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MULTI-DIMENSIONAL DETERMINANTS OF CANCER INCIDENCE, CANCER DEATHS AND CANCER-RELATED YEARS OF LIFE LOST

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Abstract – *Objective:* *The aim of this study is to reveal the effects of lifestyle, the environmental, health services, and demographic characteristics on cancer incidence, cancer deaths, and cancer-related years of life lost.*

Materials and Methods: *The population of the study is composed of 36 OECD countries. All variables used in the study were examined under four dimensions: lifestyle, environmental, health services, and demographics. The OECD database was used to obtain data on the variables used in the study over five-year periods (2000, 2005, 2010, and 2015). In order to reveal the variables affecting cancer incidence, cancer deaths, and cancer-related years of life lost, ordinary least squares regression analysis was used.*

Results: *In consideration of research findings, the incidence of cancer is affected by variables related to lifestyle, environmental, and health services; cancer deaths and lost life years were affected by variables related to lifestyle and health services. Also, while lifestyle variables were more effective on cancer in the 2000s, in the following years, both lifestyle variables and health service-related variables were found to be effective.*

Conclusions: *This finding shows that the effect of health services on individuals' health levels is increasing compared to the past.*

KEYWORDS: *Cancer incidence, Cancer deaths, Cancer-related years of life lost, OECD countries.*

INTRODUCTION

Non-communicable diseases such as cardiac diseases, stroke, cancer, chronic respiratory diseases, and diabetes are one of the leading reasons for death around the world. Cancer is expected to be the leading cause of death and the main impediment to increasing life expectancy at birth among such diseases[1]. Hence, cancer is considered to be a significant mortality and morbidity reason affecting individuals in all countries, and it is in the second place on the list for the cause of death.

Cancer incidence and cancer deaths have increasingly become higher around the world. Hence, cancer incidence increased to 14.1 million in 2012 while it was 12.7 million in 2008 and finally, it reached 18.1 million in 2018. It is foreseen that in the following years, the number of new cases will increase by 75% and cancer incidence will reach 25 million. Similarly, the number of deaths due to cancer was 8 million in 2012 but it became 9.6 million in 2018[1,2-5]. Just like all the other countries, cancer constitutes a crucial health issue for Turkey.

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According to 2017 data, the number of deaths in Turkey due to cancer (19.6%) comes in second after cardiovascular disease (39.7%). It is observed that cancer incidence in Turkey was 133.5 in every hundred thousand in the year 2002, but this rate went up to 212.6 in every hundred thousand in 2015[6,7].

The global increase in cancer cases causes significant physical, emotional and financial constraints on individuals, families, communities, and the healthcare system. The severity of such constraints is mainly experienced more in low and middle-income countries due to two main reasons. One such reason is that the vast majority of deaths due to cancer are observed in low and middle-income countries. Secondly, such countries have limited access to high-quality diagnoses and treatments. Therefore, countries aim to develop cancer prevention plans in order to fight back against such constraints[8,9].

The prevention of cancer is the main component of all cancer plans. Although cancer prevention is less costly than cancer treatment, not many countries give sufficient importance to cancer prevention. Yet 40% of deaths that occur due to cancer can be preventable. The prevention of cancer is very vital for the prevention of other diseases with common risk factors such as cardiovascular diseases, diabetes, chronic respiratory diseases, and alcohol addiction. Firstly, the risk factors should be listed in the cancer prevention activities[10,11], which can be smoking, alcohol consumption, insufficient consumption of fruits and vegetables, physical inactivity, obesity, air pollution, bacteria, viruses, hormone treatment, genetic factors, food additives, weakness of the immune system, chemicals and exposure to radiation and carcinogenic substances[9,12-20]. In addition to risk factors such as smoking, alcohol, obesity, and radiation, the National Cancer Institute stated that age, cancer-causing substances, chronic inflammation, common cancer myths and misconceptions, diet, hormones, immunosuppression, infectious agents, and sunlight are risk factors for cancer. Such a high number of cancer-related risk factors requires the identification of relative impacts imposed by such factors. This study aims to reflect the change in the effects of lifestyle, environmental, health system, and demographic factors on cancer incidence, cancer deaths, and years of life lost due to cancer.

MATERIALS AND METHODS

Population and Sample

The population of this study is comprised of 36 OECD countries. For this study, no sample was selected and all of the population was included. However, 9 of the countries (Chile, Estonia, Greece, Israel, Latvia, Lithuania, Luxembourg, Portugal, Slovenia) do not have any data for the model developed to identify the factors affecting cancer incidence as well as 6 countries (Chile, Greece, Israel, Latvia, Luxembourg, Portugal) do not have any data for the model developed to identify the factors affecting the cancer deaths and cancer-related years of life lost. Therefore, 27 OECD countries were covered under the analysis regarding the factors affecting cancer incidence, and 30 OECD countries were taken into consideration for the analyses for the factors affecting the cancer deaths and cancer-related years of life lost.

Research Variables

The dependent variables of this study are cancer incidence, cancer deaths, and cancer-related years of life lost, and the independent variables that are given under Table 1 and expected to be effective on such variables are lifestyle, environmental, health system and demographic aspects.

The study data was generated from the OECD database. The effects of risk factors (independent variables) on the countries' cancer incidence, cancer deaths, and cancer-related years of life lost are given in five-year periods (2000, 2005, 2010, and 2015); the missing data about some variables were completed with the data from the latest year in the previous five year period.

TABLE 1. Research variables.

Dependent Variables
y1: Cancer Incidence (per 100,000 people; adjusted for age)
y2: Cancer Deaths (per 100,000 people; Age Adjusted)
y3: Cancer-Related Years of Life Lost (per 100,000 people; ages 0-69)
Independent Variables
Lifestyle Variables
x1:Daily Smoking Rate (Amount in Adult Population)
x2: Adult Population Alcohol Consumption (Litres)
Environmental Variable
x3: Population Exposed to PM2.5 Levels (More Than 10 Micrograms/m3; %)
Health System Variables
x4: Population Covered Under Public + Private Insurance (%)
x5: Out-of-Pocket Expenditure Rate (Household Consumption Expenditures;%)
x6: Annual Number of Physician Consultations (per 1.000 People)
x7: Beds (per 1,000 people)
Demographic Variable
x8: Population aged 65 and up (as a percentage of the total population)

Statistical Analysis

Descriptive statistics such as mean and percentage were used to describe the variables of the study. The Ordinary Least Squares regression (OLS) analysis was performed in order to reflect the variables affecting cancer incidence, cancer deaths, and cancer-related years of life lost. However, Pearson correlation analysis was applied prior to the regression analysis in order to determine whether there was any multicollinearity issue among independent variables as the main assumptions of the analysis.

RESULTS

Table 2 provides the mean values from the data of dependent and independent variables between the years 2000-2015 for OECD countries used in this research. Cancer incidence, which is one of the dependent variables, was observed to show a 6% increase in 2015 when compared with 2000, while the cancer deaths and cancer-related years of life lost diminished by 14% and 26%, respectively. It is identified that "daily smoking rate" as one of the lifestyle variables used as an independent variable showed a decrease of 29% and "alcohol consumption (liter)" decreased by 9%. The environmental variable of "Population exposed to PM2.5 levels" diminished by 11%. While "population covered under public + private insurance", "rate of out-of-pocket expenditures in household consumption expenditures" and "annual number of consultations to a physician per person" among the health system variables increased by 1%, 8%, and 10%, respectively, while "the number of beds" decreased by 13%. Finally, "population ages 65 and above" increased by 25%.

Table 3 provides the correlations between the risk factors (independent variables) that would be analyzed whether they have any effects on the dependent variables of study (cancer incidence, cancer deaths, and cancer-related years of life lost). Hence, only "number of consultations to physicians" and "number of beds" were identified to have statistically significant correlations for the year 2010 (r=0.74) and 2015 (r=0.79), yet such correlations are not strong enough (>0.85) in the way of causing multicollinearity problems for regression analysis.

Table 4 includes the results of OLS regression analysis, which was conducted to identify the factors affecting cancer incidence, cancer deaths and cancer-related years of life lost in OECD countries (lifestyle, environmental, health system, and demographic characteristics) and to detect the change in their effects for 5-year-periods between the years of 2000-2015. Four regression models developed to identify the factors affecting cancer incidence for five-year periods were found statistically significant ($p<0.05$). Consequently, cancer incidence was explained by the independent variables by 57% for 2000, 79% for 2005, 71% for 2010, and 48% for 2015. For the year 2000, the

TABLE 2. Descriptive statistics on variables.

Variables	*2000 Mean*	*2005 Mean*	*2010 Mean*	*2015 Mean*	*Change Between and 2015 (%)*
Dependent Variables					
Y1: Cancer incidence	261.74	268.41	268.07	278.19	0.06
Y2: Cancer deaths	241.84	229.37	217.58	208.26	-0.14
Y3: Cancer-related years of life lost	1194.32	1073.68	966.16	881.06	-0.26
Independent Variables					
Lifestyle Variables					
X1: Daily smoking rate	25.19	23.04	20.07	17.93	-0.29
X2: Alcohol consumption	9.67	9.52	9.07	8.78	-0.09
Environmental Variable					
X3: Population exposed to PM2.5 levels	15.41	15.37	15.55	13.76	-0.11
Health System Variables					
X4: Population covered under public + private insurance (%)	97.67	96.89	98.15	98.52	0.01
X5: Rate of out-of-pocket expenditures (%)	2.05	2.28	2.37	2.22	0.08
X6: Annual number of consultations to physician	6.48	6.56	6.96	7.11	0.10
X7: Beds	5.70	5.33	5.19	4.96	-0.13
Demographic Variable					
X8: Population ages 65 and up	13.41	14.22	15.04	16.70	0.25

TABLE 3. Correlations between independent variables (2000-2015).

2000	x1	x2	x3	x4	x5	x6	x7	x8
x1	1							
x2	0.21	1						
x3	0.06	-0.22	1					
x4	-0.02	0.60**	-0.48	1				
x5	-0.24	-0.08	-0.17	-0.33	1			
x6	0.11	0.35	0.25	0.30	-0.33	1		
x7	0.13	0.46*	0.03	0.38	-0.22	0.65**	1	
x8	0.23	0.52**	-0.56	0.60**	-0.01	0.15	0.46*	1
2005	**x1**	**x2**	**x3**	**x4**	**x5**	**x6**	**x7**	**x8**
x1	1							
x2	0.18	1						
x3	0.41*	-0.26	1					
x4	0.32	0.47*	-0.42*	1				
x5	-0.32	-0.08	-0.12	-0.40*	1			
x6	0.29	0.26	0.36	0.27	-0.27	1		
x7	0.26	0.39*	0.10	0.35	-0.22	0.67**	1	
x8	0.10	0.43*	-0.45*	0.60**	-0.14	0.19	0.52**	1
2010	**x1**	**x2**	**x3**	**x4**	**x5**	**x6**	**x7**	**x8**
x1	1							
x2	0.40*	1						
x3	0.32	-0.38	1					
x4	0.50**	0.37	-0.28	1				
x5	-0.30	0.11	-0.19	-0.63	1			
x6	0.45*	0.16	0.44*	0.22	-0.21	1		
x7	0.36	0.25	0.22	0.27	-0.17	0.74**	1	
x8	0.30	0.42*	-0.43	0.52**	-0.13	0.20	0.53**	1
2015	**x1**	**x2**	**x3**	**x4**	**x5**	**x6**	**x7**	**x8**
x1	1							
x2	0.20	1						
x3	0.48*	-0.36	1					
x4	0.02	0.11	-0.35	1				
x5	-0.15	0.22	-0.22	-0.04	1			
x6	0.39*	0.20	0.50**	0.07	-0.16	1		
x7	0.35	0.32	0.31	0.04	0.01	0.79**	1	
x8	0.14	0.37	-0.45	0.43*	0.00	0.15	0.38*	1

*$p<0.05$; **$p<0.01$.

only variable that affected cancer incidence was observed as the environmental variable of the population exposed to PM2.5 levels ($p<0.05$). For 2005, the variables that affect cancer incidence are the alcohol consumption as one of the lifestyle variables, and the population with insurance and out-of-pocket health expenditures among the health variables. According to the standardized beta coefficients, out-of-pocket health expenditures affect cancer incidence more than other variables. With regard to the model of 2010, the variables of alcohol consumption as the lifestyle variable and the population exposed to PM2.5 levels as the environmental variable have statistically significant effects, while alcohol consumption has been identified to have a relatively greater effect on cancer incidence. Finally, alcohol consumption was found to be the only variable affecting cancer incidence in 2015. Considering the detailed effects of the variables that were found to be statistically significant, there is a positive relationship between all of the variables and cancer incidence.

TABLE 4. Factors affecting OECD countries' cancer incidence, cancer deaths and cancer-related years of life lost.

Variables	*Cancer Incidence*				*Cancer DeathsCancer-Related*				*Years of Life Lost*			
	2000 (β)	*2005(β)*	*2010 (β)*	*2015 (β)*	*2000 (β)*	*2005 (β)*	*2010 (β)*	*2015(β)*	*2000(β)*	*2005(β)*	*2010(β)*	*2015(β)*
Constant	61.21	-13.29	-201.15	-113.32	26.20	3.96	104.19	338.44	843.09	308.98	2535.52	3829.90
X1: Daily smoking rate	0.53	-2.74	0.22	0.38	2.33	0.08	1.23	2.57*	12.64	14.74	20.00*	19.23**
X2: Alcohol consumption	2.81	7.47**	7.96*	7.34*	5.99**	7.08**	6.92**	6.31**	38.21*	51.61**	36.57*	25.11*
X3: Population exposed to PM2.5 levels	3.74*	1.69	2.85*	3.10	-0.29	0.73	-0.05	-1.09	6.07	8.87	4.33	-0.82
X4: Population covered under public + private insurance	1.98	3.16**	4.67	4.06	0.92	1.48	0.12	-2.10	-5.94	-3.45	-24.35**	-35.23***
X5: Rate of out-of-pocket expenditures	14.63	14.75**	9.49	-3.32	0.12	-0.39	-2.73	-11.99*	-15.09	6.33	-32.47	-37.55
X6: Annual number of consultation to physician	3.20	-0.55	0.97	2.95	4.27	-2.82	4.83	-4.96*	28.33	15.65	12.36	4.51
X7: Beds	-	-	-	-	-3.21	-4.26	-6.10	-7.29*	-	-	-	-
X8: Population ages 65 and above	-1.95	-2.48	-3.34	-3.08	0.41	0.36	1.25	0.91	-	-	-	-
R-squared	0.57	0.79	0.71	0.48	0.54	0.61	0.52	0.71	0.42	0.55	0.57	0.74
F	3.601	9.514	6.555	2.484	3.273	3.936	3.006	6.836	2.920	4.563	5.359	11.274
p	0.012	<0.001	0.001	0.054	0.013	0.006	0.019	<0.001	0.028	0.004	0.001	<0.001

β: Standardized Beta Coefficients.
*$p<0.05$.
**$p<0.01$.
***$p<0.001$.

Therefore, cancer incidence shows an increase as the alcohol consumption, population exposed to PM2.5 levels, population under insurance coverage, and out-of-pocket health expenditures in the household consumption expenditures increase.

The regression models developed to identify the factors affecting the cancer deaths for five-year periods in the OECD countries were found statistically significant ($p<0.05$). Consequently, the cancer deaths were explained by the variables by 54% for 2000, 61% for 2005, 52% for 2010, and 71% for 2015. For the years 2000, 2005, and 2010, the only variable that affected the number of cancer deaths was observed to be the lifestyle variable of alcohol consumption. For 2015, the variables that affect the number of cancer deaths are the smoking rate, alcohol consumption as lifestyle variables, and the out-of-pocket health expenditures, number of consultations to physicians, and number of beds among the health variables. In 2015, the rate of out-of-pocket health expenditures had a greater impact on cancer deaths than other variables. The alcohol consumption rate, which was found to be statistically significant during the analyzed periods, and smoking rate among adults, which was found to be statistically significant in one model, were found to have a positive effect on the cancer deaths. Therefore, the number of cancer deaths increases as the alcohol consumption and the smoking rate increase. According to the effects of other variables that were found to be statistically significant, the number of cancer deaths decreases as the out-of-pocket health expenditures in the household consumption expenditure, the number of consultations to physicians, and the number of beds increase.

Finally, in consideration of the models developed to identify the factors affecting cancer-related years of life lost in OECD countries, all the models are considered statistically significant ($p<0.05$). With regard to the R^2 values of models, the cancer-related years of life lost were explained with the variables by 42% for 2000, 55% for 2005, 57% for 2010, and 74% for 2015. For the year 2000 and 2005, the only variable that affects the cancer-related years of life lost was observed as the lifestyle variable of alcohol consumption. For 2010 and 2015, the smoking rate and alcohol consumption as the lifestyle variables, and the population under insurance coverage among the health variables were identified to have a statistically significant effect on the cancer-related years of life lost. In 2010, the amount of alcohol consumed was determined to be the most effective variable in explaining cancer-related years of life lost, while the population covered by insurance has the greatest effect for 2015. Considering the detailed effects of variables, there is a positive relationship between cancer-related years of life lost and the smoking rate and alcohol consumption; and a negative relationship with the population under insurance coverage. Therefore, the cancer-related years of life lost show an increase as alcohol consumption and smoking increase, and they show a decrease as the population under insurance coverage increases.

DISCUSSION

This study aims to analyze the change in the effect of factors such as lifestyle, environmental, health system, and demographic factors on cancer incidence, cancer deaths, and cancer-related years of life lost in OECD countries over the years. While the only variable affecting cancer incidence was found as "population exposed to PM2.5 levels" among the environmental variable for the year 2000; the variables that affected cancer incidence in 2005 were found to be "alcohol consumption" from lifestyle variables, "population under insurance coverage", and "out-of-pocket health expenditures" among the health system variables. In 2010, it was identified that "alcohol consumption" from the lifestyle variables and "population exposed to PM2.5 levels" as the environmental variables have a positive effect on cancer incidence. Finally, in the year 2015, the variable that only affects cancer incidence was found as "alcohol consumption from the lifestyle variables. In general, cancer incidence shows an increase as alcohol consumption, the population exposed to PM2.5 levels, the population under insurance coverage, and out-of-pocket health expenditures increase accordingly. The positive correlation between the population under the insurance coverage and out-of-pocket health expenditures and cancer incidence can be explained by the fact that individuals with insurance can access healthcare services easily and, hence, more cancer cases can be diagnosed by the healthcare system. Similar to this study, the work by Grundy et al[21] conducted in Canada analyzed the effect of alcohol consumption on cancer incidence and concluded that the increase in alcohol consumption also increases cancer incidence. The study by Allen et al[22], which used data from England, found that women who drink alcohol have a higher cancer incidence. The study by Schütze et al[23] performed in eight European countries showed that alcohol consumption increases cancer incidence. Cigarette and alcohol consumption increase the risk of cancer, according to a study conducted by Marchand et al[24] on five different ethnic groups (Japan, Caucasian, Philippines, Hawaii, and China). The study by Poirier et al[25] conducted on individuals living in Canada showed that lung cancer incidence increases as the population exposed to PM2.5 levels does. The study by Datzmann et al[26] conducted in Saxony concluded that air pollution has an effect that would increase the mouth and throat and skin cancer incidence. Kulhanova et al[27] analyzed the impact of air pollution in France on lung cancer and identified that lung cancer incidence becomes higher as air pollution does. Similarly, a study by Guo et al[28] conducted in China indicated that lung cancer incidence increases as air pollution levels increase. Ades et al[29] performed a study on 27 European Union Member States and analyzed the effect of health expenditures on cancer incidence and concluded that cancer incidence becomes higher with an increase in health expenditures. As a result, the literature and this study show a positive correlation between health expenditures and cancer incidence, with an increase in health expenditures allowing for an increase in cancer screening and diagnosis of new cases[29-31].

Within the framework of research, the factors that affect the cancer deaths in the OECD countries were also analyzed and "alcohol consumption" as one of the lifestyle variables was found as the only variable with an effect on the cancer deaths in the years of 2000, 2005 and 2010. However, in the year 2015, the health variables like "out-of-pocket health expenditures", "number of consultations with the physician" and "number of beds" were found to have a significant effect other than "smoking rate" and "alcohol consumption". Hence, the number of cancer deaths increases as the smoking rate and alcohol consumption rate do, yet the cancer deaths decrease as the out-of-pocket health expenditures in household expenditures, the number of consultations to physicians, and the number of beds increase. This can be explained by the fact that cancer patients get to benefit from the healthcare services and are treated, and the number of cancer deaths decreases respectively. Similar to this study, Stare and Jozefowich[32] conducted a study with 30 OECD countries and concluded that lung cancer deaths increase with the increase in smoking. The study by Xu et al[33] conducted in China for the effect of smoking on cancer deaths for the years 2005, 2010, and 2015 indicated that the deaths due to smoking are becoming higher with each passing year. The study by Stefler et al[34] performed in East European countries stated that one out of every three men who died due to cancer, smoked and/or consumed alcohol. The study by Jiang et al[35] conducted in Australia showed that smoking and alcohol use have a positive effect on cancer deaths. Similarly, the study by Kunzmann et al[36] performed in America showed the positive effect of smoking and alcohol use on cancer deaths. Moreover, the study by Ades et al[29] provided a similar result to this study and concluded that the number of cancer deaths decreases as health expenditures increase, which means better cancer screening and improvement in care quality allow early diagnosis of cancer and fewer cancer deaths [29,37,38].

Finally, the research analyzed the factors affecting the cancer-related years of life lost and concluded that alcohol consumption as one of the lifestyle variables is the only variable that affects the cancer deaths in 2000 and 2005, while in 2010 and 2015, the population under insurance coverage as one of the health system variables is also effective, in addition to smoking and alcohol consumption. Hence, the number of cancer-related years of life lost increases as smoking and alcohol consumption increase; yet the number of cancer-related years of life lost decreases as the population under insurance coverage increases. Similarly, the studies by Perez-Perez et al[39] in Mexico, Nelson et al[40] in America, and Rehm et al[41] in Canada showed that cancer-related years of life lost show an increase as the amount of consumed alcohol does.

In consideration of research findings, the lifestyle variables such as alcohol consumption and smoking are effective on cancer incidence, cancer deaths, and cancer-related years of life lost in the 2000s; the health system related variables start to be effective in addition to the lifestyle variables in the following years. This is particularly evident in the models developed to identify the factors affecting cancer deaths and cancer-related years of life lost. This finding is compatible with the literature that indicates a relative increase in the effect of healthcare systems on the health statuses of individuals and societies over the years[42-46]. The explanations for this aspect emphasize the developments in health technologies and the increase in the accessibility of healthcare services.

CONCLUSIONS

Countries should work on measures to lower smoking and alcohol use at the individual level in order to tackle the increasing cancer incidence, cancer deaths, and cancer-related years of life lost, while they should prioritize the macro-level topics such as minimize air pollution, improvement of insurance coverage, and increase of physician recruitment and beds.

This study aimed to explain cancer incidence, cancer deaths, and y cancer-related years of life lost with a limited number of variances such as lifestyle, environmental, health system, and demographic conditions, yet it is concluded that there are still a significant number of variations with regard to three variables. Additionally, the results may be considered limited in terms of their validity as the relative effects of risk factors regarding lifestyle, environmental, health system, and demographic conditions were analyzed over a five-year period between the years of 2000 and 2015 only for OECD countries. In order to have studies with stronger validity, further horizontal studies that cover the non-OECD countries and studies with different variables that may be related to cancer incidence, cancer deaths, and cancer-related years of life lost yet not covered under this study should be conducted accordingly. Another restriction of this study is that the variables of cancer incidence, cancer deaths and cancer-related years of life lost are not separated for cancer types. Therefore, it is recommended that studies analyzing the factors that affect cancer incidence, cancer deaths, and cancer-related years of life lost for each type of cancer should be conducted respectively.

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