Exploring the determinants of global life expectancy in an ecological perspective

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Abstract

Objective: This study is designed to understand the impacts of demographic events, socioeconomic differentials, health factors' availability, and environmental reasons which influence life expectancy (LE) globally. **Methods:** Data of 183 countries were taken from the United Nations agencies. The predicted variable was LE, and the determinants were demographic events, socioeconomic factors, health-related factors, and environmental issues. Descriptive statistics, correlation analysis, and backward multiple regression analysis were used to reach the research objectives. **Results**: The lowest LEs are found in the African countries; and LE is found significantly associated ($p<0.05$) with a wide range of demographic, socioeconomic, health, and environmental factors. The necessity of full coverage of immunization, higher income, and improved sanitation are more expected to raise LE. However, LE may be increased by way of decrease fertilities, Human Immunodeficiency Virus (HIV) prevalence, and carbon dioxide (CO_2) emissions. **Conclusions**: The LE is influenced by different demographic, socioeconomic, health, and environmental factors. Country-level and global efforts should be taken to raise LE throughout the reduction of HIV infection, births, and CO_2 emissions. The policy-makers should focus on the advancing reproductive decisions, increasing immunization coverage, and upturning improved sanitation usage.

Keywords: Life expectancy; determinantsof life expectancy; ecological analysis; HIV infection

Introduction

The life expectancy (LE) at birth reflects the overall mortality level of a population. It is defined as “the years a newborn infant would live if prevailing patterns of age-specific mortality rates at the time of birth were to stay the same throughout the child’s life”.[1] The LE is considered as a commonly used indicator to measure the overall improvement of a country. It is of actual importance for the low- and lower middle-income countries and especially for the African countries since these countries are struggling to reach socioeconomic advancements by significant investments in the social and health areas. In most of the countries of the world, LEs have been increasing during the last decade. In 2015, the global LE was found 71.40 years (female, 73.80 years; male, 69.10 years), extending from 60 years in the World Health Organization (WHO) African region to 76.80 years in the WHO European region, giving a ratio of 1.30 between the two regions. Globally, it is observed that females live longer than males. In 1990, the difference in LEs between the sexes was observed 4.50 years and it had remained almost the same by 2015 (4.60 years). Optimistically, the global average LE raised by 5 years between the years 2000 and 2015, the fastest rise since the 1960s. From 2000 to 2015 the increase of LE was observed greatest in the WHO African region, where LE raised by 9.40 years to 60 years, mostly dominated by the developments in child survival and extended entrance to antiretroviral therapy of Human Immunodeficiency Virus (HIV).[1]

An ecologic study focuses on the comparison of groups, rather than individuals which are often used to measure the prevalence and incidence of diseases. In an ecologic analysis, the variables may be aggregate measures, environmental measures, or global measures. It is inexpensive and easy to carry out, using routinely collected data, but they are prone to bias and confounding.[2] The contributing factors in increasing LE are one of the principal interests among demographic and health researchers. Today people across the globe enjoy better health, economically solvent, and living longer than ever before. The LE is expected to be increased by seven years for the period of 1998-2025, and it would be greater than 80 years in 26 countries.[3] Till now the mentionable disparities in LE are observed between the high- and low-income countries. The significant determinants were the development of technology, drugs, environmental development, and international cooperation. Moreover, the rises in LE were initiated by the higher income and education, access to improved sanitation, and clean water; developed healthcare facilities; and enormous rises in agricultural production. The changeability of LE has significant effects on personal and combined human activities since they affect fertility performance, socioeconomic development, human capital investment, intergenerational transmissions, and encouragements for pension subsidy rights.[4-5] LE focuses the population's physical condition of a country and the healthcare services that people generally receive when they fall ill.[6] The demographic and economic factors of LE include sex, age, residence, schooling, and income [gross national income (GNI) per capita].[7-9] Research also shows that income play important role for increasing recent LE. For example, enhanced income contributed an affirmative influence on LE in South Korea.[10] The older people in Thailand with improved earnings and innovative education had better health outcomes.[11] In the recent times, economic solvency and schooling in equalities were observed to explain the regional dissimilarities in LE with other health indicators.[12] The lower earnings and joblessness were seen to undesirably affect health outcomes.[13] Significant associations were observed between LE and education in Brazil,[14] Finland, Sweden, Norway, Denmark,[15-16] and some European countries.[17] Again, LE was found to be significantly associated with lower infant mortality rates and higher schooling rates.[18] When and where death risks are higher, usually the women give births extremely to raise the possibility that at any rate, some offspring will stay alive to adulthood.[19] The contributing factors of LE were taken into account healthcare expenses and resources, death rates, HIV prevalence, and health consequences.[20] The services related to healthcare, e.g., the increased numbers of healthcare persons, hospital supplies, and prenatal checkups diminish deaths and raise LE.[21] Moreover, some researchers have pointed rigorous recommendations of the effects of demographic measures, socioeconomic variability, and accessibility of healthcare resources on LE.[22-24] The previous studies on global inequalities in LE have usually explored the overall mortality. Until recently no study has ever been investigated globally considering demographic, socioeconomic, health, and environmental factors together. This study attempts to fill in research gap. Therefore, the main objective of this study is to explore the impacts of demographic events, socioeconomic differentials, health factors' availability, and environmental reasons that influence LE globally. It is believed that the study will help understanding the factors that have significant effects on LE globally.

Methods

Data and necessary information of 183 WHO member countries were taken from the different United Nations (UN) agencies.[1, 25-27] Due to the inavailability of LE data; some countries were not included in this study. The factors that had significant effects on LE in the earlier researches were considered.[8-10, 22-23, 28] The factors considered in this study, along with their definitions and sources are shown in Table 1. The contributing factors of LE (Y) are classified into 4 main groups: demographic events, social and economic status, health factors, and environmental issues. The demographic events were the total fertility rate (TFR) (X_1), adolescent birth rate (ABR) (X_2), and population density (X_3); social and economic determinants were mean years of schooling (X_9), and GNI (X_7); health-related variables were HIV prevalence rate (X_5), physicians density (X_4), and immunization coverage rate (X_6); and the environmental issues were improved sanitation usage rate (X_8) and carbon dioxide (CO_2) emissions rate (X_{10}).

To analyze the collected data, descriptive statistics, correlation analysis, and stepwise (backward) regression analysis were used. Descriptive statistics were used to see the maximum, minimum, mean, median values, and standard deviations (SDs). The Pearson correlation analysis was used to set up the relationships among variables. Backward stepwise regression is a stepwise regression approach, which begins with a full (saturated) model and at each step gradually eliminates variables from the regression model to find a reduced model that best explains the data. The stepwise approach is useful because it reduces the number of predictors, reducing the multicollinearity problem and it is one of the ways to resolve the over fitting. Assume the regression model considering all the covariates is:

$$Y = \beta_o + \sum_i \beta_i X_i + \varepsilon. \qquad (1)$$

In Eq. (1), Y is the outcome variable (LE), X_i (i =1, 2, 3,. . ., 10) are the explanatory variables, β_0 is the constant, β_i $(i = 1, 2, 3, \ldots, 10)$ are the unknown regression coefficients, and ε is the error term with an $N(0, \sigma^2)$ distribution. To check the multicollinearity problem among the predictors, the variance inflation factor (VIF) was used. The VIF for the explanatory variables, X_j is:

$$VIF_j = \left(1 - R_j^2\right)^{-1}, \quad j = 1, 2, 3, \ldots, l. \qquad (2)$$

In Eq. (2), l is the number of predictors, and R_j^2 is the square of the multiple correlation coefficient of the jth variable with the remaining (l-1) variables. The VIF is always positive and if it is less than 5, then there is no multicollinearity; if it is less than 10, then there exists a reasonable multicollinearity; and if it is greater than 10, there exits considerable multicollinearity among the variables.[29] The analyses were performed by using the Statistical Package for Social Sciences (SPSS) (SPSS Inc, Chicago, IL; USA).

Results

The study was included a total of 183 WHO member countries. The influences of TFR, ABR, population density, schooling, GNI, physicians' density, immunization rate, HIV prevalence rate, improved sanitation, and CO_2 emissions on LE are explored here sequentially.

The descriptive statistics of dependent and independent variables are presented in Table 2. The extreme values (maximum and minimum) of all the factors as well as the variables' mean, median, and SDs are presented in this table to explore their main features. This type of analysis is considered very meaningful since the diverse factors are frequently calculated in diverse units.

The LEs of the African courtiers are found remarkably low than that of other countries in the globe. Among these countries, the LE of Sierra Leone is found the lowest (50.10 years). The LEs are found 52.40, 53.50, 53.10, 53.30, and 53.70 years of Angola, Central African Republic, Chand, Côte d'Ivoire, and Lesotho respectively; which are around three-fifth compared to the countries like Japan (83.70 years), Switzerland (83.40 years), Singapore (83.10 years), etc. The TFR and ABR are found the highest in the African countries. The TFR of Nigeria is 8, in Somalia, Mali, Chand, Angola, the Democratic Republic of the Congo, Burundi, Uganda, Nigeria, and Burkina Faso it is 6. The average TFR is found 1.70 in the more developed countries. A comparable trend is found for ABR. The highest ABR (229) is observed in the Central African Republic. It is the second highest in Niger (206) followed by Chand (203), Angola (191), and some other African countries. The highest densely populated countries are Singapore (7,829 population/km^2), Bahrain (1,789 population/km^2), Maldives (1,364 population/km^2), Malta (1,348 population/km^2), Bangladesh (1,237 population/km^2), etc. On the other hand, a good number of the lowest population density countries are found, e.g., Mongolia (2 population/km^2), Namibia (3 population/km^2), Australia (3 population/km^2), Iceland (3 population/km^2), Suriname (3 population/km^2), etc. The physicians' density is observed very low in the countries of the African region. It is mentionable that there are only 1 physician per 10,000 people in the Central African Republic, Togo, Burkina Faso, etc.; 2 physicians per 10,000 people in Madagascar, Angola, Zambia, etc. The HIV prevalence rates are observed the maximum in the countries of the African region (Swaziland 28.70%; Botswana 22.30%; Lesotho 22.75%; South Africa 19.25%, Zimbabwe 14.65%; etc.) while it is <0.10% in the most developed countries. Immunization covers almost 100% children in the globe except for some countries e.g., Equatorial Guinea (24%), South Sudan (39%), Somalia (42%), etc. The economic factor, GNI was found very low of the countries where the LEs are found lower (e.g., GNI of Central African Republic is 600$). The lower improved sanitation facilities were observed in the African countries (e.g., South Sudan, 7%; Niger, 11%; Togo, 12%, etc.) where the LEs are found also lower. The mean years of schooling were found very small in the countries of the African region (Niger, 1 year; Mali, 2 years; etc.). The highest CO_2 emissions rates were found in the middle-income countries e.g., Qatar (40.50), Trinidad and Tobago (34.50), Kuwait (27.30), etc.

In bivariate analysis, the results of Pearson correlation coefficients (r) are presented in Table 3. The results revealed that the LE was found significantly positively correlated with physicians density, immunization, income, sanitation, schooling, and CO_2 emissions; and significantly negatively correlated with fertilities (TFR and ABR), and HIV prevalence rate.

The results of the stepwise regression analysis are presented in Table 4. In this analysis, five sets of regression models (Models 1-5) were performed. There were no multicollinierity among the variables because the VIFs were less than 5 for all the cases except TFR (VIF = 5.116) and improved sanitation using rate (VIF = 5.858). Model 1($R_a^2 = 0.837$) considered all the explanatory variables, among these predictors TFR, HIV prevalence, and CO_2 emissions indicated significant negative effects; and income and sanitation indicated significant positive effects on LE. Model 2 ($R_a^2 = 0.840$) retained the predictors except population density where TFR, HIV prevalence rate, income, sanitation, and CO_2 emissions were identified as the significant factors. Model 3 ($R_a^2 = 0.843$) retained all the predictors except population density and schooling where TFR, HIV prevalence rate, GNI per capita, sanitation, and CO_2 emissions were identified as the significant factors. Model 4 ($R_a^2 = 0.845$) excluded ABR, population density, and mean years of schooling; and among the retained predictors TFR, HIV prevalence, GNI per capita, sanitation, and CO_2 emissions were identified as the significant predictors of LE. Model 5 ($R_a^2 = 0.845$) excluded the predictors ABR, population density, physician density, mean years of schooling; and among the retained predictors TFR, HIV prevalence, immunization, GNI per capita, sanitation, and CO_2 emissions were identified as the significant factors of LE.

Discussion

The univariate analysis clearly explained the global scenario of LE. The correlation analysis established the significant relationships between LE and demographic, socioeconomic, health, and environmental factors. Finally, the regression model (Model 5) identified TFR, HIV prevalence, income, sanitation, and CO_2emissions as the significant predictors of global LE.

In 2015, the global LE was 71.40 years and it is improved at a rate of more than 3 years per 10 years from 1950. In the 1990s, the growth on LE stalled in the countries of African region because of the tremendous rising of HIV prevalence rate; and increased death rate in many former Soviet countries following the fallen down of the Soviet Union. In most of the regions, the LEs have been increased from 2000 onwards. The overall global increment of LE was 5.00 years from 2000 to 2015. The larger increment (9.40 years) was observed in the African countries. Now, the LE is more than 82 years in 12 countries (Switzerland, Spain, Italy, Iceland, Israel, France, Sweden, Japan, Singapore, Australia, the Republic of Korea, and Canada) and it is on an average 80 years in 29 countries. On the other hand, there are 22 countries with LEs less than 60 years.[1]

Globally the fertility patterns have changed dramatically over the last few decades. In 2015, the global TFR was 2.50 which mask wide regional variations. Africa remains the region with the highest TFR (4.70) and Europe has the lowest TFR (1.60).[30] The higher TFR may also have a negative effect on LE. Clearly, the families having the higher number of births, the lower duration between births, and insufficient resources allotted for those children may reduce breastfeeding duration and make threats malnutrition to those children. The consistent results are observed in this study. In addition, LE was inversely correlated with fertilities and from the regression analysis; the TFR is identified as the significant determinant of LE.

In the developing countries, the TFR has fallen remarkably since 1950. The higher fertility $(TFR \geq 5)$ and closely-spaced births characterized 33 countries among them 29 are in Sub-Saharan Africa. The higher fertility creates the higher health which risks for infants and mothers, derails the wealth investment, downturns economic growth, and worsens ecological coercions.

The significant downturn in births may contribute to raise the productive output. The present study identified that the higher fertility contributed to lower LE. Obviously, the declining trend of TFR assists to raise economic growth through the positive changes in age-structure. The ABR and coverage of modern contraceptives are two proposed indicators of the Sustainable Development Goal Target 3.7 on general entrance to reproductive healthcare services. It was estimated that the global ABR= 44 which was 5 times more prevalent in the low-income countries compared to the high-income countries.[30] Early sexual activities (marital or extramarital) contribute to ABR. In 2014, it was estimated globally 700 million girls were married before 18 years among them 250 million were experienced extramarital sexual relations.[31] Globally the adolescents are showing to excess reproductive health hazards. The adolescent fertility results to adverse mother and infant health outcomes and it is strongly associated with obstructed delivery, low birth weight, fetal growth retardation, and higher maternal and infant deaths.[28] The higher availability of unsafe sexual activities among unmarried girls threats them to unexpected pregnancies, risky abortions, and sexually transmitted diseases. On the other hand, delayed giving births raise the survivorship.[32]

The availability of physicians contributes to raise LE. In an area or in a country, if we find an inadequate number of medical personnel that treats the general population would more likely not to have sufficient healthcare services. Availability and easy access to healthcare services are considered an important issue to save from diseases and to hasten recovery from sickness and disabilities. In this study, the physician density is significantly associated with LE which is consistent with the previous studies.[12, 20-21] On the other hand, an inadequate number of healthcare personnel, lack of skilled health workers and not having easy access to healthcare services may contribute to raise the disease prevalence.[33] Moreover, the physicians may contribute to increasing LE by reducing fertilities.[8]

The prevalence of HIV is found significantly negatively correlated with LE and in all the regression models (Models 1-5), it was retained as the significant predictor of LE. HIV leads to untreatable disease and hits the immune system. The HIV infected person may survive 9-11 years without treatment. This means that the HIV-infected individual have a shorter lifetime. The higher HIV prevalence in an area or a country may cause to increase more HIV infected persons. As a result, the higher prevalence of HIV infection effects to lower LE. Globally, the differences of LEs among regions are also seen, as the numerous countries in the African region with the higher prevalence of HIV experienced a fall in LE and established a relationship between higher prevalence of HIV and lower LE.[34]

Immunization was found significantly positively correlated with LE. In all the regression models (Models 1-5) this factor retained as the significant determinant. Vaccination greatly reduces diseases, disabilities, deaths, and increases LE worldwide. It has significantly reduced the burden of infectious diseases. Today, the vaccines have been considered as an excellent safety record. In a previous study, it is identified that the vaccination significantly contributes to increasing LE by lowering morbidity and mortality.[35]

National income (GNI per capita) has shown significant positive correlation with LE. In regression analysis, GNI is identified as the significant determinant of LE in all the models (Models 1-5). The present study identified that financial development establishes upgrading the social status and increases LE. The populations of a country live longer when they have a quality livelihood and have a lower death rate.[11] The quality livelihood of a country's population is measured by that country's national income which has been established in this study. There is significant evidence concerning income dissimilarity to unfortunate health outcomes. In the low- and lower middle-income countries, a smaller amount of money is allotted for healthcare services which might contribute to having lower LE. The findings of this study authenticate the previous study results on the effects of national income on LE.[8, 13]

Improved sanitation was found significantly positively correlated with LE and identified as the significant determinant of LE (Models 1-5). An increase in the lifespan was determined mostly by the improvements in sanitation system during the 1990s and early 2000s centuries. The transmissions of most infectious diseases (e.g., cholera, typhoid, infectious hepatitis, polio, cryptosporidiosis, ascariasis, etc.) implicated through human waste. In each year around 1.80 million populations died due to diarrheal diseases, among them 90% were less than 5 years aged, they were mostly in the low- and lower-income countries.[36] Usually, the unhealthy sanitation systems may contribute to having various infections. In the tropical and subtropical areas in terms of socioeconomic and public health concern, the ranks of malaria and schistosomiasis were placed first and second respectively among the human parasitic diseases. Globally, around 0.6 million deaths occur per year are caused by severe Ascaris infections.[37]

Education is another influential factor was found significantly positively correlated with LE. This finding has likewise important implications. An educated nation might contribute to be raised LE. The higher schooling rates are strongly correlated with timely receipt of healthcare services and better healthcare knowledge. The educated population is more likely to have improved prenatal care and they can be promoted to optimize the use of mothers' healthcare services, thus keeping away from childbirth-related difficulties.[38] Usually, more educated population can earn more money, which contributes to have higher household income and enable them to enhance to buy quality healthcare services. Besides these, the educated individuals have a tendency to better realization about personal hygiene, nutritional status, knowledge regarding illness, etc.[39]

The CO_2 emission was significantly positively correlated with LE, and it was retained all in the regression models (Models 1-5). The regression analysis identified it is a significant determinant of LE. The higher energy usage is essential for economic development, which is the prerequisite for human development. The higher energy usage leads to higher CO_2 emissions. The higher LE is companionable with low carbon emissions. From the perspective of a sustainable development, the countries would reach both higher GNI and higher LEs at low levels of CO_2 emissions.[40]

A limitation of this study is that we analyzed data for the most common determining factors, *i.e.*, those were found to be significantly associated with LE in the previous studies. In addition, the analysis was limited to those countries whose data were available. The present study identified associations and determinants of LE but did not investigate the determinants that explain gender and urban-rural differences in LE in these countries. Data on the 183 counties were obtained from the different UN agencies. However, the sources and quality of data vary according to country. Some countries have comprehensive civil registration and vital statistics and regular censuses of the entire population. However, many countries have incomplete or dysfunctional birth and death registration systems and therefore lack continuous empirical data on mortality and LE.

Conclusion

The study analyzed how demographic, socioeconomic, health, and environmental factors affect LE globally and empirically identified the determinants of LE. All the selected factors are found to be statistically correlated with LE. Among these factors, physicians' density, immunization coverage, national income, and improved sanitation were positively; but the higher fertilities (TFR and ABR), and HIV prevalence rate were negatively associated with LE. However, TFR, HIV prevalence rate, immunization rate, national income, improved sanitation, and CO_2 emissions were identified as the influential factors of LE. The findings of this study have some important policy implications for all countries particularly for the African countries. To raise LEs of those countries imperative steps should be taken. National and international programs may be taken to raise LE by raising schooling, immunization coverage, improved sanitation, and the number of physicians; and limiting fertilities and HIV infection in the countries where LEs are still very low. We analyzed cross-sectional data of 183 countries of 10 demographic, socioeconomic, health, and environmental determinants. To identify the factors that influence LE, further research should evaluate considering panel data sets with a broader range of predictors. We do not expect any ecological fallacy in the present study as aggregate level data are used for analysis. The result reflects the actual scenario of the country and the geographical regions. **Abbreviations:** ABR: Adolescent birth rate; CO_2: Carbon dioxide; GNI: Gross national income; HIV: Human Immunodeficiency Virus; LE: Life expectancy; SD: Standard deviation; TFR: Total fertility rate; UN: United Nations; VIF: Variance inflation factor; WHO: World Health Organization

Ethics approval and consent to participate: Ethics approval for this study was not required since the data is secondary and is available in the public domain.

Consent for publication: Not applicable.

Availability of data materials: Data for this study were sourced from:

1. World Health Organization (WHO) 2016; and available here:
http://apps.who.int/iris/bitstream/10665/206498/1/9789241565264_eng.pdf
2. World Health Statistics 2015; and available here:
http://apps.who.int/iris/bitstream/handle/10665/170250/9789240694439_eng.pdf?sequence=1
3. World Population Data Sheet 2016; and available here:
https://assets.prb.org/pdf16/prb-wpds2016-web-2016.pdf
4. Human Development Report 2016; and available here:
http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf

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