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Original Article

Economic Impacts of Cardiovascular Diseases: An Econometric Evaluation in Turkey

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Abstract

Background: The study aimed to determine the impact of the burden of cardiovascular diseases on Gross Domestic Product (GDP) in Turkey.

Methods: GDP was taken as the dependent variable and the burden of cardiovascular diseases was taken as the independent variable. The variables were analyzed within the frame of Panel Data Analysis.

Results: Significant relationships were found between GDP and burden of cardiovascular diseases. The unidirectional Granger causality relationship was determined from burden of cardiovascular diseases to GDP and revealed that they acted together in the long term. The analysis that made with using econometric regression models revealed that generally 1 unit increased in per capita of cardiovascular diseases decreased GDP by between 477651.8 – 624485.6 units (PPP$).

Conclusion: The empirical results of the study revealed that the cardiovascular disease burden was one of the reasons for the decrease in GDP and their economic effects would continue in the long term in Turkey. From this perspective establishing and implementing policies to improve the burden of cardiovascular diseases in Turkey could be an important approach for the economic development.

Keywords: Burden; Cardiovascular diseases; Gross domestic product; Econometric evaluation

Introduction

Health economics-related studies have tried to determine the impact of Non-Communicable Diseases (NCD) on individuals and economies using health measurements such as good health status, mortality rate, disability-adjusted life years (DALY), etc. One of the NCD was Cardiovascular diseases (CVD) and also have a large impact on productive life years (1-5). Cardiovascular Diseases are disorders of the heart and blood vessels. These diseases are including coronary heart disease, cerebrovascular and peripheral artery diseases. Various forms of cardiovascular diseases such as arrhythmias, heart failure, coronary vessel disease, vascular disease, venous thrombosis, peripheral arterial diseases, ischemic and hemorrhagic stroke are the leading causes of death in the World for all ages. The most important risk factors of CVD have included dyslipidemia, hypertension, type 2 diabetes, obesity, overweight, tobacco smoking, and aging. In 2019, CVD related death estimated at 17.9 million people which means 32% of all global deaths. 85% of these deaths were caused by stroke and heart attack and over three-quarters of these deaths occurred in low-income and middle-income countries. Besides, in 2019, NCD related premature deaths were 17 million under 70 years of age and 38% of these deaths were caused by CVD (6).

Mortality and morbidity caused by diseases have significant socio-economic impacts. Some units of measure such as DALY, Years Life Lost (YLL), and Years Life Disability (YLD) have been developed to evaluate the deterioration in health. Measurement units are based on years. DALY is one of the health measurement units for years of life lost due to disability or premature death. DALY is a health metric that measures healthy life years lost due to illness, injury, or risk factors (7). Health measurement units make it possible to identify the causes that express the most significant health deficiency for the population and categorize the deficiency causes (diseases) according to their importance. DALY could combine knowledge of morbidity and mortality creating an important measurement tool and reducing the disease incidence (8). One unit of DALY is equaled to one year of lost healthy life (9).

When making an economic assessment of diseases, these measurement units such as DALY, consider direct and indirect costs of the diseases. Direct costs include the diagnosis, treatment, and rehabilitation expenditures for a disease. Indirect costs include expenses incurred in terms of loss of productivity caused by disease, lost earnings from premature death, payments to individuals who are too ill to work due to illness, or payments to rights holders due to premature death.

CVD, which has an important share in NCD in terms of mortality and morbidity, has important economic effects.

In USA, the cost of cardiovascular diseases was calculated as 555 billion dollars in 2015, with 318 billion dollars of direct costs and 237 billion dollars of indirect costs; and this figure would reach 1.1 trillion dollars in 2035 (10). In the study, which evaluated 83 studies related to cardiovascular disease and economic burden, per episode costs, ranged for while CVD and hypertension was between $500-$1500; coronary heart disease and stroke costs were determined over $5000 (11). Another study estimated the annual cost of coroner heart diseases to the European economy at 49 billion Euros and showed that this cost corresponded to approximately 2.6% of total health expenditures (12). In 2015, 6700 people aged 45-64 year left the workforce due to the ischemic heart diseases, this situation resulted in a loss of income of US$263 million, and these costs have been going to increased to US$426 million in 2030. From 2015 to 2030, extra welfare payments for the government are expected to rise from US$102 million to US$138 million, and the lost income tax revenue for these fifteen years was estimated at US$42 million. In 2015 while a loss of US$755 million in GDP was predicted, this loss has been going to increase to US$1082 million in 2030 (13). In a study, while the direct costs of myocardial infarction in the acute period were calculated per admission between 6790 € - 8918 €; then the following year, this cost was between 13838 – 14792 € per patient (14). In the same study, the direct costs for patients with chronic heart failure ranged from €3417 to €5576 per patient per year; the average cost of perioheral artery disease was calculated €4963 for the treatment of acute phase per admission and €1390-2535 for the later stages of treatment; besides this, the cost of an ischemic stroke was calculated as 17399-21954 € per patient and €6260-6496 for the later stages of treatment per year(14).

While the mean of per capita heart failure expend per year in high-income countries was $69.75; this expends in middle and low-income countries were $2.76. While 18% of the global population that lives in high-income countries was spent 86% of global heart failure expenditures; middle- and low-income countries, which make up 82% of the global population, was spent 14% of global heart failure spending (15).

In a study including 197 countries that covers 98.7% of the world's population, the direct, indirect and total costs of heart failure were calculated in 2012 were $65 billion, $43 billion and

$108 billion respectively (15). In this study for Turkey in 2012, the direct, indirect, and total costs of heart failure were calculated as $59 million, $474 million, and $533 million respectively (15). According to this result, only the cost of heart failure per capita in Turkey in 2012 corresponded to $7.14. The cost of CHD health care per capita in the EU has been calculated to be around 50 euros (16).

According to the CVD prevalence from 2016 to 2035, cases would be increased from 3.4 million to 5.3 million, and the economic burden due to this disease was estimated at US$ 9.2 billion for these nineteen years. This increase would be largely due to demographic changes; more specifically, the expected aging of the population over the next 20 years. It also meaned that the rate of CVD cases would be shifting to older age groups (17).

The common features of the studies made in the field of CVD were trying to explain the disease costs according to the costs types and focused on estimating direct effects on health expenditures and indirect effects on the economy. However, these efforts could not clearly reveal the effects of CVD costs on the economy. The most important aim of this study was to try to explain the effect of the burden of CVD on the economy with an econometric model. The use of econometric methods in health-related studies gives significant results that support this aim.

In this context, the hypothesis of the study was determined as follows:

H_1: The burden of cardiovascular diseases has being affected GDP negatively.

Methods

The relationship between cardiovascular health and GDP was analyzed by panel data method. In the analysis, firstly, descriptive information about the variables was explained, and the significance test of the econometric model established for the study was carried out using the Least Squares Method. In the next step, unit root tests were carried out to determine the stability of the variables; the lag length of the model was determined and the causality relationships between the variables were analyzed by using the Granger causality test (18). Finally, Dynamic Least Square (DOLS) and Fully Modified Ordinary Least Square (FMOLS) and ARDL tests were applied to determine the effects of cardiovascular diseases on GDP (19).

Variables

GDP as the dependent variables; cardiovascular disability-adjusted life year was taken as the independent variable showing the deterioration in cardiovascular health. Information on the variables is given in Table 1. This study included regular data on DALYCVD and GDP for the period from 1990-2017 in Turkey.

Table 1: Defining variables

Variables		*Source*	*Abbreviation*
Gross Domestic Product (PPP$)	Per capita	https://stats.oecd.org/	PGDP
Cardiovascular disability-adjusted life year/in Turkey	Per capita	http://ghdx.healthdata/	DALYCVD

Statistical Analysis

The statistical analyses was performed using Eviews 10 Statistics program.

Ethical Issues/Statement

The data of this study was public, so the etic issues not required for this study.

Results

The median of PGDP in Turkey was 5379.404 + 3705.879 (max: 12519.39; min: 2270.338); the median of DALYCVD was 0.037285 + 0.005772 (max: 0.050066; min: 0.035240).

The econometric model installed for this study was as follows::

*PGDP = C(1)*DALYCVD + C(2)*

*PGDP = -509403.198967*DALYCVD + 27624.3097911*

The significance test of the model established for the study was carried out using the panel least squares method and the results are given in in Table 2. The R-value was 63% and the R^2 value was 62%, showing that the model established for the study has good explanatory power, and it was also significant in the relationship between dependent and independent variables (*P*<0.0001). Besides, diagnostic tests (Jarque Bera Normality Test; Ramsey Reset Test, Breusch-Godfrey Serial Correlation LM Test, Heteroskedasticity Breusch-Pagan-Godfrey Tests) explaining the relationship between the dependent and independent variables and the model confirm the significance of the model also. For this reason, the model established in the study was considered significant (*P*<0.05).

Table 2: Results of panel least squares

Dependent Variable	*Independent Variable*	*Coefficient*	*Prob.*	*R^2*	*Adjusted R^2*	*F-Statistic*	*Prob(F-statistic)*
PGDP	DALYCVD	-509403.2	0.0000	0.63	0.62	44.15795	0.0000
	C	27624.31	0.0000				
Jarque Bera Normality Test: 0.499706; Ramsey Reset Test: 0.0919; Breusch-Godfrey Serial Correlation LM Test: 0.0093**; Heteroskedasticity Breusch-Pagan-Godfrey: 0.0212**; Ramsey Reset Test: 0.2398.							

**significance at level 5%

Granger causality analysis

The Granger causality test was used to determine the causality relationship between the variables. While applying the Granger causality analysis, first of all, the variables in the analysis should be stationary at the same level. For this purpose, unit root tests were performed on the variables. The results of unit root tests of the variables were given in Table 3. These tests were performed in five types: Im et al., Levin et al., Breitung t-stat, ADF Fisher Chi-square, and PP Fisher Chi-square tests. In these tests, the null hypothesis indicates that the variables have a unit root, while alternative hypotheses indicate the absence of a unit root. In Table 3, the stationarity of the variables used in the study was evaluated at 1%, 5%, and 10% significance levels.

Since the unit root tests for the evaluation of stationarity were stationary at level I(0), the causality analysis I(0) model was used. The second assumption of causality analysis was to determine the lag length of the variables. For this purpose, the VAR model was established to determine the lag length of the variables and the lag length was estimated. In Table 3, the maximum lag length of the variables was found in the 2nd lag length. Then in the VAR model, the causality relationship was estimated at the 2nd lag length and results were shown in Table 3. Diagnostic tests (JB Normality test, VAR Residual Heteroskedasticity Test, VAR Residual Serial Correlation LM Test, and The stability condition) were performed to confirm the Granger Causality test results. As a result of the Granger causality test performed for the evaluation of the causal relationship between the variables and the diagnostic tests of the results, the existence of a causal relationship from cardiovascular disease burden to GDP was determined at the 1% significance level (*P*<0.0024).

Table 3: Results of tests

A. Unit Root Tests Results

Variables			Levin, Lin ve Chu	Breitung t-stat	IM, Pesaran and Shin W-stat	ADF	PP
PGDP- DALYCVD	Level	İndividual Effects	0.0584***	-	0.5788	0.5210	0.8573
		İndividual Effects and İndividual Linear Trends	0.0147**	0.4328	0.0696***	0.0520**	0.9283
		None	0.0821***	-	-	0.3232	0.1741
	1.diff.	İndividual Effects	0.0031*	-	0.0008*	0.0014*	0.0014*
		İndividual Effects and İndividual Linear Trends	0.0039*	0.0054**	0.0054**	0.0088**	0.0094**
		None	0.0002*	-	-	0.0001*	0.0001*
	2.diff.	İndividual Effects	0.0000*	-	0.0000*	0.0000*	0.0000*
		İndividual Effects and İndividual Linear Trends	0.0000*	0.0000*	0.0004*	0.0000*	0.0000*
		None	0.0000*	-	-	0.0000*	0.0000*

*, **, *** significance level at 1%; 5%;10% respectively

B. VAR Lag Order Selection Criteria Results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-125.7812	NA	144.4272	10.64843	10.74660	10.67448
1	-51.90645	129.2808	0.428447	4.825538	5.120051	4.903672
2	-42.11463	15.50372*	0.267005*	4.342886*	4.833742*	4.473110*
3	-41.74434	0.524576	0.369535	4.645362	5.332560	4.827676
4	-38.43718	4.133950	0.408305	4.703099	5.586639	4.937502

* indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

C. Granger Causality/Block Exogeneity Wald Tests Results

Nul Hypothesis	Prob.	Condition	Description
PGDP ≠> DALYCVD	0.1720	Received	PGDP was not the Granger cause of the DALYCVD
DALYCVD ≠> PGDP	0.0024	Rejected	DALYCVD was the Granger cause of the PGDP

JB Normality test: 0.2024; VAR Residual Serial Correlation LM Tests: 0.3397; VAR Residual Heteroskedasticity Tests: 0.9200; VAR satisfies the stability condition between 0.177948-0.894749 ; * significance level at 1% and in the estimation 2nd lag length was used.

ARDL Test

According to Table 4; ARDL [1,2] model was determined as the most suitable model for this study and the F statistic was calculated as 5,531 within the scope of ARDL limit test. Since this value was greater than the critical upper limit value, the null hypothesis, which suggests that there was no long-term relationship between the variables, was rejected. This results indicate the existence of a long-term, stable relationship between the related variables. After determining the cointegration relationship between the dependent and independent variables in the model, the long and short-term coefficients of this relationship were estimated. The coefficients of the explanatory variables in the model were statistically significant. In this context, an increase in DALYCVD negatively affects per capita income in the long run.

Table 4: ARDL test results

		F		*%95 alt sınır -%95 üst sınır*
ARDL (1,2)		5.531		3.30*** – 4.09**
	Variables	Coefficient		*t* Statistic
Long Run Form	D(DALYCVD)	-624485.6		-5.354476*
Error Correction Form	CointEq(-1)	-0.276553		-4.263343*
			R : 0.44	R^2 : 0.40

JB Normality test: 0.939763; Ramsey Reset Test: 0.1762; Breusch-Godfrey Serial Correlation LM Test: 0.5263; Heteroskedasticity Breusch-Pagan-Godfrey: 0.3155; lag was set as 2; *, **,*** significance level at 1%; 5%, 10% respectively

The ARDL coefficient estimation results showed that DALYCVD effective on GDP negatively and 1 unit increase in DALYCVD at 1% significance level decreased GDP by 624485.6 units. Considering the results of the CUSUM (cumulative sum) and CUSUMSQ (cumulative sum of squares) tests, which were conducted to determine whether the coefficients estimated by the ARDL bounds test were stable within the relevant period, it was seen that the null hypothesis, which states that the estimated coefficients were stable between 1990-2017 periods, was accepted (Figs. 1-2). Again, according to the results of the diagnostic tests applied to the model, there was no autocorrelation and changing variance problem in the model and that no model-building error has been made.

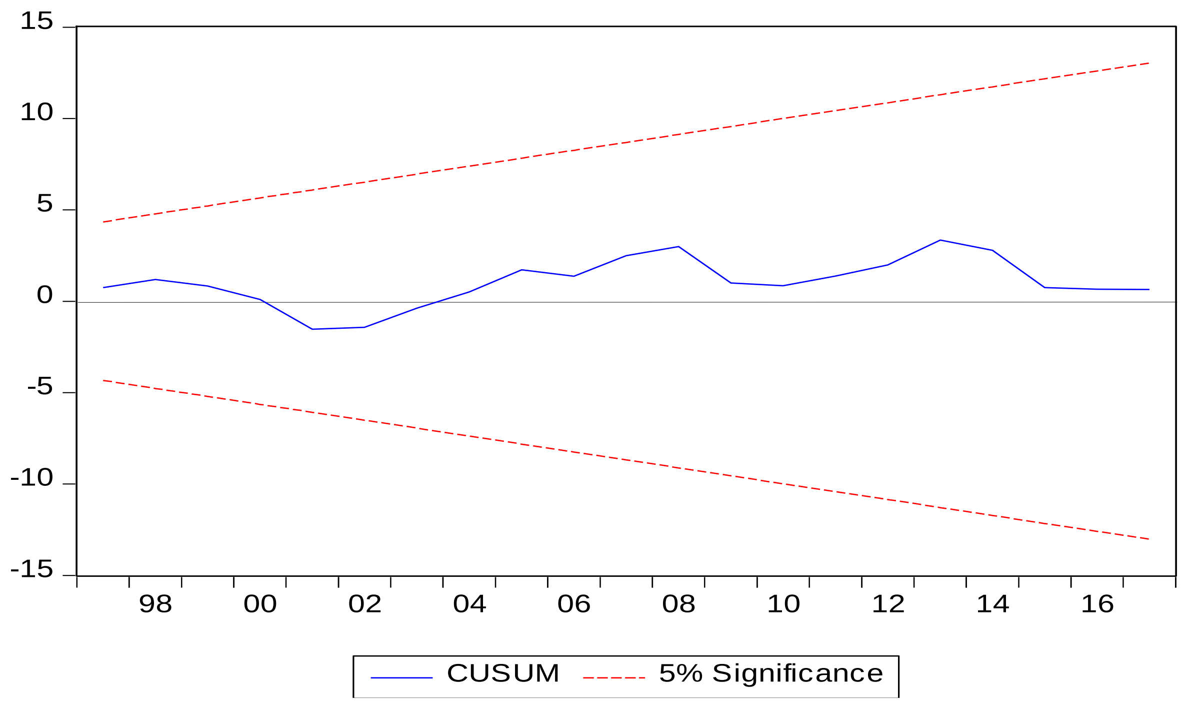

Fig. 1: CUSUM Test

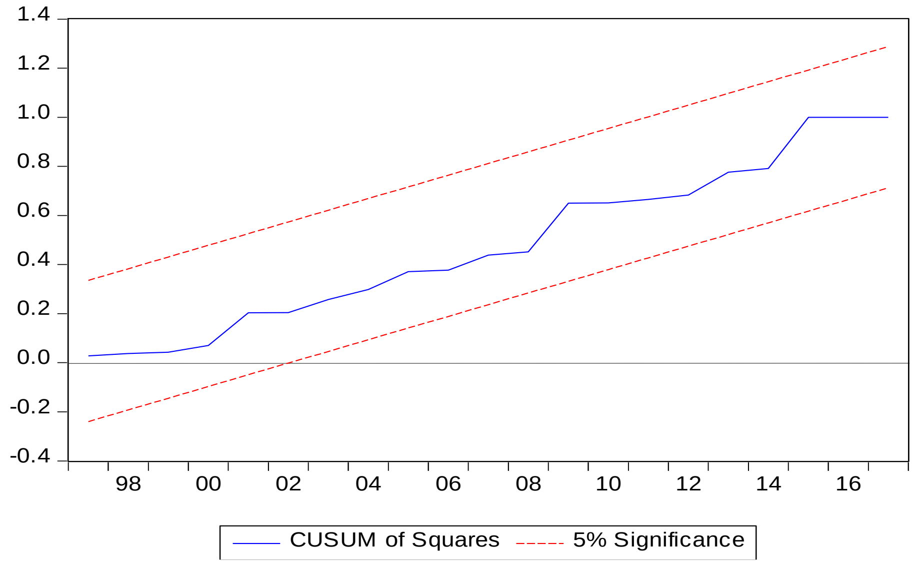

Fig. 2: CUSUMSQ Test

Dynamic Least Square (DOLS) and Fully Modified Ordinary Least Square (FMOLS) Tests

In Table 5, the DOLS and FMOLS test results for cointegrated panels are presented. According to the Engle-Granger tau-statistic (t-statistic) and normalized autocorrelation coefficient (the z-statistic), the results rejected the null hypothesis of no cointegration. The evidence suggested that DALYCVD and GDP were cointegrated. DOLS coefficient estimation results, DALYCVD effective on GDP negatively and 1 unit increase in DALYCVD at 1% significance level decreased GDP by 477651.8 units. FMOLS coefficient estimation results, DALYCVD effective on GDP negatively and 1 unit increase in DALYCVD at 1% significance level decreased GDP by 488770.0 units. In summary, the main findings obtained from FMOLS and DOLS forecasting methods confirmed the negative impact DALYCVD effective on GDP.

Table 5: DOLS and FMOLS tests results

The dependent variable: PGDP				
	DOLS		FMOLS	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
DALYCVD	- 477651.8*	-4.730923	- 488770.0*	-4.587239
	R : 0.84 R^2 : 0.81		R : 0.57 R^2 : 0.55	
	JB Normality test 0.530781		JB Normality test 0.599526	

Engle-Granger tau-statistic: 0.8033; Engle-Granger z-statistic: 0.7635; Phillips-Ouliaris tau-statistic :0.8396; Phillips-Ouliaris z-statistic : 0.8496 ; **receive significance at level 1%. In the DOLS estimation method, lead and lag were set as 1.

Discussion

The burden of cardiovascular diseases, the prevalence, and incidence in Turkey has been increasing over the years generally. In thirty years cardiovascular diseases related deaths in Turkey are 53%; DALY 26%; YLD 102%; YLL increased by 17%. In 2019 compared to 1990 CVD prevalence in Turkey was 104%; incidence 92% increased. This situation increases the health and social expenditures in the cardiovascular field; besides this situation, it leads to a regressive situation in the economy.

In a study assessing the impact of cardiovascular disease mortality on economic growth using a panel regression framework, a robust negative contribution of increased cardiovascular disease mortality rates on subsequent five-year growth rates in high-income countries has been determined (20). Namely, an increase in the mortality rate by 1% decreased the per capita income growth rate by about one point which means a small amount in terms of growth rates, but when this small amount summed up over the lifespan of an economy means a large amount (20).

Another study also revealed that CVD-related premature deaths accounted for 51659 working years in 2003, and and this loss of productivity (loss working years) means giving up $2.69 billion when modeled on the present value of lifetime income to 2030 (21). In the context of cardiovascular disease-related productivity published studies have pointed to productivity costs were significant as accounting for 21% to 63% of the full economic burden of this disease (21).

In 2016, total costs (including direct healthcare costs and indirect costs as loss productivity) of cardiovascular diseases, were estimated at US$10.2 billion in Turkey. Most of these costs (US$ 5.9 billion) were associated with IHD, while costs for cerebrovascular diseases were estimated as US$4.2 billion also. Of the estimated $10.2 billion economic burden for 2016 from CVD diseases, one-third was attributed to direct costs (direct healthcare costs as $3.4 billion) and two-thirds to indirect costs (US$6.8 billion). It was estimated that the cardiovascular disease burden in Turkey will increase by 40% with costs of US$14.2 billion by 2025. In addition, direct and indirect costs are expected to reach US$19.4 billion in total in 2035 compared to 2016. In addition, direct costs were expected to increase more slowly than indirect costs reaching US$5.4 billion and US$13.9 billion respectively (17).

In this study, a unidirectional causality relationship was determined from DALYCVD to GDP with a long-term equilibrium. Generally, if per capita DALYCVD was increased by 1 unit, per capita GDP was being decreased by between 477651.8 – 624485.6 units ($PPP). So in this studys' results were compatible with the literature (17, 20,21).

This was the first study conducted in Turkey in which the effects on the economy by both the cardiovascular disease burden treatment process costs (direct costs) and the disease-related loss of productivity and the social payments (indirect costs) revealed together. From this perspective, Turkey needs to reduce the burden of cardiovascular diseases, which have important socioeconomic effects on individuals and the economy. To manage the burden of CVD in Turkey effectively; the first suggestion could be focusing on measures to improve and protect public health. For example, a healthy lifestyle could reduce the risk of cardiovascular disease; like nutritionally, the Mediterranean diet has been suggested to help reduce the risk of cardiovascular disease, while taking excessive carbohydrate and high-fat diets may increase the incidence of cardiovascular disease (22); or if consuming an average of 2 g sodium (5 g salt) per day, the overall cost of US$84 million caused by annual 47017 deaths to the Brazilian Health System, and US$827 million of costs from premature deaths could be prevented to damage the country's economy (23). The second suggestion is choosing/adopting a population-appropriate approach in the management of cardiovascular diseases or reviewing existing practices and addressing innovative approaches. For example; the incremental cost-effectiveness of implementing South Africa's Primary Care guidelines over current treatment would be a saving of US$24902 per DALY averted compared with a saving of $17587 under WHO's a package of essential non-communicable disease interventions (PEN) guidelines (24).

Another approach is to set a budget for research and development for cardiovascular diseases and providing/increasing access to innovative treatments recommended.

The strengths of this study include the use of publicly available, nationally representative, and robust data from Global Health Data Exchange systems concerning the burden of the disease system, disaggregated by DALY, YLL, YLD, prevalence, and incidence group. The second strength of this study was using the econometric methodology to estimate the effects of the burden of disease which gives the results clearly. The limitation of this study is the year range for the data belonged to variables was between 1990 and 2017, so the time has been accepted as an important constraint for this study.

Conclusion

A healthy and educated human capital structure of a country is one of the determinants of economies. Individuals in this structure support the economic structure with their productivity. One of the effective factors in the human capital structure is the health status of the individuals. Deterioration in health status negatively affects the productivity of individuals, and this situation is reflecting the economy also.

Cardiovascular diseases are also an important group of diseases that have negative effects on the health of individuals and cause significant income losses due to direct and indirect costs.

In this context, the negative effects of cardiovascular diseases create on the productivity of individuals could be evaluated as an indicator of deterioration in human capital.

As a matter of fact, the results of the study revealed that the cardiovascular disease burden was one of the reasons for the decrease in GDP and their economic effects would continue in the long term in Turkey. In this context, it is recommended to make arrangements to adopt healthy life processes for individuals against to cardiovascular diseases, to control the direct-indirect costs of the disease, and to ensure optimal management of the diagnosis and treatment processes of cardiovascular diseases with innovative research.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The author declare that there is no conflict of interests.

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