

RESEARCH ARTICLE

Artificial Light at Night and Cancer: Global Study

Redhwan A. Al-Naggar^{1*}, Shirin Anil²

Abstract

Background: Artificial light at night (ALAN) has been linked to increased risk of cancers in body sites like the breast and colorectum. However exposure of ALAN as an environmental risk factor and its relation to cancers in humans has never been studied in detail. **Objective:** To explore the association of ALAN with all forms of cancers in 158 countries. **Materials and Methods:** An ecological study encompassing global data was conducted from January to June 2015, with age-standardized rates (ASR) of cancers as the outcome measure. ALAN, in the protected areas, as the exposure variable, was measured with reference to the Protected Area Light Pollution Indicator (PALI) and the Protected Area Human Influence Indicator (PAHI). Pearson's correlations were calculated for PALI and PAHI with ASR of cancers for 158 countries, adjusted for country populations, electricity consumption, air pollution, and total area covered by forest. Stratified analysis was conducted according to the country income levels. Linear regression was applied to measure the variation in cancers explained by PALI and PAHI. **Results:** PALI and PAHI were positively associated with ASR of all forms of cancer, and also the four most common cancers ($p < 0.05$). These positive correlations remained statistically significant for PAHI with all forms of cancer, lung, breast, and colorectal cancer after adjusting for confounders. Positive associations of PALI and PAHI with cancers varied with income level of the individual countries. Variation in all forms of cancers, and the four most common cancers explained by PALI and PAHI, ranged from 3.3 – 35.5%. **Conclusion:** Artificial light at night is significantly correlated for all forms of cancer as well as lung, breast, colorectal, and prostate cancers individually. Immediate measures should be taken to limit artificial light at night in the main cities around the world and also inside houses.

Keywords: Artificial light at night- lung cancer- breast cancer- colorectal cancer- prostate cancer

Asian Pac J Cancer Prev, 17 (10), 4661-4664

Introduction

Among non-communicable diseases, cancers are a leading cause of morbidity and mortality worldwide, with 14.1 million cases diagnosed in 2012 and 8.2 million cancer deaths in the same year (Ferlay et al., 2012). It is estimated that cancer incidence will increase to 22.2 million cases in 2,030 (Bray et al., 2012). Most commonly occurring cancers in the world are lung, breast, colorectal and prostate cancer, which accounts for four in ten cases diagnosed of cancer (Ferlay et al., 2010; Cancer Research UK, 2015).

Various risk factors have been identified playing a crucial role in causing cancer. Alcohol consumption, smoking and low intake of fruits and vegetables are major factors for cancers in low and middle income countries, while alcohol use, smoking, and obesity play an important role in cancer causation in high income countries (Danaei et al., 2015). Environmental carcinogens including outdoor and indoor air pollution, and soil and drinking water contamination have been linked to cancer of the lungs, oesophagus, mouth and throat, blood, skin, bladder, liver, colon, kidneys, breast, and prostate (Boffetta and

Nyberg, 2003).

Recently, light pollution in the form of artificial light at night (ALAN) has been detected to cause breast cancer, melatonin being the mediator between environment and the epigenome (Yang et al., 2014; Haim and Zubidat 2015). ALAN can also increase the risk of colorectal cancer in night shift workers (Schernhammer et al., 2001). ALAN not only adversely effects humans directly exposed to it, but it also affects the 'protected areas', undisturbed natural habitat of flora and fauna, vital to the human existence and well being (Aubrecht et al., 2010).

The protected areas are defined by the International Union for Conservation of Nature (IUCN) as "clearly defined geographical spaces, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (International Union for Conservation of Nature, 2015). Such areas include wild life and forests and national park and reserves. It provides humans with clean drinking water, food and medicine, protects from natural disasters and helps to combat climate change (International Union for Conservation of Nature, 2015). The phenomenon of

¹Faculty of Medicine, Universiti Teknologi MARA (UiTM), Selangor, Malaysia, ²Department of Health and Human Services Victoria, Melbourne, Australia. *For correspondence: radhwan888@yahoo.com

ALAN in the protected areas can have health consequences on human beings in the form of cancer causation, evidence regarding which is non-existent up to the best of our knowledge. Hence objective of this research was to study the effect of ALAN in the protected areas to the causation of all forms of cancers especially the four most commonly diagnosed cancers i.e. lung, breast, colorectal and prostate cancer in humans.

Materials and Methods

Study Design

An ecological study was conducted from January- June 2015 on secondary data from 158.0 countries.

Variables and data extraction

Age standardized incidence rate (ASR) of all forms of cancer, lung, breast, colorectal, and prostate cancers were the outcome variables. Data regarding the ASR of cancers in each country were obtained from International Agency for Research on Cancer (IARC), which reported the estimates of 2012 (IARC, 2015).

Exposure was to the artificial light at night (ALAN) in the protected areas, represented by the spatial indicators namely Protected Area Light Pollution Indicator (PALI) and Protected Area Human Influence Indicator (PAHI) (Aubrecht et al, 2010). PALI represents the direct exposure of the protected areas to ALAN. As the light emitted from the source can spread and scatter with the help of media like water, air molecules and suspended particles, to take this into account, indicator measuring the light exposure within 5.0 km of the lighting source measuring widespread influence of ALAN due to human influence on the protected areas is represented by the PAHI. The data regarding PALI and PAHI were obtained from the Global assessment on Light Pollution by the Centre for International Earth Science Information Network (CIESIN) (Aubrecht et al., 2010).

Data was also collected on the variables which could confound the relationship between ANL in protected areas

and cancers. These included population of the country, national electricity consumption in kWh, air pollution (annual mean particulate matter PM10 in $\mu\text{g}/\text{m}^3$), total land area of the country covered by the forest in sq. km, and income status of the country. These estimates were extracted for the year 2012 or the closest available from the World Bank and World Health Organization databases.

Statistical analysis

Pearson's correlation 'R' was calculated for PAHI and PALI with ASR of all forms of cancer, lung, breast, colorectal and prostate cancer in 158 countries. Partial correlations were calculated adjusted for population size of the country, national electricity consumption, air pollution (particulate matter PM10), and total land area of the country covered by the forest. 'R' was calculated to measure the association between ALAN in the protected areas and cancers for countries grouped in four income levels (lower, low-middle, upper-middle and high) as defined by the World Bank. A p-value of less than 0.05 was considered significant. Linear regression was conducted and R2 calculated to measure the variability of ASR of cancers that can be explained by PALI and PAHI. Data analyses were conducted in SPSS (Version 19.0, 2010, IBM Corp, Armonk, NY).

Results

ASR of all forms of cancer, lung cancer, breast cancer, colorectal cancer and prostate cancer were significantly positively correlated with PALI and PAHI, stronger for PAHI (Table 1). When adjusted for population size, electricity consumption, air pollution, and total land area of the country covered by forest, the positive association remained significant for PALI with colorectal cancer and for PAHI with all forms of cancers, lung cancer and breast cancer (Table 1).

Linear regression showed that variation in all forms of cancers, lung, breast, colorectal and prostate cancer explained by PALI was 6.8%, 3.3%, 12.9%, 12.2%, and 7.5% respectively (Figure 1). The variation in all forms

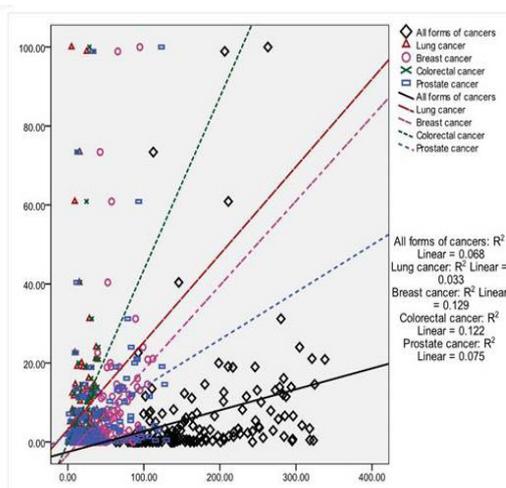


Figure 1. Scatter Plot of Protected Area Light Pollution Indicator (PALI) with Age-Standardized Incidence Rates (ASR) of Cancers in 158.0 Countries

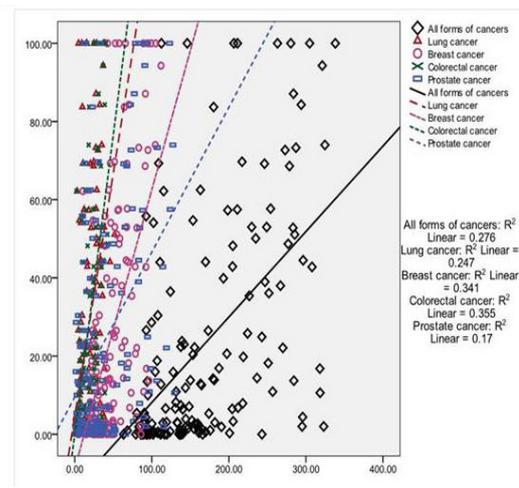


Figure 2. Scatter Plot of Protected Area Human Influence Indicator (PAHI) with Age-Standardized Incidence Rates (ASR) of Cancers in 158.0 Countries

Table 1. Pearson's Correlation 'R' of PALI and PAHI with Age-Standardized Incidence Rates of Cancers in 158.0 Countries

Cancer type	PALI				PAHI		
	Crude 'R'	p-value	Adjusted ^a 'R'	p-value	Crude 'R'	p-value	Adjusted ^a 'R'
All forms of cancer	0.3	0.001*	0.1	0.333	0.5	<0.001*	0.4
Lung cancer	0.2	0.022*	0.2	0.148	0.5	<0.001*	0.4
Breast cancer	0.4	<0.001*	0.2	0.053	0.6	<0.001*	0.5
Colorectal cancer	0.4	<0.001*	0.3	<0.001*	0.6	<0.001*	0.5
Prostate cancer	0.3	0.001*	0.0	0.732	0.4	<0.001*	0.2

^aAdjusted for population size; electricity consumption in kWh; air pollution (particulate matter PM10 in µg/m³); and total land area of the country covered by the forest in sq. km ;*Statistically significant relationship

Table 2. Correlation of PALI and PAHI with Age-Standardized Incidence Rates of Cancer According to the Income Status of the Countries

Cancer type	Income status							
	Lower income		Low-middle income		Upper-middle income		High income	
	PALI	PAHI	PALI	PAHI	PALI	PAHI	PALI	PAHI
All forms of cancer	-0.03	-0.04	0.13	0.22	0.23	0.393*	-0.08	0.2
Lung cancer	0.27	0.384*	0.17	0.26	0.21	0.386*	-0.22	0.1
Breast cancer	-0.11	-0.15	0.21	0.17	0.307*	0.412**	0.09	0.307*
Colorectal cancer	0.11	0.02	0.372*	0.404*	0.29	0.478**	0.01	0.2
Prostate cancer	0.20	0.03	-0.08	-0.07	0.17	0.08	0.00	0.1

*p-value < 0.05, **p-value < 0.01

of cancers, lung, breast, colorectal and prostate cancer explained by PAHI was 27.6%, 24.7%, 34.1%, 35.5%, and 17% respectively (Figure 2).

When stratified by income groups, PALI showed significant positive correlation with colorectal cancer in low-middle income countries and breast cancer in upper-middle income countries. PAHI was significantly positively associated with lung cancer in lower income countries, colorectal cancer in low-middle income countries, with all forms of cancer, lung, breast and colorectal cancers in upper-middle income and with breast cancer in high income countries (Table 2).

Discussion

This study found that artificial light at night leads to cancer causation in humans, even after adjusting for population size, particulate matter representing air pollution, electricity consumption at national levels, and the land area covered by forests. This may be due to the disruption of circadian system by exposing to much light at night and this is can be generalized to the whole population and not only to certain occupational groups such as nurses. Another possible explanation is that the connection of artificial light at night with melatonin hormone which produced in nighttime darkness that promote sleep. Therefore, exposure to night light may suppress the release of melatonin which typically peaks in the middle of the night.

Though PALI was significantly associated with all forms of cancers, as well as the four most common cancers, the relationship remained highly significant ($p < 0.001$) after adjustment for confounding for colorectal

cancer and marginally significant ($p=0.053$) for breast cancer. This finding of direct effect of light in protected areas is similar to the finding by Schernhammer et al (2001), who found that artificial light at night increased the risk of breast cancer and colorectal cancer in women working in rotating night shifts. It should also be observed that the variability in the age-standardized incidence rates of breast and colorectal cancer explained by PALI were found to be the highest (12.9% and 12.2% respectively) as compared to other cancers. The correlation of PAHI with all forms of cancer, lung, breast, and colorectal cancer remained significant ($p= 0.001$) after adjusting for confounders. Moreover the variability in cancers explained by PAHI was much more than that found for PALI, almost three times in case of breast and colorectal cancer.

The ASR of all forms of cancers (excluding non-melanoma skin cancers) is 1.8 times higher in more developed countries than less developed countries of the world (268 vs. 148 cases per 100,000 population per year respectively) (World Cancer Research Fund International, 2015). Our study showed consistent results, i.e. ASR increased as the income status of the countries raised being 114, 125, 165 and 238 per 100,000 population per year in low, low-middle, upper-middle and high income countries respectively ($p < 0.001$). The cancer burden by the type of cancers also differs by human development (Bray et al., 2012). Hence we explored the association of PALI and PAHI with ASR of all forms of cancers and the four most common cancers in the world by income status of the country. PALI was significantly positively correlated to colorectal cancer in low-middle income and breast cancer in upper-middle income countries. PAHI

had considerable positive relationship with lung cancer in low income, colorectal cancer in low-middle income, all forms of cancer, lung, breast and colorectal cancer in upper-middle income and breast cancer in high income countries. This gives an indication that cancer incidence of these cancers can be lowered in these countries by decreasing the risk due to ALAN.

The mechanism of causation cancer due to ALAN in protected areas cannot be commented upon, as this is the first study to explore this relationship and more extensive studies need to be done. Seventeen studies were found in Pubmed/ MEDLINE in the previous ten years (2005 - 2015), composed of ten reviews, one meta-analysis, three animal studies, and three observational studies, to explore the role of ALAN as a risk factor for breast cancer and the possible theory of disruption in circadian rhythm- melatonin inhibition theory as its causative mechanism. Meta-analysis of 12 case-control and four cohort studies studying the relationship of ALAN and breast cancer found that high artificial light exposure can increase the risk of breast cancer by 17% (Yang et al., 2014). Review by Bonmati-Carrion et al (2014) suggested that artificial blue light, as used extensively nowadays due to use of energy-saver bulbs and LEDs, is highly disruptive to the melatonin rhythm and hence lighting systems which can preserve the natural melatonin rhythm should be invented and used. These mechanisms should also be explored when finding the plausible causes of lung, breast, colorectal and prostate cancers by ALAN.

The strength of this study is that it utilized the data from different repositories in 158 countries to assess the association between ALAN in the protected areas and cancers, which was not studied before. Bias due to confounding was also addressed in the analysis.

This study is limited in the sense that it is an ecological study, not studying the exposure of humans to ALAN in protected areas and its impact on cancer directly. Nevertheless, with the help of this study we can form the hypothesis that ALAN can lead to cancer causation in humans. Further studies should be conducted to test the hypothesis generated from this study.

Conclusion: Artificial light at night is a significantly correlated for all forms of cancer including lung, breast, colorectal, and prostate cancer. Immediate measures should be taken to reduce artificial light at night in the main cities around the world.

References

- Aubrecht C, Jaiteh M, De Sherbinin A (2010). Global assessment of light pollution impact on protected areas. Columbia University, New York, 6-7.
- Aubrecht C, Stojan-Dolar M, De Sherbinin A, et al (2010). Lighting governance for protected areas and beyond- Identifying the urgent need for sustainable management of artificial light at night Earthzine. *PLoS One*, **8**, e61460.
- Bray F, Jemal A, Grey N, Ferlay J, Forman D (2012). Global cancer transitions according to the Human Development Index (2008 - 2030): a population-based study. *Lancet Oncol*, **13**, 790-801.
- Boffetta P, Nyberg F (2003). Contribution of environmental factors to cancer risk. *Br Med Bull*, **68**, 71-94.
- Bonmati-Carrion MA, Arguelles-Prieto R, Martinez-Madrid MJ, et al (2014). Protecting the Melatonin Rhythm through Circadian Healthy Light Exposure. *Int J Mol Sci*, **15**, 23448-500.
- Cancer Research UK (2015). Worldwide cancer statistics. <http://www.cancerresearchuk.org/health-professional/cancer-statistics/worldwide-cancer#heading-Zero>. Accessed May 25.
- Danaei G, Vander Hoorn S, Lopez AD, Murray CJL, Ezzati M (2005). Comparative Risk Assessment collaborating g. Causes of cancer in the world: comparative risk assessment of nine behavioural and environmental risk factors. *Lancet*, **366**, 1784-93.
- Ferlay J, Shin HR, Bray F, et al (2010). Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. *Int J Cancer*, **127**, 2893-2917.
- Ferlay J, Soerjomataram I, Dikshit R, et al (2015). Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. *Int J Cancer*, **136**, 359-86.
- Haim A, Zubidat AE (2015). Artificial light at night: melatonin as a mediator between the environment and epigenome. *Philos Trans R Soc*, **370**.
- IARC. GLOBOCAN 2012: Estimated Cancer Incidence, Mortality and Prevalence Worldwide in 2012. <http://globocan.iarc.fr/Default.aspx>. Accessed May 10, 2015.
- International union for conservation of nature. what are protected areas? http://worldparkscongress.org/about/what_are_protected_areas.html. Accessed May 25, 2015.
- Schernhammer ES, Laden F, Speizer FE, et al (2001). Rotating night shifts and risk of breast cancer in women participating in the nurses' health study. *J Natl Cancer Inst*, **93**, 1563-68.
- World Cancer Research Fund International. Cancer facts and figures - comparing more and less developed countries. <http://www.wcrf.org/int/cancer-facts-figures/comparing-more-less-developed-countries>. Accessed May 26, 2015.
- Yang WS, Deng Q, Fan WY, Wang WY, Wang X (2014). Light exposure at night, sleep duration, melatonin, and breast cancer: a dose-response analysis of observational studies. *Eur J Cancer Prev*, **23**, 269-76.