of annual global nighttime data that is produced from monthly cloud-free average radiance grids (C. D. Elvidge et al., 2021). The filtering process removes sunlit, moonlit, and cloudy pixels – the rough composites are first made on monthly increments and then combined to form annual composites where light, fire, aura, and background are unveiled.

Table 1: Descriptive Statistics

Variable	N	Mean	St. Dev.	Min	Max
%OfLowBirthweight	781	0.0803115	0.0144423	0.0499655	0.1909565
%ofShortenedGestationLength	784	0.1116613	0.0254071	0	0.4819731
Annual average light	837	6.033098	7.752577	0.1245829	49.80516
Annual median light	837	2.807765	6.152779	0.05	46.01

The nighttime satellite imagery then produces a global nighttime light map of the highest quality. I collect annual light data from VIIRS for the years 2012-2020, which are correspondingly matched up with the county data for adverse births during the same years.

Whether or not the independent light variable has a direct effect on the dependent health variables is now proven using a few two-way fixed effect regression models in the methodology section. By meticulously organizing data on percentage of affected births, low birth weight, shortened gestational length, coupled with annual light data from VIIRS over 9 years, I draw closer to studying the relationship between artificial light exposure and the effects on infant health.

METHODOLOGY AND REGRESSION RESULTS

This paper establishes whether a mother's exposure to artificial light at night during her pregnancy can have a negative health effect on her child once they're born. The dependent variables of interest in this analysis are percentage of low birth weight and percentage of shortened gestational length, which come from a collection of panel data tracking birth data over various US counties over the course of nine years (2012-2020). These percentages are derived from looking at the number of total births for 84 counties across the United States, and then how many of those are affected by one or more of my dependent health variables (Low Birthweight and Shortened Gestational Length).

The independent variables, titled "annual average light" and "annual median light", are two different sets of light data from The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument that collects visible and infrared images and global observations of our land and atmosphere. The numbers in our data essentially reflect that the higher the light data number, the more light pollution is present in said county, during said year. In this study, I want to add on to the already existing literature over how artificial light negatively affects adult human health by seeing if I can prove that it affects infant health as well.

A two-way fixed effect method of running a regression is required in order to account for both an alpha and a delta, in this case county and year. The regressions begin with one of our two health-related dependent variables on the left side of the equation and are then followed up on the right side by $\beta 0$, the intercept term. $\beta 1$annualaveragelight (ij) and $\beta 1$annualmedianlight (ij) each represent a different set of light data and indicate the effect of this coefficient on the dependent variable. Both a(i) + Δ(j) are our fixed effects for county and year, and the final error term captures the unobserved factors that may be affecting the dependent health variable but aren't represented in the model. To estimate this model, I use the following regression methodology. There is a total of 4 regressions, each containing fixed effects for both year and county.

A.) % of Low Birthweight(ij) = ꞵ0 + ꞵ1annualaveragelight (ij) + a(i) + Δ(j) + error(ij)

B.) % of Shortened Gestational Length (ij) = ꞵ0 + ꞵ1annualaveragelight (ij) + a(i) + Δ(j) + error(ij)

C.) % of Low Birthweight(ij) = ꞵ0 + ꞵ1annualmedianlight(ij) + a(i) + Δ(j) + error(ij)

D.) % of Shortened Gestational Length (ij) = ꞵ0 + ꞵ1annualmedianlight(ij) + a(i) + Δ(j) + error(ij)

Table 1: Annual Average Light Regression Results

Variables	**% of Low Birthweight**		**% of Shortened Gestational Length**	
	Coefficient	Standard Error	Coefficient	Standard Error
Annual average light	0.0003432***	0.0000979	0.0006534**	.0002602
Constant	0.0854863***	0.0024821	0.1025849***	0.0065997
R-Squared		0.7891		0.5176
Adjusted R-Squared		0.7606		0.4526

Beginning with the annual average light, low birth weight produces a p-value and constant of 0.000, indicating an extremely low chance of the observed relationship being due to random chance, and thus are statistically significant at the 1 percent level. Shortened gestational length is similar as it also has a constant of 0.000, but differs because the p-value is 0.012. Despite being rather close to 1 percent, since it is slightly more, it is labeled with two asterisks as it is statistically significant at the 5 percent level.

The R-squared value measures how well the independent variables in these regression models explain the variability in the dependent variables. The adjusted R-squared values slightly differ as it takes into account the number or predictors and penalizes the inclusion of irrelevant predictors. The adjusted R-squared value will always be equal to or less than the standard R-squared value, and I use it in the study as it provides a more reliable assessment and results. Here I see that 76.06% of the variability in low birth weights is explained by the independent light variable, while only 45.26% of the variability in shortened gestational length is explained by it. Although one explains a large portion of the variability while the next explains around half, both are still significant results.

Table 2: Annual Median Light Regression Results

Variables	**% of Low Birthweight**		**% of Shortened Gestational Length**	
	Coefficient	Standard Error	Coefficient	Standard Error
Annual median light	0.0004754***	0.0001313	0.000678*	0.0003501
Constant	0.0865813***	0.0024655	0.1046111***	0.0065711
R-Squared		0.7893		0.5159
Adjusted R-Squared		0.7608		0.4506

Notes *** indicate significance at the 1% level, ** indicate significance at the 5% level, and * indicate significance at the 10% level.

As for the annual median light, low birth weight produces a p-value and a constant of 0.000 that concludes that it is statistically significant at the 1 percent level. Shortened gestational length varies only slightly as the constant is also 0.000, but the p-value for this variable is 0.053. Despite being very close to 5 percent, it is slightly larger and thus categorized as statistically significant at the 10 percent level. The adjusted R-squared value of 0.7608 shows that 76.08% of the variability in low birth weights is explained by the independent light variable, while the adjusted R-squared value of 0.4506 demonstrates that 45.06% of the variability in shortened gestational length is explained by the light variable. These results align with the conclusions made by Argys et al. (2021) study regarding adverse birth outcomes as they found that the likelihood of preterm birth increases by about 1.48 percentage points or 12.9% as a result of a one unit decrease in the Naked Eye Limiting Magnitude (i.e., an increase in skyglow). This indicates a reduction in one third to one fourth of the stars that can be seen with the naked eye during the natural, unpolluted nighttime sky (Argys et al., 2021). They too test for both low birth weight and gestational length, and calculate statistically significant p-values at the one percent level, meaning a large portion of the variability in their dependent health variables is due to the increased light pollution and the subsequent reduction in being able to see stars at night. My results align with theirs as I have found a statistically significant relationship between pregnant mothers being exposed to artificial light and skyglow across the United States and their chances increasing of giving birth to an infant with either a low birth weight or before the 37th week of pregnancy.

CONCLUSION

The culmination of this research provides evidence supporting the relationship between artificial light exposure during a mother's pregnancy and the potential health issues for their infants. This study shows a correlation between infants across The United States being born with a low birthweight of less than 2500 grams or a shortened gestational length of less than 37 weeks, and their mother's exposure to light pollution.

By using two different annual light data sets, I'm able to more confidently prove that this relationship is indeed present regardless of the light data being average or median. Regression results for both show adjusted R-squared values that describe that most of the variance in the dependent health variables is due to the light pollution – more for low birthweight than shortened gestational length, but both at a statistically significant level regardless. These statistical insights show the importance of understanding the potential harm that is caused to humans given their differing quantities of exposure to artificial light.

The expansive review of already existing literature on the topic serves as a basis for the research I conduct in this study. Exposure to light pollution is known to disrupt the adult circadian rhythm and lower melatonin levels, and the subsequent implications that stem from that vary from mild to quite serious. As such, I contribute to this knowledge by doing research in a subcategory that isn't as highly studied: infant health. It's important to assess where the problem starts if a baby is already born with health complications, so I look for information on the mother first to examine her location during pregnancy and the amount of light in her county of residence. I do this over a period of nine years to make sure my results aren't only valid in one given year, but rather as a general consensus regardless of the year these births are recorded.

My research is conducted with the help of the CDC's publicly available data on births across 32 states and 84 counties. VIIRS' data sets provide the annual composites that capture nighttime light data using satellite imagery. By using this combination of tools to look for a correlation between their variables, pregnant mothers can now be advised over the amount of exposure they receive from artificial light at night, bringing them newfound knowledge that allows them to take precaution as they prepare to bring new life into our bright world.

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