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Greenhouse Gas Emissions and Obesity in Africa: A Disaggregated Panel Corrected Standard Error Model

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ABSTRACT

Obesity is a growing problem in Africa, promoting morbidity and contributing to mortality from non-communicable diseases. Although nutrition and genetical factors have been implicated in promoting obesity, the impact of environmental factors like carbon dioxide emissions is rarely emphasized in literature. This paper contributes to the body of existing knowledge by providing some empirical linkages between carbon dioxide emissions and obesity in Africa. The study used a longitudinal research design, and the data were from a panel of fifty-two African countries covering the 2000-2016 periods. The data were sourced from the Food and Agriculture Organization (FAO) database and the World Bank's World Development Indicators. Data analyses were implemented with panel corrected standard error model due to the presence of contemporaneous correlation among some panels and the presence of cointegration. The results showed that obesity significantly increased ($p<0.05$) across all regions with increase in carbon dioxide emission, per capita growth in gross domestic product (GDP) and percentage of food importation. Political stability had mixed results on obesity with positive impacts in West and Central Africa, and negative impacts in South Africa and in the combined results. It was concluded that addressing carbon dioxide emissions in Africa presents a positive signal towards reduction in the incidence of obesity. A framework for African leaders to fully comply with the Paris Agreement is therefore fundamental in reducing the future impacts of GHG emissions on obesity and other associated health problems. Similarly, promotion of political stability and health induced economic growth are vital for addressing the African obesity epidemic.

Keywords: Carbon dioxide; obesity; non-communicable diseases; Africa

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INTRODUCTION

Emission of greenhouse gases (GHGs) remains one of the major environmental concerns the world currently faces.[1] Economic policymakers across the world have realized the impact of environmental degradation on economic growth and our collective existence on the planet Earth. Environmental pollution is also having some negative health consequences across the world. Some definitive probes into the sources of these environmental calamities emphasize the fact that the 21st century is witnessing rapid changes in some climatic parameters, which are being promoted by unregulated emission of GHGs.[1,2]

Therefore, global warming has been aggravated by human activities to a magnitude of about 1.0°C more than the pre-industrial era.[4] Projections have now shown that given the current emission rate of GHGs, the global temperature may increase by 1.5°C in the next two decades,[5] with some stern warnings on the possibility of reaching a 2°C threshold.[6] The dimension of currently required environmental interventions for safeguarding future environmental catastrophes is notably profound. This is vividly portrayed by current changes and adjustment speed of disequilibrium in some essential indicators of global environmental safety.[7]

Some empirical findings have highlighted the negative impacts of environmental pollutants like CO_2 on some global health outcomes.[8] Therefore, besides the public health concerns that are being promoted by droughts, floods, and cyclones, the stock of human health is being gradually depleted by climate-change-induced epidemic like obesity. Moreover, obesity had been classified as a disease by the American Medical Association,[9] and it is clinically defined as possession of Body Mass Index (BMI) of 30 and above.

Climate variability is promoted by GHG emissions, which can facilitate progression into obesity through their adverse impacts on production of nutritious food and inculcation of sedentary lifestyles.[10] Similarly, it had been submitted that GHG emissions promote obesity through their effects on the functionality of the endocrine systems, inability to produce healthy food due to extreme temperature, and promotion of sedentary lifestyles.[10] Similarly, it was submitted that obesity may be associated with emission of GHGs.[11] Some probable biological insights indicated the role of hormonal reactions due to CO_2 pollution that decreases blood PH and promotes obesity.[12]

Empirical analyses on the association between obesity and GHG emissions follows three basic conceptual perspectives.[13] The first highlights the effect of GHG emissions on obesity and overweight. The second perspective implicates obesity in the growing problem of GHG emissions, while the third presents bidirectional relationships between the two variables. The conceptual framework by An et al.[13] was adopted in this study, which proposes a bidirectional relationship between obesity and GHG emissions, with primary role played by fossil fuel utilization in either case. Specifically, it was conceptualized that agricultural productivity, land use change and increased transportation are promoted by population growth, industrialization, and availability of fossil fuels. These processes result into emission of GHGs, which leads to climate change that promotes obesity through distortion of food supply in favour of non-nutritious food. Similarly, the transport and agricultural production systems promote obesity through some transitions in nutritional status and sedentary lifestyle. Obesity in turn promotes GHG emissions through increased pressure on fossil fuel utilization during transportation and increase in energy expenditure.

The pathway through which GHG emissions influence obesity had been emphasized in the literature. Systematic development of pathological eating disorder due to residence in warmer climate has been emphasized.[12] The role of temperature during child conception and after delivery, on the prevalence of overweight among female African-American adolescents was also emphasized.[14] Some other authors emphasized how some climatic variables influence the body shape of adults,[15] the linkage between weight gain, low energy expenditure and low ambient temperature,[16] and reduction in seasonal cold and thermogenesis due to intake of fat and high sugar diets.[17] Using county-level data for 2004-2008, Zheutlin et al.[18] conducted a linear mixed effect modelling of the ecological association between fossil fuels CO_2 emissions and obesity. The results showed that obesity was marginally increased by CO_2 emissions.

Among the studies that explored the effect of obesity on GHG emissions, Koengkan and Fuinhas[19] found emission of GHGs to be influenced by overweight. Zheutlin et al.[18] found positive association between obesity and GHG emissions. Trentinaglia et al.[20] also found increase in Body Mass Index (BMI) to influence increase in temperature. Other authors emphasized the burden of fossil fuel utilization while transporting obese and overweight people as promoter of GHG emissions.[13, 21]

In addition, some studies have highlighted some transitions in nutrition as the major determinants of obesity. This line of thought hypothesizes the role of consumption of fat loaded food and perpetual progression into sedentary lifestyles.[22] Minos[23] focused on per capita income as the major determinant of obesity among women using panel data from some countries, while food importation, urbanization, female schooling, and time were the control variables. The results showed that per capita income and urbanization significantly influenced overweight, while per capita income and per capita income squared reduced and increased obesity, respectively.

The objective of this study is to analyse the effect of carbon dioxide emissions on obesity using a regionally representative dataset for the African continent. It was hypothesized that obesity is not significantly influenced by carbon dioxide emissions. Provision of appropriate answer to this hypothesis is fundamental because it will constitute a vital contribution to the existing body of knowledge on the effect of carbon dioxide emissions on obesity. The policy relevance of the study can also be evaluated from the need to address obesity and the growing environmental concern that emission of GHGs recently poses in a global policy environment.

METHOD

Sources of Data

The data for this study covered the 2000-2016 periods and were obtained from the World Development Indicators (WDI) database of the World Bank, and the Food and Agriculture Organization

(FAO) statistical database. Precisely, obesity among adults (% incidence among people 18 years and above), political stability index and food imports (% in total merchandise) were obtained from the FAO, while greenhouse gas emissions (kt of CO_2 equivalent) and per capita gross domestic product (GDP) were obtained from the World Bank's WDI. The choice of the variables was inspired by some conceptual propositions by several authors. In addition, missing values also affected computation of some diagnostic tests, thereby compelling dropping of some variables. The setting of the panel was not balanced and the data were from fifty-two countries in Africa. These countries were Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gambia, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe.

Estimated Model

The model that was estimated in this study can be specified as:

$$OBS_{it} = \alpha_0 + \alpha_1 logCO_{2it} + \alpha_2 logGDP_{it} + \alpha_3 FDX_{it} + \alpha_4 POS_{it} + u_{it} \qquad 1.$$

In equation 1, OBS_{it} represents the incidence of obesity (%) in ith country in time t, $logCO_{2it}$ is the log of emissions of carbon dioxide emissions in ith country in time t, POS_{it} is the indicator of political stability in ith country in time t, $logGDP_{it}$ is the log of per capita gross domestic product in ith country in time t, and FDX_{it} is the food imports (% in total merchandise) in ith country in time t.

Test for Multicollinearity

The Variance Inflation Factor (VIF) and correlation matrix were used to infer the presence of multicollinearity in the estimated model. These processes resulted in replacement of total GHG emission variable with total carbon dioxide because of its high correlation with per capita GDP. A VIF of 4 and above or tolerance of 0.25 or less shows the presence of multicollinearity.[24]

Test for Cross-Section Dependency

The cross-sectional dependency test that was proposed by Pesaran[25] was conducted on the selected variables. This test, which was implemented by the *xtcdf* command in STATA, seeks to identify the presence of cross-sectional dependence or correlation among the panel error terms. This test is most accurate for this study because N, which is the number of countries (52), is larger than T, which is the number of years (17). The specification for the test can be presented as:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \qquad .2$$

Where $\hat{\rho}_{ij}$ is the residual's pairwise correlation coefficient.

Unit Root and Cointegration Test

Unit root test was conducted to determine if the series are stationary at level or not. Given the unbalanced nature of the panel data, this study utilized the Im, Pesaran, and Shin (CIPS) unit root test.[25] The mathematical expression for test is specified as:

$$CIPS(N,T) = \bar{T} = N^{-1} \sum_{i=1}^{N} t_i(N,T) \quad .3$$

where t_i denotes the t-statistics of the cross-sectional estimation of the Augmented Dicky Fuller (ADF) regression. In STATA 17, this test was implemented by indicating that *xtunitroot* should deduct the series' cross-sectional averages since there was evidence of cross-sectional dependency.[26] A second-generation panel cointegration approach of Westerlund[27] was adopted.

RESULTS

The series were first examined for multicollinearity using the correlation coefficients and Variance Inflation Factor (VIF). Table 1 shows that the degrees of correlation among the variables were very low and the overall VIF is 1.40. These two approaches revealed that multicollinearity was not a problem among the included explanatory variables.

Table 1: Correlation coefficients and variance inflation factor (VIF) of included variables

Variables	Obesity	Political	Food	Carbon dioxide	Per
Obesity	1.0000				
Political stability index	0.0675	1.0000			
Food imports	-0.1106	0.1493	1.0000		
Carbon dioxide	0.6054	-0.2239	-0.3975	1.0000	
Per capita GDP	0.7023	0.3332	-0.0800	0.3743	1.0000
Variance inflation	-	1.34	1.20	1.59	1.48

Table 2: Results of the test for cross-sectional dependence among the variables

Variable	CD-test	p-value	average joint T	mean ρ	mean abs(ρ)
Obesity	149.882	0.000	17.00	1.00	1.00
Political stability index	9.9	0.000	17.00	0.07	0.37
Food imports	2.195	0.028	17.00	0.01	0.42
Carbon dioxide emissions	85.867	0.000	17.00	0.57	0.69
Per capita GDP	109.722	0.000	16.42	0.72	0.78

Table 3: Results of the test for unit root among the variables

Variable	Level data	p-value	First difference	p-value	Inference
Obesity	6.52	1.000	16.66	0.000	I(1)
Political stability index	-6.89	0.000	-	-	I(0)
Food imports	4.99	1.000	-10.20	0.000	I(1)
Carbon dioxide emissions	1.39	1.000	-12.53	0.000	I(1)
Per capita GDP	-0.98	1.000	-12.39	0.000	I(1)
Cointegration test					
Variance ratio	2.44	0.002			

Table 3 shows the results of unit root and cointegration tests. The results showed that except political stability index that was stationary at level [I(0)], all the series were [I(1)]. Using the Westerlund method, we rejected the null hypothesis of no cointegration in the panels, in favour of the alternative hypothesis that states that some panels are cointegrated. The presence of cointegration further justifies our choice of panel corrected standard error approach.

Determinants of Obesity - Panel Corrected Standard Error

Table 4 presents the results of the panel correction standard error regression for the combined dataset. In Tables 5-9, the results were also generated for each of the African regions to ensure robustness and comparison of the estimated parameters. In Tables 4-9, the results were generated for different forms of autocorrelation under the single lag Ordinary Least Square (OLS) residuals, and error structures. Therefore, nine results were generated in each of the Tables. The essence of this approach is to evaluate the estimated parameters for each of the specifications and decide the best among the estimated models. Moreover, in Tables 4-9, the chi-square statistics showed that the models were all statistically significant ($p<0.01$). This implies that we cannot accept the null hypothesis underlying the goodness of fit of the model, which states that all the estimated parameters are jointly equal to zero. Similarly, under each of the assumed error structure, the results for no form autocorrelation that are in columns 1, 4 and 7 had be highest chi- square. It was only in Table 7 that results for panel AR(1) presented the highest chi-square.

The results further revealed that the parameters of carbon dioxide were positively and statistically significant ($p<0.01$) in all the estimated models for Africa (Table 4), Central Africa (Table 5), North Africa (Table 7), and South Africa (Table 8). In Table 4, assuming heteroscedastic and panel correlation and AR(1) autocorrelation, the result showed that a 1 percent increase in carbon dioxide emissions in Africa will result in 3.578 unit increase in obesity. However, the smallest parameter is for panel AR(1), and it shows that a one percent increase in carbon dioxide will result into 1.709 unit increase in obesity. In Table 5, the results under AR(1) (column 2) showed that a one percent increase in carbon dioxide emissions in Central Africa will result into 1.138 unit increase in obesity. However, for the result in column 3 with panel AR(1) assumption, obesity will increase by 0.684 unit in Central Africa if carbon dioxide emissions increase by 1 percent. In Table 7, the parameters of carbon dioxide for AR(1) and panel AR(1) were the best under the assumptions of heteroscedastic and panel independence.

Table 6 shows that irrespective of the form of autocorrelation that was assumed, the parameters of carbon dioxide were mostly statistically insignificant when heteroscedastic and panel correlation were assumed for East Africa. With the assumption of heteroscedastic and panel independence, the parameters for AR(1) and panel AR(1) autocorrelation were statistically significant ($p<0.05$). Under the assumptions of AR(1) and panel AR(1) autocorrelation, a one percent increase in carbon dioxide emission will result into 0.639 and 0.621 unit increase in obesity, respectively. In the results for North Africa, Table 7 reveals that all the estimated parameters for carbon dioxide were positive and statistical significantly associated ($p<0.01$) with obesity. The least of the parameters shows that a one percent increase in carbon dioxide emissions will result into 6.878 unit increase in obesity. In Table 8, all the parameters of carbon dioxide are also with positive sign and statistically significant ($p<0.01$). In the least scenario, the results showed that a one percent increase in carbon dioxide will increase obesity by 3.463 units in Southern Africa. In Table 9, the results for AR(1) and panel AR(1) for heteroscedastic and panel independence have positive sign and statistically significant ($p<0.05$). These revealed that a one percent increase in carbon dioxide emissions will result into 0.498 unit increase in obesity.

The results in Tables 4-9 further show that indicator of political instability has different associations with obesity across the African regions. Specifically, in Table 4, statistical significance was only found in the results under column 1 at $p<0.05$. This implies that if the indicator of political stability increases by a unit, African obesity will decline by 0.303 unit. Furthermore, in Central Africa, Table 5 reveals that political stability was positively associated with obesity and statistically significant ($p<0.05$) in columns 1, 4, 5 and 7. These results showed that a unit increase in political stability will increase obesity by 0.759 and 0.142 under no autocorrelation and AR(1) assumptions, respectively. The parameters of political stability did not show statistical significance ($p>0.10$) in East Africa (Table 6). However, in Table 7, the parameters of political stability show statistical significance for the models presented for heteroscedastic (columns 4-6) and panel independence (columns 7-9). More importantly, parameters for AR(1) and panel AR(1) are with negative sign, while those for no autocorrelation are with positive sign. These results indicate that in North Africa, under AR(1) and panel AR(1) assumptions, a unit increase in political stability will reduce obesity by 0.499 and 0.492 unit, respectively. In Tables 8 and 9, political stability parameters only showed statistical significance ($p<0.05$) under the no autocorrelation assumption. Specifically, a unit increase in political stability in Southern Africa reduces obesity by 0.705 unit, while it increases it by 0.225 unit in West Africa.

The results in Tables 4-9 further reveal the positive and statistical significance ($p<0.01$) of per capita GDP parameters in all the estimated models. Since all the parameters are statistically significant, the focusing will be on the largest parameters. Table 4 shows that in Africa, a one percent increase in per capita GDP will lead to a 7.632 unit increase in obesity. However, in Central Africa (Table 5) and East Africa (Table 6), a percentage increase in per capita GDP will result in 3.522 unit and 5.321 unit increase in obesity, respectively. The impact of per capita GDP on obesity is highest in North Africa. Specifically, Table 7 shows that there will be a 7.717 unit increase in obesity if per capita GDP increases by one percent. Similarly, in Southern Africa (Table 8) and West Africa (Table 9), a percentage increase in per capita GDP will result in 4.783 unit and 5.890 unit increase in obesity, respectively.

The results further show the estimated parameters for food imports. Table 4 shows that the parameters of food imports were statistically significant ($p<0.01$) under the assumption of no form of autocorrelation. These results revealed that a percentage increase in food imports will result in 0.0049 unit increase in African obesity. In Central Africa, the parameters of food imports in Table 5 are with positive sign and statistically significant across all the estimated models. Therefore, a percentage increase in food imports will increase obesity by 0.0978 unit. In East Africa, Table 6 shows that a percentage increase in food imports will lead to 0.0033 unit increase in obesity. Similarly, in North Africa, Table 7 shows that a percentage increase in food import will lead to 0.114 unit increase in obesity, while in South Africa an increase of 0.099 unit would be had (Table 8). Table 9 however reveals that in West Africa, a percentage increase in food imports will reduce obesity by 0.0023 unit.

Table 4: Panel Corrected Standard Error Regression for the Determinants of Obesity in Africa

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Form of Autocorrelation	None	AR(1)	Panel AR (1)	None	AR(1)	Panel AR (1)	None	AR(1)	Panel AR (1)
Error Structure	Heteroscedastic and Panel Correlation			Heteroscedastic			Panel Independence		
Political Stability	-0.303**	-0.0104	0.0108	-0.303*	-0.0104	0.0108	-0.303*	-0.0104	0.0108
	(-2.138)	(-0.230)	(0.339)	(-1.856)	(-0.211)	(0.326)	(-1.725)	(-0.210)	(0.346)
Food imports	0.00490***	-4.98e-5	-0.0001	0.00490***	-4.98e-5	-0.00010	0.00490***	-4.98e-5	-0.0001
	(6.850)	(-0.179)	(-0.563)	(5.785)	(-0.140)	(-0.420)	(4.961)	(-0.113)	(-0.369)
Carbon dioxide	3.371***	3.578***	1.709***	3.371***	3.578***	1.709***	3.371***	3.578***	1.709***
	(34.23)	(19.80)	(10.36)	(12.61)	(13.65)	(9.301)	(16.61)	(16.94)	(10.30)
Per capita GDP	7.632***	3.446***	2.789***	7.632***	3.446***	2.789***	7.632***	3.446***	2.789***
	(24.25)	(9.248)	(8.003)	(26.51)	(14.17)	(15.72)	(22.58)	(14.13)	(18.79)
Constant	-16.36***	-9.03***	-3.58***	-16.36***	-9.03***	-3.58***	-16.36***	-9.03***	-3.58***
	(-24.77)	(-9.818)	(-4.509)	(-19.94)	(-10.44)	(-5.819)	(-23.00)	(-11.89)	(-6.292)
Observations	852	852	852	852	852	852	852	852	852
R-squared	0.641	0.462	0.641	0.641	0.462	0.641	0.641	0.462	0.641
Panel	51	51	51	51	51	51	51	51	51
Chi square	13143.26	532.74	119.08	1339.87	468.51	351.94	1521.73	672.80	465.63
Chi square prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 5: Panel Corrected Standard Error Regression for the Determinants of Obesity in Central Africa

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Form of	None	AR(1)	Panel AR	None	AR(1)	Panel AR	None	AR(1)	Panel AR
Error Structure	Heteroscedastic and Panel Correlation			Heteroscedastic			Panel Independence		
Political Stability	0.759***	0.142	0.0575	0.759***	0.142**	0.0575	0.759**	0.142*	0.0575
	(3.120)	(1.445)	(0.603)	(3.106)	(1.998)	(0.896)	(2.514)	(1.836)	(0.922)
Food imports	0.0978***	0.0280***	0.0429***	0.0978***	0.0280***	0.0429***	0.0978***	0.0280**	0.0429***
	(13.15)	(3.103)	(5.318)	(10.16)	(3.478)	(5.635)	(6.226)	(2.491)	(5.906)
Carbon dioxide	0.745***	1.138***	0.684**	0.745**	1.138***	0.684*	0.745**	1.138***	0.684*
	(4.399)	(4.071)	(2.084)	(2.507)	(3.200)	(1.956)	(2.043)	(2.774)	(1.959)
Per capita GDP	3.522***	1.737***	1.073***	3.522***	1.737***	1.073***	3.522***	1.737***	1.073***
	(8.356)	(3.985)	(2.614)	(6.200)	(4.776)	(3.767)	(6.115)	(4.966)	(3.679)
Constant	-2.282**	-0.152	0.847	-2.282*	-0.152	0.847	-2.282	-0.152	0.847
	(-2.456)	(-0.135)	(0.905)	(-1.840)	(-0.130)	(0.850)	(-1.443)	(-0.106)	(0.847)
Observations	136	136	136	136	136	136	136	136	136
R-squared	0.551	0.135	0.776	0.551	0.135	0.776	0.551	0.135	0.776
Panels	8	8	8	8	8	8	8	8	8
Chi square	511.37	41.18	32.86	196.43	55.30	48.85	167.05	49.54	48.68
Chi square prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6: Panel Corrected Standard Error Regression for the Determinants of Obesity in East Africa

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Form of	None	AR(1)	Panel AR	None	AR(1)	Panel AR	None	AR(1)	Panel AR
Error Structure	Heteroscedastic and Panel			Heteroscedastic			Panel Independence		
Political	0.0497	-0.00092	0.00491	0.0497	-0.00092	0.00491	0.0497	-0.00092	0.00491
	(0.287)	(-0.0214)	(0.132)	(0.296)	(-0.0193)	(0.121)	(0.263)	(-0.0176)	(0.119)
Food imports	0.00327***	-0.00013	-0.00024	0.0033***	-0.00013	-0.00024	0.0033***	-0.00013	-0.00024
	(3.547)	(-0.397)	(-0.965)	(3.157)	(-0.399)	(-1.150)	(4.693)	(-0.448)	(-1.076)
Carbon dioxide	0.330*	0.639	0.621*	0.330	0.639**	0.621***	0.330	0.639**	0.621***
	(1.755)	(1.504)	(1.859)	(1.368)	(2.050)	(2.704)	(1.532)	(2.347)	(2.640)
Per capita GDP	5.321***	2.828***	2.624***	5.321***	2.828***	2.624***	5.321***	2.828***	2.624***
	(18.00)	(6.758)	(5.904)	(16.88)	(10.90)	(10.57)	(16.88)	(10.59)	(12.71)
Constant	-3.937***	-0.103	-0.926	-3.937***	-0.103	-0.926	-3.937***	-0.103	-0.926
	(-4.108)	(-0.0564)	(-0.652)	(-3.563)	(-0.0987)	(-1.202)	(-4.338)	(-0.108)	(-1.143)
Observations	279	279	279	279	279	279	279	279	279
R-squared	0.617	0.288	0.294	0.617	0.288	0.294	0.617	0.288	0.294
Panel	17	17	17	17	17	17	17	17	17

Chi square	2760.96	55.09	38.33	787.21	126.97	134.10	449.77	122.04	168.75
Chi square prob	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 7: Panel Corrected Standard Error Regression for the Determinants of Obesity in North Africa

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Form of Autocorrelation	None	AR(1)	Panel AR (1)	None	AR(1)	Panel AR (1)	None	AR(1)	Panel AR (1)
Error Structure	Heteroscedastic and Panel Correlation	Heteroscedastic	Panel Independence						
Political Stability	1.171***	-0.499	-0.472	1.171**	-0.499**	-0.472**	1.171***	-0.499***	-0.472***
	(3.679)	(-1.049)	(-1.024)	(2.487)	(-2.399)	(-2.479)	(2.700)	(-2.790)	(-2.758)
Food imports	0.114***	0.00241	0.0624	0.114***	0.00241	0.0624**	0.114***	0.00241	0.0624**
	(3.503)	(0.0447)	(0.898)	(3.661)	(0.0831)	(2.058)	(4.358)	(0.0823)	(2.286)
Carbon dioxide	6.878***	7.717***	7.570***	6.878***	7.717***	7.570***	6.878***	7.717***	7.570***
	(6.236)	(4.551)	(4.465)	(5.319)	(7.421)	(12.17)	(6.888)	(7.023)	(12.12)
Per capita GDP	10.95***	5.087*	4.182	10.95***	5.087***	4.182***	10.95***	5.087***	4.182***
	(10.39)	(1.734)	(1.576)	(10.84)	(4.521)	(3.935)	(11.11)	(4.767)	(4.181)
Constant	-34.85***	-24.68**	-24.21***	-34.85***	-24.68***	-24.21***	-34.85***	-24.68***	-24.21***
	(-6.738)	(-2.205)	(-2.647)	(-5.586)	(-4.735)	(-6.636)	(-6.875)	(-4.604)	(-6.684)
Observations	81	81	81	81	81	81	81	81	81
R-squared	0.733	0.785	0.961	0.733	0.785	0.961	0.733	0.785	0.961
Panel	6	6	6	6	6	6	6	6	6
Chi2	278.02	25.35	68.50	204.11	105.35	539.05	222.71	94.53	397.95
Ch2p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 8: Panel Corrected Standard Error Regression for the Determinants of Obesity in South Africa

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Form of	None	AR(1)	Panel AR (1)	None	AR(1)	Panel	None	AR(1)	Panel
Error Structure	Heteroscedastic	Heteroscedastic	Panel						
Political Stability	-0.705***	-0.0542	-0.0596	-0.705***	-0.0542	-0.0596	-0.705***	-0.0542	-0.0596
	(-4.888)	(-0.397)	(-0.445)	(-2.861)	(-0.336)	(-0.397)	(-2.610)	(-0.384)	(-0.408)
Food imports	0.0988***	-0.00374	0.0105	0.0988***	-0.00374	0.0105	0.0988***	-0.00374	0.0105
	(3.638)	(-0.188)	(0.462)	(3.579)	(-0.197)	(0.442)	(3.141)	(-0.193)	(0.527)
Carbon dioxide	3.463***	3.909***	4.064***	3.463***	3.909***	4.064***	3.463***	3.909***	4.064***
	(20.95)	(13.56)	(6.787)	(11.87)	(7.381)	(5.723)	(9.382)	(8.123)	(5.738)
Per capita GDP	4.783***	2.569**	2.278***	4.783***	2.569***	2.278***	4.783***	2.569***	2.278***
	(5.908)	(2.528)	(3.065)	(6.940)	(3.640)	(3.211)	(6.502)	(3.667)	(3.508)
Constant	-9.791***	-4.644**	-5.039**	-9.791***	-4.644*	-5.039*	-9.791***	-4.644**	-5.039*
	(-4.792)	(-2.138)	(-2.199)	(-4.895)	(-1.946)	(-1.724)	(-4.514)	(-2.025)	(-1.879)
Observations	84	84	84	84	84	84	84	84	84
R-squared	0.863	0.734	0.870	0.863	0.734	0.870	0.863	0.734	0.870
Panel	5	5	5	5	5	5	5	5	5
Chi2	2616.03	492.45	110.59	647.04	91.35	54.13	527.78	111.72	62.02
Ch2p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 9: Panel Corrected Standard Error Regression for the Determinants of Obesity in West Africa

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Form of	None	AR(1)	Panel AR	None	AR(1)	Panel AR	None	AR(1)	Panel AR
Error Structure	Heteroscedastic and Panel			Panel Heteroscedastic			Panel Independence		
Political Stability	0.225**	-0.0239	-0.0169	0.225*	-0.0239	-0.0169	0.225*	-0.0239	-0.0169
	(2.183)	(-0.354)	(-0.212)	(1.871)	(-0.457)	(-0.297)	(1.705)	(-0.458)	(-0.333)
Food imports	-0.0023***	-0.00022	-0.00048	-0.0023***	-0.00022	-0.00048	-0.0023***	-0.00022	-0.00048
	(-4.387)	(-0.265)	(-0.603)	(-3.696)	(-0.254)	(-0.618)	(-2.876)	(-0.283)	(-0.657)
Carbon dioxide	-0.421***	0.957***	0.498**	-0.421***	0.957***	0.498*	-0.421**	0.957***	0.498**
	(-4.361)	(2.889)	(2.010)	(-2.943)	(3.373)	(1.892)	(-2.369)	(3.585)	(2.175)
Per capita GDP	5.890***	1.975***	2.202***	5.890***	1.975***	2.202***	5.890***	1.975***	2.202***
	(15.88)	(3.859)	(4.378)	(16.92)	(6.780)	(7.422)	(15.23)	(6.753)	(8.004)
Constant	-0.812*	0.647	1.622*	-0.812	0.647	1.622*	-0.812	0.647	1.622**
	(-1.795)	(0.469)	(1.727)	(-1.377)	(0.663)	(1.799)	(-1.237)	(0.686)	(2.043)
Observations	272	272	272	272	272	272	272	272	272
R-squared	0.489		0.604	0.489		0.604	0.489		0.604

Panel	16	16	16	16	16	16	16	16	16
Chi2	550.14	26.78	27.56	392.86	72.34	67.78	259.80	72.18	79.40
Ch2p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

DISCUSSION

The results showed the positive impact of carbon dioxide emissions on obesity. Although this finding should be taken with some cautions due to the complexity of several socio-economic and genetic factors promoting obesity, the role of carbon dioxide emissions on obesity had been reported in literature. Some studies have implicated obesity as part of the major factors promoting emissions of greenhouse gases.[11,19] Therefore, a possibility of reverse causality between obesity and greenhouse gas emissions empirically authenticates some pathways of theoretical reasonings. Hersoug et al.[28] noted that escalated concentration of atmospheric carbon dioxide may be responsible for the growing incidences of obesity and diabetes. In a study that utilized USA's district-level data, Zheutlin et al.[18] found a positive association between obesity and GHG emissions although it was noted that the ecological nature of the study compels a cautious conclusion.

Other authors such as Koengkan and Fuinhas[19] and Trentinaglia et al.[20] found an association between obesity and carbon dioxide emissions. Some other authors have concluded that obesity is a promoter of carbon dioxide emissions through increased utilization of fossil fuel during transportation of overweight and obese people and relatively higher metabolic rate.[13,21] Furthermore, there are several indirect mechanisms through which emission of greenhouse gases and obesity might be related. In some cases, some authors have followed the line of thoughts on the role of decreased production of nutrient-dense food due to climate change as a potential indirect way of promoting unhealthy food consumption pattern that can promote obesity.[22] This perspective cannot be jetissoned following the on-going progressive integration of global economies. Therefore, globalization is a precursor of climate change and other environmental degradation that indirectly impact agricultural productivity in less technologically advanced countries. More importantly, globalization has been found to facilitate unhealthy consumption that eventually promotes obesity.[29-32]

The perspective through which political stability and absence of terrorism influence obesity had been highlighted in the literature. It had been emphasized that a politically chaotic environment will promote sedentary lifestyle due to insecurity. Engagement in physical exercises like jogging, walking, and biking on the streets will become very difficult when terrorism and political instability prevail in a society. Therefore, sedentary lifestyle has been considered as one of the most important factors promoting obesity.[33-36] Another important channel through which obesity can be promoted by terrorism and political instability is through promotion of psychosocial and environmental stressors.[37] Specifically, stress hormones and associated physiological impacts can promote eating disorder that promotes obesity.[37] It should be further noted that conflicts discourage agricultural productivity, thereby reducing availability of healthy foods in the short-run, and promoting a long-run nutritional imbalances.[38-41] Such scenario can stimulate increased consumption of processed food, which may result into increased incidence of non-communicable diseases with indirect obesity consequence.[42,43]

The association between obesity and GDP is well documented in literature. Precisely, income growth may promote or reduce obesity, depending on healthy lifestyles' adoption behaviour. Income growth is associated with health enhancing lifestyles adopted by the people as economic prosperity persists. Income growth is expected to induce households' socioeconomic status with diverse impacts on individual's inactivity and consumption of healthy foods. A study that was conducted in South Africa by Pisa and Pisa[44] found a positive association between GDP and obesity. Similar finding had been reported by other authors.[45,46] Steyn and Mchiza[47] noted that obesity and GDP had rising over time, while increase in per capita energy, fat and protein intakes can promote the incidence of Non-Communicable Diseases (NCD). Another study that reported a positive association between GDP and obesity is that by Osayomi.[48]

Food imports are a good indicator of economic growth and globalization, which had been reported by many studies to be positively associated with obesity.[49] Food importation can constitute negative externality to the importing countries, thereby promoting obesity.[50] In some African countries, consumption of imported foods is of significant relevance to the incidences of obesity and overweight. In some previous studies, Lin et al.[50] submitted that consumption of sugar and processed imported foods increased obesity and overweight across the world. The results further revealed that for those in West Africa, food imports reduced obesity. This gives some indications that food importation could have different results on obesity, depending on some other inherent influence of externalities that promote obesity prone behaviours.

CONCLUSION

Addressing the global epidemic of obesity is a fundamental prerequisite for achieving some of the Sustainable Development Goals (SDGs). This is becoming an urgent concern for African policymakers, considering the growing incidence of non-communicable diseases and associated mortality. This study presents some empirical evidence on the linkage between obesity and carbon dioxide emissions in Africa. The results have overwhelmingly pointed at the positive influence of carbon dioxide emissions in Africa and across each of the regions. This clearly underscores the need for proactive measures to address GHG emissions in the African continent. It also emphasizes the need for political will and cooperation among African leaders in ensuring strict compliance with the policy framework for the implementation of the Paris Agreements. In addition, the study emphasises the need to have an economic growth process that is environmentally benign with strict consideration of people's health. Therefore, African economic growth and associated socioeconomic development should be properly aligned with consumption and lifestyle behaviours that can impact the population's health positively. Political stability was also linked to obesity thereby re-echoing the role of peace on human welfare and adoption of health-promoting lifestyles. Although this study has provided a viable platform for evaluating the impact of carbon dioxide emissions on obesity in Africa, it important to highlight some limitations. The major problem that is associated with the finding concerns the data coverage. This study used unbalanced panel data structure and missing data compelled removal of some variables which were initially considered important in explaining obesity.

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