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The impact of BMI on life expectancy in Portugal

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ABSTRACT. The overweight represents a serious public health problem in Portugal, with a prevalence that exceeds 50%. Obesity-related diseases constitute the health system's main causes of death and economic issues. Despite this, there is no consensus on the relationship between the Body Mass Index (BMI) and the risk of early mortality. In this context, assessing the impact of the average BMI on life expectancy in Portugal is important. A retrospective cross-sectional observational study was carried out using an Autoregressive Distributed Lag model. The dependent variable is life expectancy at birth, expressed in the total years obtained from the World Development Indicators (WDI). The independent variables are: (i) the average BMI of the population (calculated based on the average male and female BMI obtained from Our World in Data); and (ii) the total population obtained from the WDI. The population's mean BMI variable limited the study's time horizon, comprising annual statistical data from 1975 to 2016. The increase in BMI negatively affects the life expectancy of the Portuguese population in the short term. A 1% variation in BMI reflects a 1.98% reduction in life expectancy. The result was statistically significant at 1%, and the p-value was 0.0001. In the long term, there was no statistically significant effect of the mean BMI on the population's life expectancy. Also, in the long term, population growth has a positive and statistically significant effect on life expectancy. Although there is no consensus in the literature that BMI is associated with increased mortality, the results obtained through this model captured this trend in Portugal in the short term. Therefore, promoting life expectancy by improving the Portuguese's health and quality of life is necessary. The adoption of measures that favor the recovery or maintenance of normal weight is essential.

Keywords: Body Mass Index (BMI); life expectancy; portuguese population; ARDL model.

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Introduction

The overweight represents a serious public health problem in Portugal, with a prevalence that exceeds 50%. It is associated with pathologies such as diabetes, stroke, cardiovascular disease, osteoarticular pathology, and cancer, which are the main causes of death and expense in the health system. The individual, social, and economic impact is so relevant that it poses a potential risk to the Portuguese National Health Service's sustainability (Camolas, Gregório, Sousa, & Graça, 2017).

According to the most recent data from the Organization for Economic Cooperation and Development (OECD), the costs associated with the treatment of overweight and associated diseases represent 10% of total health expenditure, equivalent to 207 euros per capita per year (Gregório, Salvador, Bica, Horgan & Telo de Arriaga, 2021). Furthermore, in addition to the impact on physical morbidity, obesity has a relevant impact on psychological functioning and individual well-being (Camolas et al., 2017).

Despite this, there is no consensus on the relationship between the Body Mass Index (BMI) and the risk of early mortality (Camolas et al., 2017). Some studies identify BMI as a strong predictor of mortality (Prospective Studies Collaboration, 2009; Di Angelantonio et al., 2016) or show that a BMI within the range between 20 and 25 is associated with a lower absolute mortality rate (Prospective Studies Collaboration, 2009; Berrington de Gonzalez et al., 2010; Sasazuki et al., 2011; Camolas et al., 2017). There are several references to a "U" (Cheng et al., 2016; Sun et al., 2016; Ng et al., 2017) or "J" (Dandona, 2019; Sun et al., 2019) curve concerning mortality, with greater expression at the lower and upper extremes of BMI. When the data refer to elderly individuals, the supposed "paradox of obesity" seems to materialize with pre-obesity and class 1 obesity, with lower mortality in these groups (Berrington de Gonzalez et al., 2010; Flegal, Kit, Orpana & Graubard, 2013; Camolas et al., 2017; Ng et al., 2017; Lee et al., 2018a; O'Súilleabháin, Sutin & Gerstorf, 2020). However, Lee et al. (2018b) suggest that this paradox is explained by lean mass percentage, not fat mass. Studies also find lower mortality associated with being overweight than with normal weight (Steensma et al., 2013; Wang et al., 2016).

Alarming news in the Portuguese media about overweight and obesity in the population is easily found. For example, Expresso (2022) shows the results of the study "*O custo e a carga do excesso de peso e obesidade em Portugal*", which indicates that 68% of the Portuguese population is overweight or obese. This prevalence costs 1.14 billion euros annually, 0.6% of the gross domestic product, and 6% of the country's health expenditure.

In this context, it is important to evaluate the impact of BMI on life expectancy in the Portuguese population, which is the main objective of this investigation. Therefore, this study aims to answer the following question: What are the effects of BMI on the life expectancy of the Portuguese population?

Methodology

This section is composed of two subsections. The first one presents secondary statistical data and the source databases of the information. The nature of this subsection will be presented considering the statistical method used in the study and the statistical nature of the data. The second subsection presents the statistical model used to capture the effects between the study variables.

Data

Secondary statistical data came from two publicly accessible databases. First, the average Body Mass Index of the Portuguese population (BMI) was calculated using the BMI data found in Our World in Data. The variables used to calculate the BMI were mean body mass index in men and mean body mass index in women. The total Portuguese population (POPT) and the average life expectancy of the Portuguese population (LIFE) were obtained from the World Development Indicators of the World Bank.

The BMI variable limited the time horizon of this study between 1975 and 2016. Below, in Figure 1, the behavior of the variables over the period to be considered in this analysis is shown:

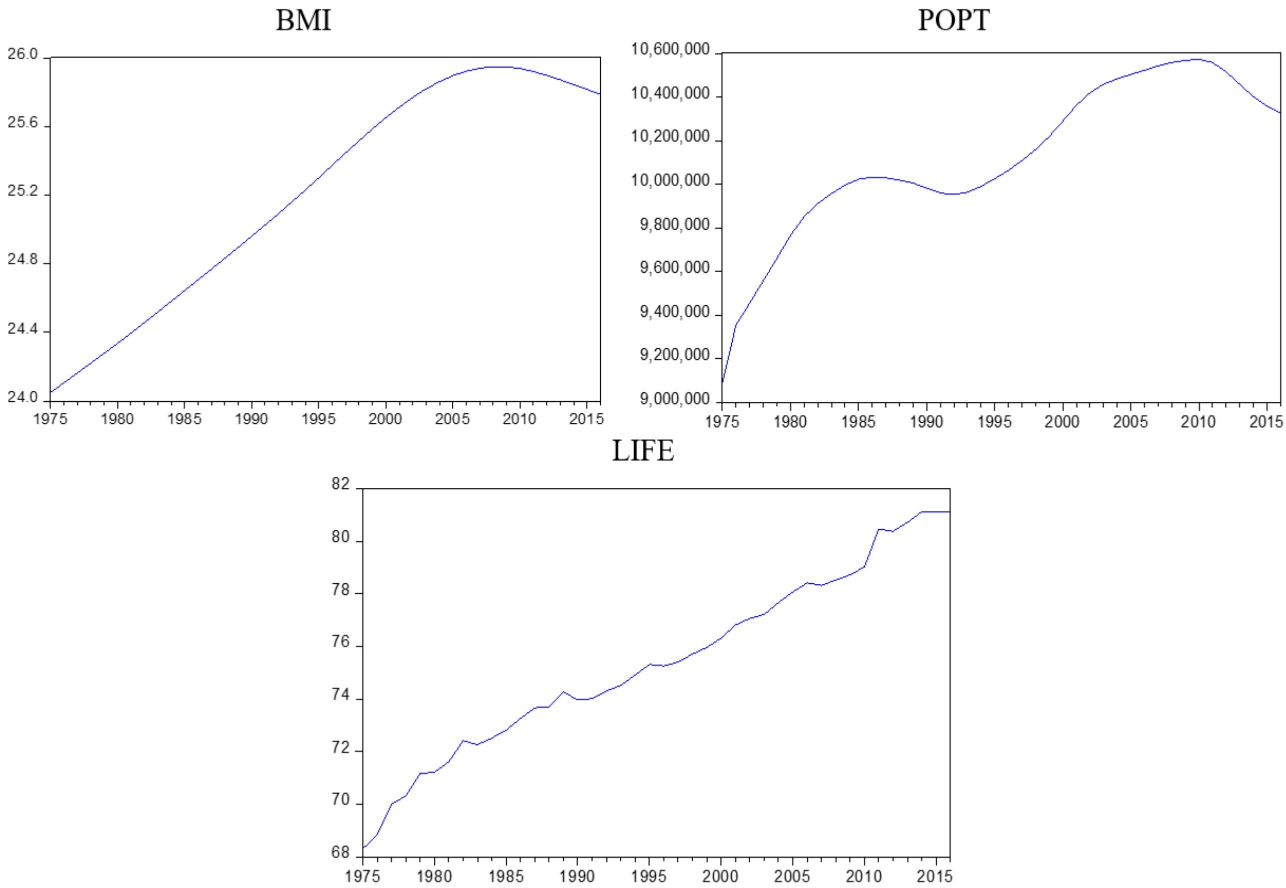

Figure 1. Historical behavior of variables.

From the analysis of Figure 1, it is possible to affirm that the trend line is positive. There is a suggestion that the statistical data of the entire series are not stationary. Natural logarithms (L) are commonly applied to normalize series with different proportions (Koengkan & Fuinhas, 2022; Koengkan & Fuinhas, 2021). Since all values in the series are positive, the calculation of L can be performed. Table 1 presents the descriptive statistics of the data. This study used the statistical software EViews 13.

Table 1. Descriptive statistics.

	LLIFE	LBMI	LPOPT
Mean	4.3218	3.2273	16.12942
Median	4.3213	3.2323	16.12292
Maximum	4.3960	3.2561	16.17382
Minimum	4.2241	3.1801	16.02307
Std. Dev.	0.0464	0.0257	0.035781
Skewness	-0.1286	-0.3991	-0.841117
Kurtosis	2.2307	1.7018	3.552903
Jarque-Bera	1.1515	4.0643	5.487319
Probability	0.5623	0.1311	0.064334
Sum	181.5153	135.5459	677.4356
Sum Sq. Dev.	0.0884	0.0271	0.052491
Observations	42	42	42

L denotes the natural logarithm of variables.

After analyzing the descriptive statistics, it has been confirmed that the database is balanced, meaning that it has the same number of observations for all variables. A negative skewness distribution has been measured for all variables. LLIFE and LBMI kurtosis are platykurtic, while LPOPT is leptokurtic. Jarque-Bera values suggest a non-normal distribution. However, this fact does not pose a barrier to regression estimation. Given the characteristics of the data, other more robust statistics and tests are required. Firstly, a statistic that assesses multicollinearity has been applied. Table 2 presents the results of the Variance Inflation Factor (VIF) statistic.

Table 2. VIF.

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
LBMI	0.0529	122433.6	7.5765
LPOPT	0.0273	1577169.0	7.5765
DLBMI	0.3229	3.4227	1.3217
DLPOPT	0.0169	1.6863	1.3217

D and L stand for first difference and natural logarithm, respectively; the dependent variables in the test were LLIFE and DLLIFE; a constant was used in the test application.

The mean values of the VIF statistic for the variables in logs are less than 8 (1.32 for non-differenced and 7.58 for first-differenced), confirming that the series does not have a multicollinearity problem that would prevent the use of regression as a method of analysis.

Next, in Table 3, the correlation between the variables was verified using the correlation matrix. This test allows for the examination of how the variables behave when analyzed in pairs.

Table 3. Correlation matrix.

	LLIFE	LBMI	LPOPT
LLIFE	1		
LBMI	0.9521*	1	
LPOPT	0.9235*	0.9317*	1
	DLLIFE	DLBMI	DLPOPT
DLLIFE	1		
DLBMI	0.0493	1	
DLPOPT	0.3148*	0.4934*	1

D and L denote the first difference and natural logarithm, respectively; "*" denotes statistical significance at the 5% level.

Correlations are all positive and statistically significant, except between DLBMI and DLLIFE. The positive correlation suggests that the pair variables have a symmetrical behavior in time. No negative correlation was detected. The negative correlation would mean asymmetrical behavior in time.

Finally, in Table 4, the stationarities test was performed. The Augmented Dickey-Fuller test for unit roots with breakpoints was used to capture any structural breaks in the time series data over the years.

Table 4. Unit Root Tests with Breaks.

Variables		Level				First differences			
		t-statistic	*Lag Length*	*P-value*	*Breakpoint Year*	*t-statistic*	*Lag Length*	*P-value*	*Breakpoint Year*
LLIFE	c	-3.1057	0	0.6236	2000	-8.2353	0	<0.01	1979
	τ	-4.6478	0	0.1748	2010	-9.0775	0	<0.01	1982
LBMI	c	-6.1562	0	<0.01	1984	-7.4173	1	<0.01	1996
	τ	-2.0650	2	>0.99	2013	-7.4676	1	<0.01	2014
LPOPT	c	-3.7204	0	0.2721	1978	-5.3963	8	<0.01	2011
	τ	-4.1479	3	0.2878	2010	-5.3551	8	0.0307	2011

C denotes Constant; τ denotes Constant and Trend; L denotes the natural logarithm; the Schwartz criterion method with nine maximum lags was applied.

After analyzing the unit roots, it was found that the LBMI is semi-stationary in level, while LLIFE, LBMI, and LPOPT are stationary after the first difference. As almost all variables have an order of integration I(1), the least squares regression method is not robust enough to analyze the impacts of the independent variables (DLBMI and DLPOPT) on the dependent variable (DLLIFE).

ARDL method

In this subsection, we present the ARDL method, which is a robust econometric model that can be used simultaneously for variables with an order of integration of I(0) and I(1). Moreover, the econometric model can capture short-term and long-term effects if the ECM (Error Correction Model) presents negative statistics between 0 and -1. The ARDL model equation applied in this study can be seen below (Equation 1):

$$dlLIFE_t = \alpha_1 + \tau_1 + \beta_{11} dlBMI_t + \beta_{12} dlPOPT_t + \gamma_{11} lLIFE_{t-1} + \gamma_{12} lBMI_{t-1} + \gamma_{13} lPOPT_{t-1} + \varepsilon_{1t} \quad (1)$$

Where, α_1 and τ_1 represent a constant and a trend introduced in the model, respectively; $\beta_{11 \ldots 1n}$are the independent variables; $\gamma_{11}$is the dependent variable lagged once, that is, the ECM of this regression; $\gamma_{12 \ldots 1n}$ are the independent variables in the long term; ε_{1t} represents the residuals of the equation; n is the number of independent variables in the model; finally, t represents the period.l

The method is commonly used to capture the impacts of explanatory variables on the dependent variable (the parameter to be explained). The method is more robust than simple regression models, such as the Ordinary Least Squares regression (OLS), because it handles several statistical data characteristics simultaneously and allows for both short-term and long-term analysis. Furthermore, this approach reveals the model's speed of adjustment to deviations from the long term (i.e., the ECM). The ECM also provides a raw measure of the completeness of the estimated model. In other words, a high ECM (say, above 50%) suggests that the variables included in the model are comprehensive.

More robust statistical methods are used to analyze the dynamics of overweight and mobility problems. A recent example is Koengkan, Fuinhas & Fuinhas (2021), who studied the urbanization process to investigate the increase of the overweight epidemic in Latin America and the Caribbean Region.

Results

Equation 1 was also estimated using the statistical software EViews 13. In Table 5, we present the model results. The model results indicate that BMI negatively impacts the Portuguese population's average life expectancy. The coefficient was -1.98, indicating that a 1% increase in average BMI would lead to a 1.98% reduction in life expectancy in the short term. The result was statistically significant at the 1% level, with a P value of less than 0.01.

We will now provide a practical example, but it is important to exercise caution when interpreting the results. Specifically, when a person increases their BMI by 1%, their life expectancy is reduced by 1.98%. However, it is important to note that this example should not be considered a universal rule, as it is based on population mean data. Nonetheless, the interpretation is valid primarily for those who are overweight or obese. In summary, in the short term, the average life expectancy of the Portuguese population has a positive tendency to improve (trend) and expand with the total population. However, in the short term, the increase in the average body mass of this same population negatively affects life expectancy.

Table 5. Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.0979	0.7120	1.5421	0.1320
TREND	0.0017	0.0004	4.9185	0.0000
DLBMI(-1)	-1.9761	0.6791	-2.9097	0.0063
LLIFE(-1)[ECM]	-0.6048	0.1070	-5.6529	0.0000
LPOPT(-1)	0.0921	0.0484	1.9044	0.0651
R^2	0,5184			
$\bar{R}^2$	0,4639			

D and L denote the first differences and natural logarithms, respectively.

The regression ECM showed a negative value (-0.60) less than 0, and regarding the limit of -1, for this reason, the long-term effects of the population can be calculated. Next, in Equation 2, we present the reparameterization of Equation 1 for long-term analysis:

$$dlLIFE_t = \alpha_2 + \tau_2 + \beta_{2\,1} dlBMI_{it} + \gamma_{2\,1} lLIFE_{t-1} + \gamma_{2\,2} lPOPT_{t-1} + \varepsilon_{2t} \quad (2)$$

The results of Equation 2 confirm that POPT has a positive impact on increasing the life expectancy of the Portuguese population. The coefficient was 0.15, indicating that a 1% increase in average POPT will lead to a 0.15% increase in life expectancy in the long term. Furthermore, the result was statistically significant at the 5% level, with a P value between 0.05 and 0.01. Details of the long-term results can be seen in Table 6 below:

Table 6. BMI long-term analysis.

Test Statistic	Value	df	Probability
t-statistic	2.098147	35	0.0432
F-statistic	4.40222	(1, 35)	0.0432
Chi-square	4.40222	1	0.0359
Normalized Restriction (= 0)		Value	Std. Err.
-C(-5) / C(4)		0.152355	0.072614

The robustness of the results obtained from the ARDL model is commonly assessed through post-estimation tests (Fuinhas, Marques & Faria, 2017). Since the regression model cannot contain heteroscedasticity, two tests were performed: the autoregressive conditional heteroskedasticity (ARCH) test and the Harvey test of heteroscedasticity. The results confirm that the model is homoscedastic; thus, the heteroscedastic effects are rejected. To assess for autocorrelation, the Breusch-Godfrey Serial Correlation LM test was conducted, and it confirmed that the model has no autocorrelation. Furthermore, the residuals of the equation are normally distributed, as evidenced by the Jarque-Bera statistic. Finally, the Ramsey RESET test proves the model has no incorrect specifications. The test results confirm that the estimated model has a good specification. Details of the robustness test results are in Table 7 below:

Table 7. Robustness of estimation.

Heteroskedasticity Test: ARCH			
F-statistic	0.820398	Prob. F(1,37)	0.3709
Obs*R-squared	0.845986	Prob. Chi-Square(1)	0.3577
Heteroskedasticity Test: Harvey			
F-statistic	1.968168	Prob. F(4,35)	0.1210
Obs*R-squared	7.345165	Prob. Chi-Square(4)	0.1187
Scaled explained SS	11.21389	Prob. Chi-Square(4)	0.0243
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic 1 lag	0.540703	Prob. F(1,34)	0.4672
Obs*R-squared	0.626163	Prob. Chi-Square(1)	0.4288
Jarque-Bera	3.045809	Probability	0.218078
Ramsey-RESET test			
	Value	df	Probability
t-statistic	0.0488	34	0.9614
F-statistic	0.0024	(1, 34)	0.9614
Likelihood ratio	0.0028	1	0.9578

The Cumulative Sum Control Chart (CUSUM) test for structural change is widely applied to verify changes in the estimated model (Figure 2). Based on the estimation presented in this research, it is evident that the test limits respected the barriers of 5%, thus confirming that the model did not undergo any significant alterations, which indicates the reliability of the model.

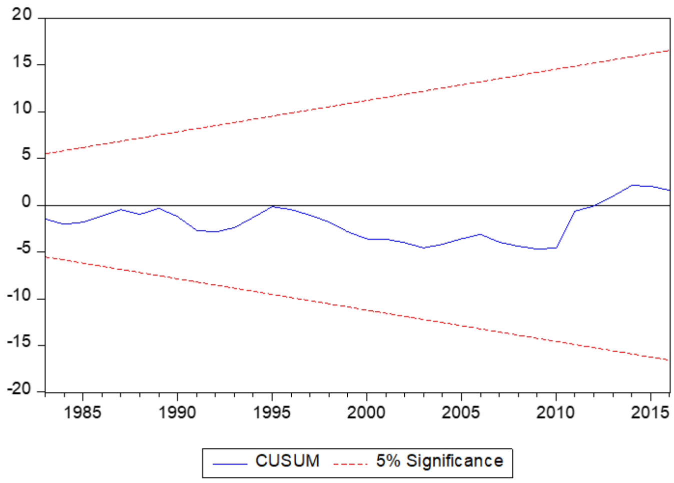

Figure 2. CUSUM test.

After confirming the model's robustness, Figure 3 summarizes the results obtained. It is important to note that there were no statistically significant results found for the population in the short term and for the BMI in the long term:

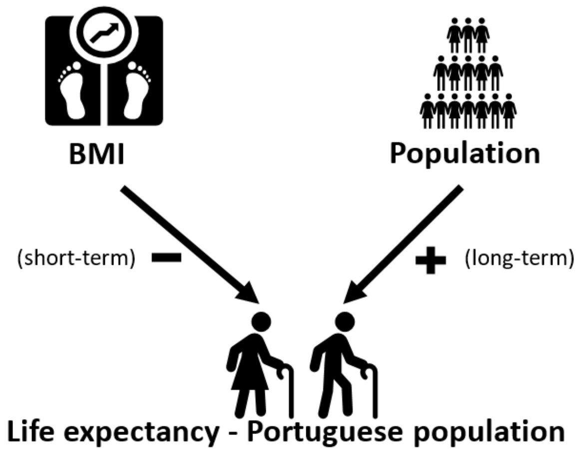

Figure 3. Influence of BMI and population on life expectancy.

Discussion

The topic of BMI has been extensively investigated in recent years. However, there is no consensus on its impact on life expectancy.

This study uses time series data from the Portuguese population rather than a sample. The time horizon analyzed spans 42 years, twice the minimum required for the methodology used, which provides robustness to the findings. Unlike most studies, this study uses mean BMI values without considering the weight categories defined by the BMI value intervals. During the time horizon studied, the average BMI values of the Portuguese population oscillated, with an increasing tendency, between 24 and 26 Kg/m^2. Life expectancy also showed an increasing trend. However, the results of this study demonstrate a negative impact of increasing BMI on the average life expectancy of the Portuguese population. A 1% increase in the average BMI results in a reduction of 1.98% in life expectancy in the short term. This impact is verified over the analyzed time series, and the trend is likely to continue into the 2020s. In the long term, a secondary result indicates that the population increase has a positive impact on life expectancy, which can be explained by factors such as improved living conditions, access to health care, and technological evolution.

Our study corroborates with the results of Di Angelantonio et al. (2016), who analyzed 239 studies from various countries across four different continents. Their study concluded that both overweight and obesity are associated with increased mortality from all causes. Furthermore, in the BMI range above 25 kg/m^2, the relationship with mortality was accentuated in all regions studied, particularly in Europe and North America, and less in South Asia. These findings suggest that if the overweight population were to achieve a normal weight, approximately one in seven premature deaths could potentially be avoided in Europe (Di Angelantonio et al., 2016).

In a study conducted by the Prospective Studies Collaboration (2009), which analyzed data from 57 prospective studies involving nearly 900,000 adults, it was found that overall mortality rates were lower for both sexes and across all age groups with a BMI between 22.5-25 kg/m^2. Additionally, for every 5 kg/m^2 increase in BMI, all-cause mortality increased by approximately 30%.

Berrington de Gonzalez et al. (2010) showed that overweight and obesity are associated with an increased risk of all-cause mortality, with five times more deaths among participants in the highest obesity categories (BMI 35.0 to 49.9 kg/m^2). In the same way, Flegal et al. (2013) found that obesity grades II and III were both associated with significantly higher mortality from all causes compared to the normal weight population. Finally, Lee et al. (2018a) proposed a relatively small ideal BMI range for the adult population, with any increase in BMI beyond this range resulting in increased mortality.

However, there are also contradictory data, namely in studies that found "U" or "J" relationships and in those referring to the "obesity paradox". Sun et al. (2019) reported that the mortality risk is higher in underweight and overweight participants, while those with a BMI of 22-25kg/m^2 have a lower mortality risk. Sasazuki et al. (2011) analyzed seven large-scale cohort studies in Japan and found a "J" relationship between BMI and cancer mortality or all-cause death, as well as a "U" curve for the relationship between BMI and mortality from cardiovascular disease. Moreover, a prospective Chinese study revealed a relatively higher risk of mortality among participants with a lower BMI and a relatively lower risk of mortality among those with a higher BMI. Interestingly, being overweight was associated with a lower risk of all-cause mortality, while obesity was linked to increased mortality (Wang et al., 2016).

Possible justifications for these differences in the literature are related to the fact that different studies use different methodologies and apply to different populations with different sample sizes and follow-up times. Moreover, there are other aspects that can interfere with the results, such as the presence of other risk factors for the disease, comorbidities, the specific cause of death, and the possible benefit of the adipose reserve during periods of acute catabolic diseases. In addition, people with a high BMI tend to use healthcare services more frequently and receive better management of risk factors from health professionals, along with other individual factors.

Limitations and future recommendations

This study has some limitations, as it follows: (i) it does not distinguish between genders, (ii) it uses BMI as an average value without considering its different categories or specifying the mortality associated with each of them, and (iii) it does not address other aspects of body composition, such as visceral fat, fat distribution, or lean mass. Furthermore, the data does not consider the specific cause of death, different cardiovascular risk factors, comorbidities, socioeconomic status, or other characteristics that may influence mortality.

Despite these limitations, this study enriches the current literature on the impact of BMI on life expectancy in Portugal, which is a controversial topic. The study provides a premise that can be verified and serves as a starting point for new research that can be supported by clinical data and related to the analysis of other factors associated with the Portuguese population. As a suggestion, further research should evaluate the impact of BMI on quality of life, specific pathologies and conditions, causes of death, and measures to combat obesity in relation to life expectancy and health. In addition, assessing groups by gender and location of residence (urban-rural) can provide more helpful information for public policy decisions to direct investment in health care.

Based on these results, policymakers now have evidence to support the development of robust health measures aimed at preventing unhealthy weight gain, promoting healthy weight, and ensuring optimal health care for the entire population.

Measures targeting the food environment have the potential to promote healthier eating habits and reduce the incidence of associated diseases while also offering economic and health benefits. An example is the legislation that regulates sugar, salt, and saturated fat content in food and imposes taxes on the amount of sugar in beverages.

These findings also reinforce the importance of practicing some of the priority health programs in Portugal, such as the promotion of healthy eating habits and physical activity, which can motivate health professionals to update themselves in obesity therapies.

Conclusion

This study highlights the impact of BMI on the life expectancy of the Portuguese population, as well as its association with several prevalent diseases. The results emphasize the importance and need to implement strategies to prevent overweight and promote the health and longevity of the Portuguese population.

The statistical results suggest that BMI negatively influences the Portuguese population's life expectancy in the short term. However, in the long term, no statistically significant effects were found between BMI and life expectancy. Still, in the long-term analysis, population growth positively influences the life expectancy in the Portuguese population.

Public policymakers and other stakeholders can use the findings of this study as a robust basis for decision-making, as it employs the ARDL method to provide short- and long-term information.

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