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ORIGINAL ARTICLE

Cointegration Analysis of the Impact of Nonmedical Health Indicators on Life Expectancy at Birth in the United Kingdom

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Main Points

- The rate of increase in life expectancy at birth has been gradually decreasing in recent years.
- Risk factors such as alcohol consumption, smoking, obesity, and calorie consumption have an impact on life expectancy at birth.
- A better understanding of the reduction in life expectancy increase at birth requires more research to develop effective intervention strategies.

Abstract

In the last decade, the rate of increase in life expectancy has slowed down in many developed countries. This change shows that several risk factors that adversely affect life expectancy are effective. Among these countries, the rate of slowdown in the United Kingdom was higher than in other countries. In this context, the main purpose of the study is to determine the effect of nonmedical health indicators such as smoking, alcohol consumption, the prevalence of obesity in the total population, and average calorie consumed on life expectancy at birth in the United Kingdom, one of the most developed countries in the world. In the study, the effect of nonmedical health indicators for the periods 1996 – 2019 on life expectancy at birth was investigated. The relationship between the variables was examined using Johansen cointegration, error correction, and Granger causality tests. According to the findings obtained within the scope of the research, it was found that while the increases in alcohol use and smoking rates negatively affected the life expectancy expected at birth in the long term, the fact that people gained weight by eating more and consuming more calories positively affected the life expectancy at birth.

Keywords: Alcohol consumption, life expectancy, obesity, risk factor, smoking, time series

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Introductıon

Life expectancy at birth (LEB) is among the critical global health indicators of a population's health status. Worldwide, LEB is increasing significantly due to rising living standards, adopting public health measures, and improving health services through medical technology and lifestyle (Raleigh, 2019). More robust health systems and accessible and better quality care have contributed to this increase. Healthy lifestyles without risk factors, influenced by health system policies, have also positively affected LEB (James et al., 2017). However, the rate of increase in life expectancy has slowed in many developed countries over the past decade (Ho & Hendi, 2018). This change shows that some risk factors negatively affecting life expectancy are influential. Therefore, it is essential to consider these factors when analyzing the factors affecting LEB.

Increasing the number of healthy years and quality of life of individuals is recognized as an essential indicator. Smoking, alcohol consumption, and obesity are the three main risk factors for

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noncommunicable diseases and account for many deaths worldwide (OECD, 2021). In recent years, studies on risk factors such as alcohol consumption, smoking, physical inactivity, and obesity have shown that they are associated with life expectancy both individually and socially (Fransen et al., 2014; Nusselder et al., 2009; Stenholm et al., 2021). It is stated that an individual with two or more of these behavioral risk factors lives approximately 12 years less than those without risk factors (Zaninotto et al., 2020).

Smoking, alcohol consumption, and obesity are considered the three main preventable risk factors in European countries (WHO, 2014). It is also said to significantly affect noncommunicable disease mortality and LEB (Lhachimi et al., 2016; McCartney et al., 2011). Smoking increases the risk of cancer and respiratory and cardiovascular disease and is recognized as a leading cause of preventable death in developed countries (Doll et al., 2004). Similarly, alcohol use is cited as a leading cause of death and disability worldwide, especially among working-age people (OECD, 2021). Obesity is ranked as the fifth leading cause of death worldwide, accounting for about half of diabetes cases and about a quarter of ischemic heart disease (Kelly et al., 2008).

Beyond health and medical conditions, risk factors have broader social and economic impacts. An estimated US$572 billion is spent in OECD (Organisation for Economic Co-operation and Development) countries to treat diabetes and prevent complications (International Diabetes Federation, 2017). On average, 2.4% of health expenditure goes to tackling the harms caused by alcohol consumption, and the level of expenditure can increase across countries (OECD, 2021).

Risk factors have affected LEB for individuals in many countries. However, the level of impact varies across countries (Mackenbach et al., 2019). In the last decade or so, the upward trend in LEB has slowed down in many countries. However, among these countries, the rate of deceleration in the United Kingdom has been higher than in other countries (Leon et al., 2019). This situation has revealed the necessity of examining the long-term relationship between LEB and some risk factors in the UK. When the literature is examined, although each of the variables used within the scope of the research is examined from different perspectives, no study investigates the effect of these nonmedical health indicators on LEB. Although studies explore each of the variables in question from different aspects, it is seen that the relationships between the variables mentioned in the scope of this research are examined between other variables, not with the LEB variable.

In this context, the main objective of this study is to determine the effect of smoking, alcohol consumption, obesity prevalence in the total population, and average calorie consumption on LEB in the United Kingdom, one of the most developed countries in the world.

Methods

This study was conducted to determine the impact of nonmedical health indicators on LEB in the UK from 1996 to 2019. Cointegration analysis was applied to reveal the level of relationship between variables in the study. The variables used in the model are life expectancy at birth (LNLEB), alcohol consumption per capita (LNAC), per capita calorie consumption (LNCC), the proportion of obese people in the total population (LNOBESTY), and proportion of 15+ smokers in total population (LNSR).

All variables are naturally logarithmically transformed. Figure 1 is a graphical representation of the natural logarithmic transformation of the series. The dependent variable in the study is life expectancy at birth (LNLEB), and the independent variables are alcohol consumption per capita (LNAC), per capita calorie consumption (LNCC), the proportion of obese people in the total population (LNOBESTY), and the proportion of smokers over 15+ in the total population (LNSR). The data type of the variables is annual. Within the scope of the research, analyses were conducted using the Eviews 9 package program. Ethics committee approval is not required as publicly available secondary data is used in the study.

Results

All of the variables used in the study contain unit roots at the level. In other words, the series is not stationary at level. Accordingly, the series was made stationary by applying different operations. The VAR (Vector Autoregressive) model constructed with the stationary series is shown as follows:

$$\Delta Xt = a\beta Xt - 1 + \sum_{i=1}^{k-1} \Gamma i \Delta t - 1 + \varphi Dt + \varepsilon i$$

The model shown above is known as the error correction model. As stated by Kutlar and Şimşek (2003:70), taking the first difference in the equation is known as the VAR model. The stationarity of time series by taking their first differences indicates that cointegration analysis C(1 1 1) analysis can be performed between the series. Different unit root tests examine the stationarity of time series. In this study, ADF (Augmented Dickey-Fuller) and PP (Phillips-Peron) unit root tests were used to analyze the stationarity of the series. The stationary states of the series were examined by unit root tests.. The unit root test results of the variables are shown in Table 1.

Table 1 above shows the unit root test results of the series at level I(1). Here, the (***) sign indicates that the series is stationary at the 1% level and the (**) sign indicates that the series is stationary at the 5% level. To determine the most appropriate approach in the modeling phase, the program was determined by the EViews program.

To accurately model VAR analysis in line with time series, it is essential to determine the most appropriate lag value. The first differences of the nonstationary series were taken, and the most appropriate lag value was determined. As in Table 2, information criteria were used to determine the optimal lag value in the model to be developed. The lag value suggested by each information criterion among the available lag values is marked with *. It is seen that the lag value marked with the maximum * is the most appropriate lag value for the model.

Within the scope of the research, the most appropriate lag value was evaluated in line with the information criteria. Within the

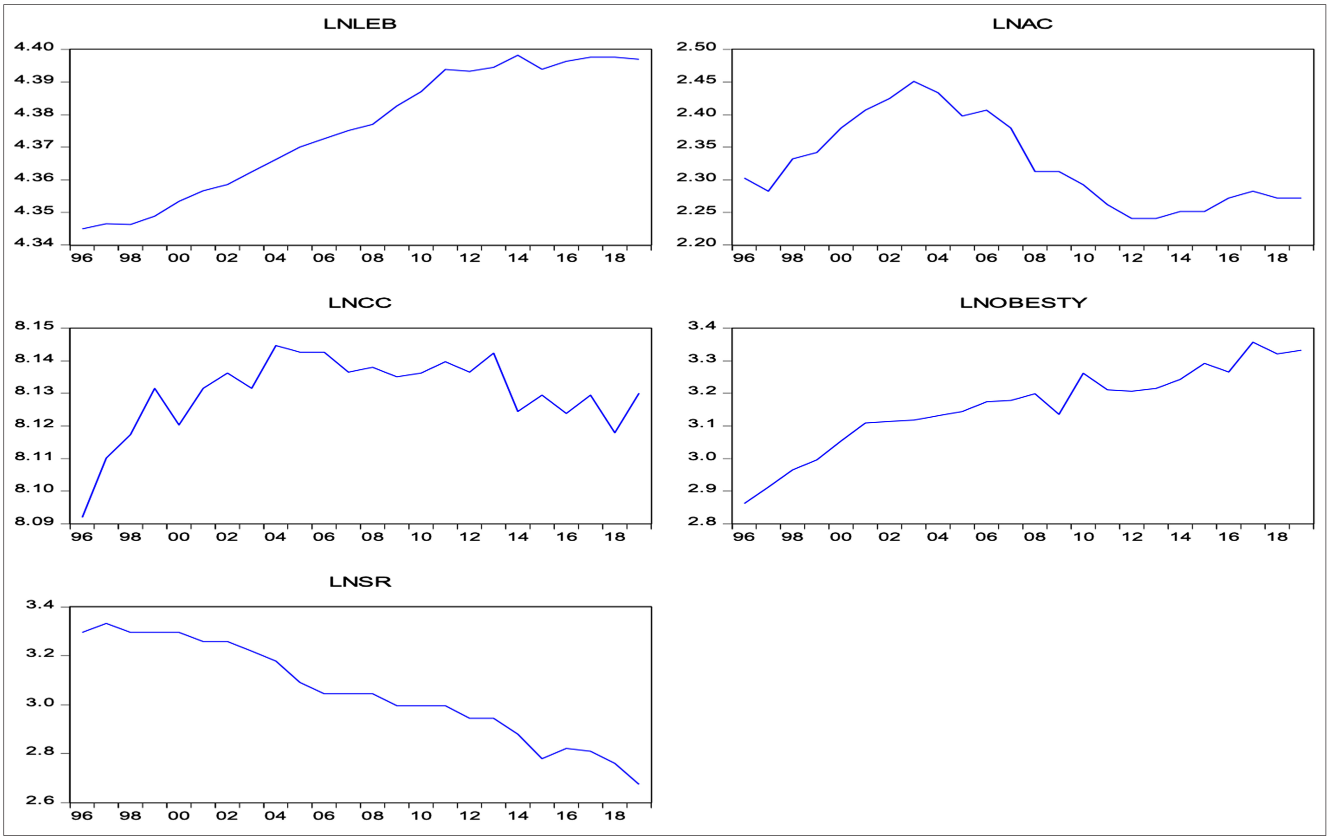

Figure 1. Graphical Representation of the UK's LEB, AC, CC, SR, and OBESTY Series; LEB = life expectancy at birth, AC = Alcohol Consumption, CC = Calorie Consumption, SR = Smokers Over 15+ in the Total Population.

scope of a total of 2 lag values, the most appropriate lag value was determined to be 1. After the optimal lag length for the model, the Johansen – Juselius cointegration test results for the model according to max-Eigen and trace test statistics are shown in Table 3.

As seen in Table 3, according to both the trace statistic and the minimum eigenvalue statistic, there are two co-integrated vectors. The null hypothesis H0, which states that there are not at least two co-integrated vectors in both equations, is rejected at the 5% significance level. In other words, there are at least two co-integrated vectors. At the same time, the statistical values of the first two of the trace and eigenvalue test statistical values are higher than the statistical value of the 5% critical value, indicating that there are co-integrated vectors. These results indicate a long-run interaction between LEB and nonmedical health indicators. According to the result that there are at least two co-integrating vectors between the variables, the most appropriate normalized co-integrating vector is as follows;

Table 4 shows the coefficients of two co-integrated vectors obtained according to the Johansen – Jeselius cointegration test results. The co-integrated equations based on these coefficients are as follows:

Co-integrated Vector Equation: LNLEB = –0.095LNAC + 1.024LNCC + 0.081LNOBESTY – 0.035LNSR – 3.88C (1)

Co-integrated Vector Equation: LNLEB= 1.767LNCC – 0.246LNOBESTY – 0.220LNSR (2)

As can be seen in the equations, the coefficients in models 1 and 2, which show the long-run equilibrium relationship between the variables, give the values in which the WBYS variable will change by 1% in case of a 1% change in the independent variables. According to the results obtained, it is predicted that a 1% increase in the amount of alcohol consumption may cause a 0.09% decrease in LEB. On the other hand, a 1% increase in average calorie consumption would lead to a 1.02% increase in the LEB. A 1% increase in the obesity rate would lead to a 0.09% increase in the LEB. Finally, in case of a 1% increase in the smoking rate, there may be a 0.03% decrease in the LEB.

Table 1.
ADF and PP Unit Root Tests

	ADF Unit Root Test Value (k = 2)		**PP Unit Root Test Value (k = 2)**	
	Level	**First Differential I(1)**	**Level**	**First Differential I(1)**
LEB	–1.44	-3.96^{***}	–1.43	-3.95^{***}
AC	–2.29	-3.79^{**}	–1.04	-3.35^{**}
CC	–0.78	-7.10^{***}	0.99	-7.20^{***}
SR	0.83	-3.80^{***}	2.13	-5.81^{***}
OBESTY	–2.53	-7.66^{***}	–2.11	-7.66^{***}

Note: ADF = Augmented Dickey-Fuller); LEB = life expectancy at birth; PP = Phillips-Peron.

Table 2.
Optimal Lag Length of VAR(3) Model.

Lags	LogL	LR	FPE	AIC	SC	HQ
0	253.5429	NA	1.06e−16	−22.34684	−22.34684	−22.53639
1	355.7516	148.6672*	1.02e−19*	−28.12599*	−28.12599*	−29.26330*
2	377.4509	21.69933	2.09e−19	−26.58611	−26.58611	−28.67118

Table 3.
Johansen-Jeselius Cointegration Test Results

Hypotheses	Eigenvalue	Trace Statistics	5% Critical Value	Probability Value
None*	0.891654	110.9750	76.97277	.0000
Maximum 1*	0.747428	62.08157	54.07904	.0082
Maximum 2	0.535620	31.80829	35.19275	.1109
Maximum 3	0.399519	14.93314	20.26184	.2302
Maximum 4	0.155284	3.712603	9.164546	.4566
Hypotheses	Eigenvalue	Maximum Eigenvalue Statistical Value	5% Critical Value	Probability Value
None*	0.891654	48.89339	34.80587	.0006
Maximum 1*	0.747428	30.27328	28.58808	.0302
Maximum 2	0.535620	16.87515	22.29962	.2405
Maximum 3	0.399519	11.22054	15.89210	.2359
Maximum 4	0.155284	3.712603	9.164546	.4566

Table 4.
Normalized Co-integrated Coefficients

	LNLEB	LNAC	LNCC	LNOBESTY	LNSR	C
1. Co-integrated Vector	1.000000	0.095230 (0.01669)	−1.024241 (0.10034)	−0.081640 (0.02211)	0.035639 (0.01619)	3.880383 (0.77569)
2. Co-integrated Vector	1.000000	–	−1.767022 (0.23339)	0.246930 (0.02664)	0.220559 (0.04401)	8.255243 (1.78449)

Note: () = standard error; LNAC = alcohol consumption per capita; LNCC = per capita calorie consumption; LNLEB = life expectancy at birth; LNOBESITY = the proportion of obese people in the total population; LNSR = proportion of 15+ smokers in total population.

When the findings of the other co-integrated equation numbered 2 are analyzed, it is predicted that a 1% increase in calorie consumption would lead to a 1.76% increase in LEB, a 1% increase in obesity rate would lead to a 0.24% decrease in LEB, and a 1% increase in smoking rate would lead to a 0.22% decrease in LEB. The VECM estimation results obtained from the calculations are shown in Table 5.

According to the estimation results in Table 5, a negative (0.09) and statistically significant relationship exists between LEB and alcohol use rate. A general increase in the level of alcohol use in society has a decreasing effect on LEB. The smoking rate also has a negative (0.03) and significant relationship with the dependent variable. On the other hand, there is a positive (1.03) and significant relationship between calorie consumption and LEB. Finally, the relationship between the obesity rate and LEB is also positive (0.07) and significant. Moreover, the lagged error correction term shows that the deviation between the actual values of the LEB and its long-run values disappears by 17% per year. Figure 2 shows the impulse response functions between the variables.

When the impulse response function graph between variables is analyzed, it is seen that smoking and alcohol consumption rates harm the LEB. In contrast, calorie and obesity indicators have a positive effect. On the other hand, the short-run relationship of the series is analyzed by the Granger causality test. The Granger causality test examines the short-run relationship of series that move together in the long run.

As seen in Table 6, the Granger causality test examined the relationships between the dependent variables and all variables included in the study. While there is no Granger causality relationship between alcohol consumption and LEB, there is a Granger causality relationship between LEB and alcohol consumption. While there is a Granger causality relationship between calorie consumption rate and LEB, there is no Granger causality relationship between LEB and calorie consumption. There is a two-way Granger causality relationship between calorie consumption and alcohol consumption. On the other hand, there is a Granger causality relationship between alcohol consumption to obesity variable. There is a one-way Granger causality relationship between smoking rate and calorie consumption rate.

Table 5.
Error Correction Model Estimation Results

Dependent Variable	Independent Variable	Coefficient
LNLEB	EC_{t-1}	−0.171644 (0.07944) [−2.16080]
	LNAC(−1)	−0.093150 (0.01709) [5.45107]
	LNCC(−1)	1.033999 (0.10271) [−10.06668]
	LNSR(−1)	−0.039239 (0.01657) [2.36808]
	LNOBESTY(−1)	0.075656 (0.02264) [−3.34237]
	C	3.934806

R^2 = .35 SE, EG = .002, $F_{(p)}$ = 17.36 (0.00) DW =2.038.

Note: ( ) = standard error; [ ] = *t*-statistic value; LNAC = alcohol consumption per capita; LNCC = per capita calorie consumption; LNLEB = life expectancy at birth; LNOBESITY = the proportion of obese people in the total population; LNSR = proportion of 15+ smokers in total population.
*The optimal lag length is determined according to the Schwartz Information Criterion.

Discussion

This study examines the relationship between nonmedical indicators and life expectancy at birth by using Johansen cointegration, error correction, and Granger causality tests for the UK's LEB indicator, using data for the period 1996 – 2019. According to the findings obtained within the scope of the research, increases in the rates of alcohol use and smoking harm LEB in the long run, while people gaining weight by eating more and consuming more calories have a positive effect on LEB.

In the literature, the effects of alcohol and obesity on different health indicators have been examined from different aspects. Both alcohol use and being overweight reduce the quality of life and cause individuals to struggle with different health problems because they cause the development of different diseases. Holford et al. (2014) stated that there is a negative relationship between the implementation of cigarette controls and increases in the price level and LEB. Wagaenaar et al. (2008) found a partial relationship between alcohol prices, alcohol tax rates, and alcohol consumption levels. The decrease in the rate of alcohol consumption has a positive effect on other health indicators, especially the LEB. Another study in this context was conducted by Kleinow and Cairns (2013). They examined the relationship between mortality rates and smoking levels in 10 developed countries. Among the countries included in the study, they stated that the rate of smoking-related deaths in total deaths in the UK and Canada varies between 5% and 10%. Within the area of the research, they stated that there is a negative and strong relationship between smoking and mortality rates. Baltagi and Griffin (1995) found that less alcohol consumption is expected to have a positive impact on the LEB as well as create a healthier life level. When smoking is added to alcohol consumption habits, it has been found that individuals' quality of life decreases significantly. Pierani and Tiezzi (2009) stated that the decrease in the amount of use of these nonmedical indicators that harm the health level will have a positive effect on the basic health indicators, primarily the LEB. Leon et al. (1997) measured the effect of alcohol use levels on mortality rates in Russia. As a result of

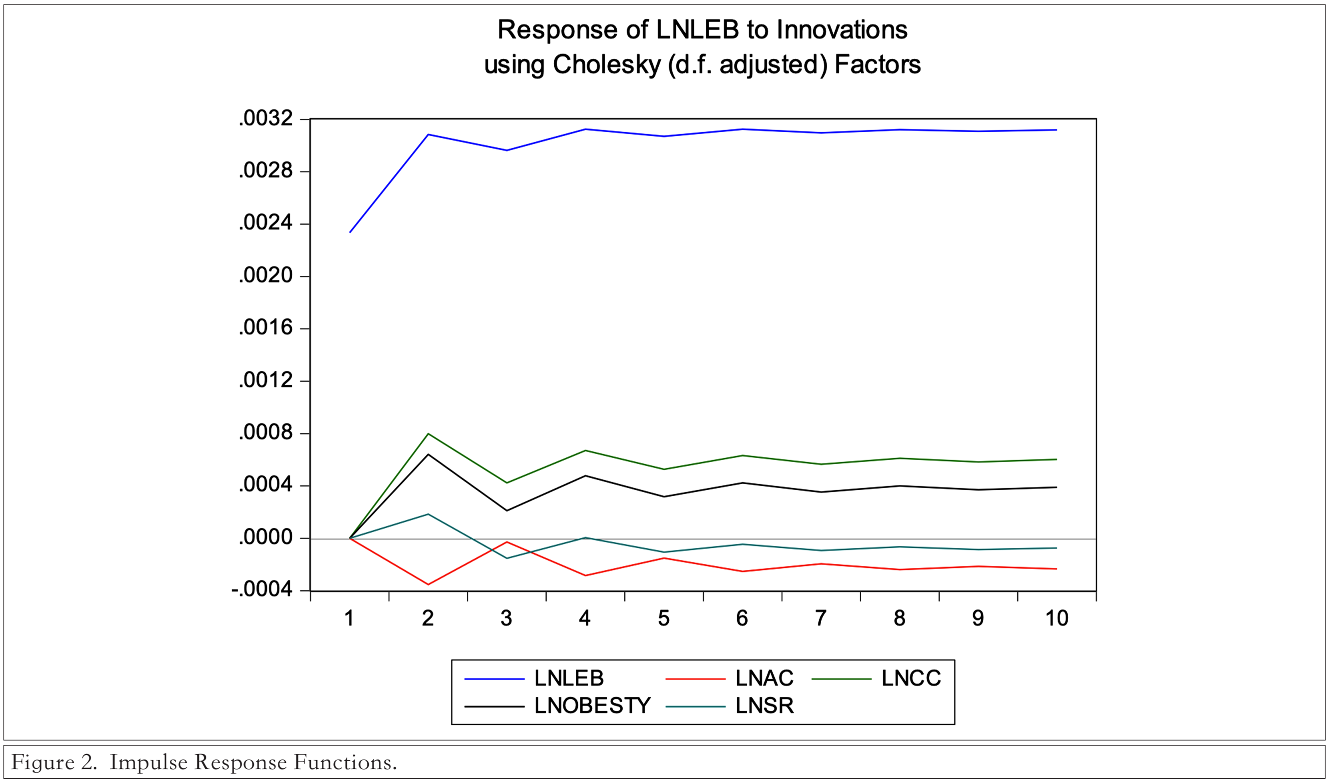

Figure 2. Impulse Response Functions.

Table 6.
Granger Causality Test Results

H_0 Hypothesis	F-Statistics	*p*
Alcohol Consumption is not a Granger Cause of LEB.	1.11442	.350
LEB is Not a Granger Cause of Alcohol Consumption.	6.47810	.008
Calorie Consumption is not a Granger Cause of LEB.	4.05734	.036
LEB is not a Granger Cause of Calorie Consumption.	2.74082	.093
Obesity is Not a Granger Cause of LEB.	0.82323	.455
LEB is Not a Granger Cause of Obesity.	1.38855	.270
Smoking Rate is not a Granger Cause of LEB.	0.05919	.942
DBMS is not a Granger Cause of Cigarette Smoking Rate.	1.57158	.236
Calorie Consumption is not a Granger Cause of Alcohol Consumption.	3.93603	.03
Alcohol Consumption is Not a Granger Cause of Calorie Consumption.	3.72520	.04
Obesity is Not a Granger Cause of Alcohol Consumption.	3.58372	.05
Alcohol Consumption is Not a Granger Cause of Obesity.	4.38072	.02
Smoking Rate is Not a Granger Cause of Alcohol Consumption.	4.05776	.03
Alcohol Consumption is not a Granger Cause of Smoking Rate.	0.30809	.738
Obesity is not a Granger Cause of Calorie Consumption.	2.05481	.1588
Calorie Consumption is Not a Granger Cause of Obesity.	2.05793	.158
Smoking Rate is Not a Granger Cause of Calorie Consumption.	3.79954	.04
Kolari Consumption is not a Granger Cause of Smoking Rate.	0.573	.574
Smoking Rate is Not a Granger Cause of Obesity.	2.29954	.04
Obesity is not a Granger Cause of Smoking Rate.	0.97182	.39

Note: LEB = life expectancy at birth.

the research, it was stated that significant changes in the level of alcohol use would significantly affect the fluctuations in mortality. While some of the studies and our findings overlap, they differ from others. It is thought that this situation can be explained by several different factors such as the difference in the time interval used in the study, the changes in medicine due to the developing technology, and healthy life habits.

On the other hand, when the research conducted in this context is examined, it is noteworthy that there are findings that tobacco and other products of tobacco use reduce LEB. The findings of this study coincide with the findings of other studies in the literature. In this study, it is seen that potential increases in the amount of alcohol consumption have a decreasing effect on LEB. A similar situation is associated with the amount of cigarette use, and this variable has a negative relationship with the LEB indicator.

The findings on obesity in this study contradict the findings of other studies in the literature. Lung et al. (2019) examined the effects of obesity levels on LEB in Australia in their study. According to the results of the research, they stated that obesity has an impact on DBMS regardless of gender and causes 27.7% more deaths, especially in men. On the other hand, Flegal et al. (2005), in their study conducted in the USA, stated that being overweight negatively affected life expectancy. Obesity and calorie consumption are positively associated with LEB. Peters et al. (2003), who measured the effect of alcohol and overweight status on LEB, stated that alcohol use caused premature deaths and had a decreasing impact on LEB. In this case, the fact that individuals consume more calories or have a higher level of weight than necessary indicates that the individuals concerned are at a certain level of welfare. It is known that welfare level is positively correlated with the LEB variable. On the other hand, the relationship between these indicators and the dependent variable is also related to other indicators included in the research.

When the findings obtained as a result of the research are evaluated in general, causality relationships between variables are analyzed within the scope of the error correction model. It is seen that there is a unidirectional causality relationship between the LEB variable to the rate of alcohol use. On the other hand, there is a unidirectional relationship between calorie consumption to the LEB variable. However, a bidirectional causality exists between calorie consumption and alcohol consumption rates. A bidirectional causality relationship exists between the obesity rate and alcohol consumption.

Limitations and Directions/Suggestions for Future Research

As in every study, there are some limitations in this study. The fact that the data of the study covers a certain period of time is considered limited. In the study, the risk factors affecting LEB were taken as smoking, alcohol consumption, obesity, and calorie consumption. Apart from these variables, it should be taken into consideration when evaluating that different risk factors may affect LEB. In addition, international comparisons of different countries can be made in future studies. The effect of different variables on LEB can be investigated. A better understanding of the reduction in life expectancy increases at birth requires more research to develop effective intervention strategies.

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