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Obesity Kuznets Curve conjecture assessment in African economies: conditioning effects of urbanization, food, and trade using gender-based regional analysis

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Abstract

Background Obesity is recognized as a significant health challenge in Africa, contributing to the double burden of malnutrition and elevating the risks of diabetes, heart disease, and hypertension. Existing studies on the Obesity Kuznets Curve (OKC) assessment overlook Africa's unique socio-economic and gender-specific dynamics. In light of the claim that different socioeconomic characteristics significantly influence the prevalence of obesity in different nations, this study examines the nonlinear relationship between economic growth and each of the obesity prevalence in males, females, and both sexes, respectively, while accounting for the effects of urbanization, trade, and food production.

Methods The study employs a panel data design to analyse the OKC hypothesis in a multivariate non-linear framework. The study focusses on Africa, with the study units consisting of African countries analysed within the framework of regional groupings and differentiated by obesity prevalence in males, females and both sexes correspondingly. Specifically, the study utilised panel data of 45 African nations sub-panelled into Eastern, Western, Central and Southern regions during the period from 2000 to 2020. The primary outcome variable is obesity prevalence, while the key exposure variable is economic growth. The study also considers trade openness, urbanization and food production as additional covariates influencing obesity prevalence to provide a nuanced analysis. Considering the existence of residual cross-sectional dependence and heterogeneity issue in the panel data, we applied the novel Biased Comment Method of Method estimator using the dynamic fixed-effect model as the main method to ensure robust and reliable estimates. This novel approach allows the study to address unobserved heterogeneity and interdependencies across regional economies.

Results The principal findings demonstrated a distinct pattern of the OKC (non-linear relationship between the country's economic growth and obesity) when analysing prevalence of obesity in both sexes collectively and also when considering obesity prevalence in males and females separately across the geographical panels used. The results further showed that trade openness is positively associated with obesity prevalence in males and females separately together with both sexes collectively across all regional classifications. However, the effect of urbanization,

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and food production on obesity prevalence in males, obesity prevalence in females and obesity prevalence in both sexes correspondingly varied across the regional classifications.

Conclusion Our analysis leads to specific policy recommendations, including the development of robust, regionally tailored health policies aimed at preventing obesity across Africa. These include promoting healthy diets through subsidies on nutritious foods, regulating trade polices to limit unhealthy food imports and integrating urban planning to encourage active lifestyles. Considering the rapid economic expansion, urbanization, trade liberalization and food production in many African nation, these strategies ought to address regional and gender-specific dynamics while aligning with global development goals such as SDG 3 (good health and well-being) and SDG2 (zero hunger), to effectively mitigate the rising prevalence of obesity.

Keywords Obesity Kuznets Curve, Economic growth, Urbanization, Trade openness, Food production, Africa

Introduction

While high-income and upper-middle-income nations, mostly in Europe, Asia, and America, are grappling with global obesity epidemic, low-income and lower-middle-income nations, primarily in Africa, are facing an unprecedented double burden of malnutrition, where rising obesity rates coexist with persistent undernutrition. This unique challenge is driven by rapid economic growth, urbanization, and dietary transitions, which have introduced calorie-dense processed foods to populations still struggling with food insecurity. Previously, obesity was not considered a public health concern in Africa. However, it has now emerged as a significant issue in many African nations, contributing to the rise of non-communicable diseases [7]. Africa is experiencing an increase in the incidence of obesity (WHO, 2022), which is a ticking time bomb (Ref. Figure 1). Specifically, Fig. 1. illustrates the upward trend in obesity prevalence across African regions over the past two decades. The data highlights the significant increases in obesity rates, particularly in urbanized and economically transitioning areas. The figure emphasizes the growing public health concern, with obesity projected to further escalate if preventive measures are not implemented. These trends underline the urgency of addressing obesity as a critical issue validating its description as a ticking time bomb. Millions of Africans face the risk of shortened lifespans, reduced quality of life, significant economic and social burdens due to growing prevalence of poor health, according to the WHO Regional Director for Africa (WHO, 2022). For

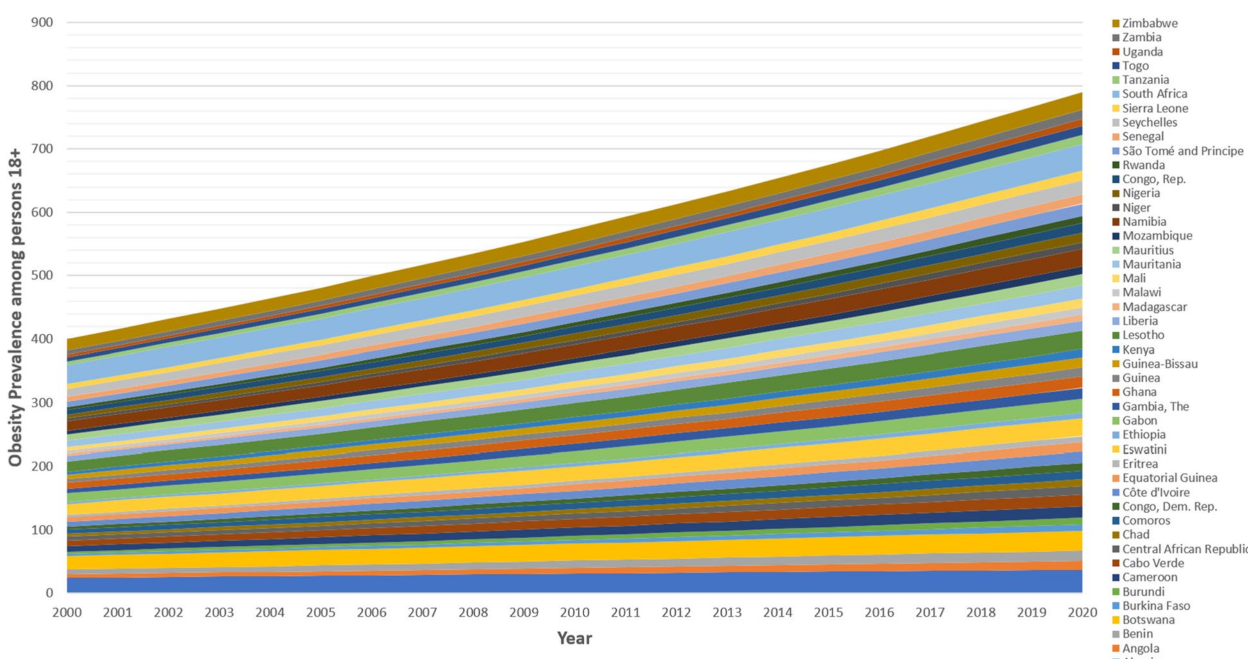

Fig. 1 Trend of obesity prevalence among both sexes (18 +) in African nations for the period 2000 to 2020. Source: Authors' computation from WHO health observatory database

example, the incidence of female obesity rose dramatically between 1975 and 2014 in West, Central, and East Africa, where it today stands between 30 and 40% (NCD-RisC, 2016). It has been documented that undernutrition and overnutrition coexist in diverse ways in Africa [4]. The age-standardized mean body mass index increased for men and women between 1980 and 2014, rising from 21.0 kg/m2 to 23.0 kg/m2 and 21.9 kg/m2 to 24.9 kg/m2, respectively (NCD-RisC, 2017). The mean obesity rate in Southern Africa alone exceeded the global norm in terms of body mass index. In Africa, the incidence of obesity rose by over a third between 1992 and 2005 [91]. This rise was only recently noted among female urban dwellers (Mangemba et al., 2020). Data, however, also consistently indicate a rise in obesity among men and those living in rural areas [4]. Therefore, the growing trend in obesity raises serious concerns about public health and has important policy ramifications for Africa.

Obesity has emerged as a major health problem in Africa, driven by macroeconomic factors such as economic development, urbanization, food production, and trade liberalization—key contributors to the obesity epidemic [9],Windarti, 2019; [15, 21, 39]. Addressing these factors is essential, as reducing obesity prevalence has been identified as a critical strategy for lowering mortality rates in projections to 2040 [59]. However, not much has been done to combat obesity on the continent, despite the rapid rise in obesity prevalence—estimated to have tripled in some African regions over the past few decades—and the associated increase in chronic illnesses projected to burden African health systems in the near future [7]. Thus, a sex-and gender-based analysis of obesity in this research across the participating nations is an essential first step in providing insights into the issue across time, which are required to guide program and policy responses to address the problem in Africa. Furthermore, in order to promote integrated public health policy actions to counter the surge of this epidemic, it is critical to understand the variables that contribute to obesity's prevalence. The incidence of obesity varies greatly between nations due to a variety of variables, such as globalization, genetic impacts, lifestyle, cultural, socioeconomic factors [23, 26, 34],and economic freedom [53].

Specifically, there is often a correlation between obesity and economic growth. For example, it is frequently highlighted that the rapid rise in obesity rates is as a result of recent expansion in developing nations, mostly in Africa [6]. This is supported by the observation that, on an individual basis, persons who have greater wages can afford and typically choose higher-calorie diets and leisure activities. However, this relationship is as well influenced by limited nutrition education, which can lead to poor dietary choices, and high cost of quality, nutrient-dense foods compared to cheaper, calorie-dense processed options. Also, cultural norms, urbanization and food production further exacerbates obesity trends, as many individuals lack access to affordable healthy foods and opportunities for physical activity [41]. This results into higher energy intake and lower energy expenditure, which increases the risk of obesity. Nevertheless, the Obesity Kuznets Curve (OKC) conjecture has been used in recent years to hypothesize the relationship between the prevalence of obesity, economic advancement, and income. According to the OKC conjecture, people acquire weight as their income increases because they can buy more food; this calorie imbalance causes an increase in the prevalence of obesity [18]. For instance, Ameye and Swinnen (6) and An et al. [9] highlight how economic growth and rising incomes influence obesity trends, particularly in developing nations. Thus, affordable and delectable meals are produced by economic progress and technological improvement, encouraging people to lead more sedentary lives with less physical activity and contributing to the obesity epidemic [46, 81]. Nonetheless, considering the claim that health is a natural good, ongoing economic growth encourages individuals to switch to a better diet and make more investments in their general well-being, which ultimately lowers the obesity rate.

Furthermore, it's been suggested that urbanization encourages sedentary lifestyles and poor eating habits, which in turn fuel obesity. In both developed and developing countries, the prevalence of obesity in urban areas has increased in recent decades (Chen, 2023). Africa is not an exception to the current urbanization trend that has accelerated the development of obesity. This is explained by the fact that people who live in cities often have fewer possibilities for physical activity since there are fewer open areas, they rely more on motorized transportation, and they spend more time indoors doing sedentary activities [41]. Additionally, the growth of fast-food restaurants in metropolitan areas makes it easier for people to get processed meals high in calories [51]. Despite rising rates, studies estimate that 20–25% of African urban residents are overweight or obese [69]. By 2025, non-industrialized nations—of which the majority of African countries are not excluded—are expected to account for three-quarters of the world's obese population [14]. According to Biadgilign (2017), urban regions in African nations appear to be facing an increasing trend of obesity prevalence.

Until now, research has connected food availability and accessibility to obesity, with some studies [39, 54, 75],Gamba, 2015) finding a beneficial link between food production and obesity. Obesogenic food environments are linked to growing obesity trends because they are defined by the predominance of foods that are high in calories but low in nutrients (Eskandari, F., et al., 2022). Obesity has also been connected to dietary practices. Foods with a high glycaemic index, for example, may exacerbate hunger and encourage overindulgence, which might lead to obesity [80]. Furthermore, highly appetizing meals such processed sugar and fat-rich foods, which can overcome internal homeostatic systems and lead to overeating and fat deposition, are associated with obesity along with excessive calorie consumption [22]. Notwithstanding, it has been suggested that greater trade openness affects the prevalence of obesity [9, 21]. Although food has been a traded good for millennia, technological supply chains and innovative marketing strategies are contributing to the present fast expansion of the global food industry. The international agri-food systems that drive the nutrition transition toward western diet are responsible for the significant changes in the kind, amount, affordability, and desirability of food accessible for consumption that accompany this increase (Bondarenko, 2024). According to Lin et al. [54], the average national obesity rate is rising as a result of the importation of processed foods, particularly sugar. [9] empirical study demonstrated that trade openness is positively correlated with the incidence of obesity, with the effect being most pronounced in developing nations.

Although there have been some researches that look at obesity in Africa, attempting to limit the rise in obesity prevalence is still one of the continent's largest social issues. In light of this difficulty, the following research query emerges: *How does economic development or income growth foster the rise of obesity prevalence in an OKC framework whilst conditioning for the effect of urbanization, trade and food production?* In this sense, the primary objective of our research is to evaluate the relationship between economic development and the prevalence of obesity in both males and females throughout Africa by applying the OKC hypothesis and taking into account the influences of trade liberalization, urbanization, and food production. Even with the growing threat of obesity, research on the disease's prevalence in Africa has been scant, despite a lengthy history of studies on the pandemic globally [3, 61, 82]. Nevertheless, in light of the rapidly rising obesity prevalence, the few relevant works that concentrate on Africa either focus on one country and one data point [5, 40, 52],Oyan and Ndu-Akinla (2023); [11] or on a panel of countries without taking sub-classifications into account (Mařincová et al., 2017 [7, 79],), or they focus on a systematic review and meta-analysis [4, 29, 38, 65]. Motivated by the shortcomings of previous research, this study contributes to the existing literature on obesity in Africa in the following significant ways;

Firstly, in contrast to previous studies on obesity in Africa, this study uses macroeconomic variables, including food production, trade openness, urbanization and economic growth, rather than socio-economic demographic variables, to assess the prevalence of obesity within the OKC context. Most obesity-related research in Africa relies on systematic reviews or demographic health survey data with socio-demographic variables, neglecting macroeconomic factors. These factors provide a comprehensive perspective on the economic environment's impact on health outcomes, including the incidence of obesity, by capturing long-term trends and systematic elements often overlooked by socio-demographic approaches. For instance, economic growth can lead to higher consumption of processed, calorie-dense foods, urbanization promotes sedentary lifestyles and easier access to fast food, trade liberalization increases the availability of obesogenic products and food production affects the affordability and diversity of foods. Together, these factors shape dietary habits, physical activity, and ultimately obesity prevalence. This study thus uniquely combines obesity prevalence and macroeconomic factors within the non-linear framework through the assessment of the OKC hypothesis to fill these gaps. **Also**, previous African studies often generalize conclusions across the continent, failing to account for significant regional differences in economic structures, resource endowment and development stages. Aggregating data masks the distinct socio-economic, cultural and environmental dynamics present across specific regions. This study addresses these limitations by classifying 46 African countries into regional panels—Eastern, Western, Central and Southern Africa— and analysing obesity prevalence and its drivers using a geographically disaggregated approach. To the best of our knowledge, no prior study has examined obesity in Africa with such specific regional classification. Additionally, it disaggregates the data by gender in terms of obesity prevalence, offering insights in into variations in prevalence of obesity and drivers across males and females. These distinctions allow the study to capture variations that aggregated data or broad-level analysis fail to address. **Methodologically**, most panel studies [1, 8, 16, 21, 41] on obesity-economic growth assessment using the OKC hypothesis employ conventional estimation techniques, which fail to account for heterogeneity and cross-sectional dependence among variables. This often results in contradictory findings. To overcome these challenges, this study, employs the novel dynamic Bias-Corrected Method of Moments (BCMM) estimation approach, a second-generation panel econometric technique that produces accurate and efficient results even in the presence of heterogeneity and residual cross-sectional correlations. This novel methodological approach enhances the reliability of findings, providing robust evidence for identifying priority regions and contexts where policy interventions may be most effective. **Moreover**, the study also emphasizes actionable policy interventions tailored to Africa's unique developmental landscape. These include taxation on ultra-processed foods and sugar-sweetened beverages, subsidies for nutritious foods, regulation of unhealthy food imports and urban planning to encourage physical activity. Such interventions are designed to address regional and gender-specific disparities driven by urbanization, trade liberalization, and dietary transitions. While some countries in Africa have policies addressing obesity, their impact has been limited by insufficient funding, weak enforcement, and a lack of region-specific adaptations. Strengthening these measures is critical to combat obesity rates amidst Africa's developmental challenges.

By contributing a refined understanding of the combined influence exerted by various developmental drivers on obesity in Africa, the study lays the groundwork for informing more holistic public health strategies. Ultimately, the research endeavours to guide targeted efforts in addressing the obesity crisis in Africa by considering the intricate interaction between obesity and the various macro-economic factors that shape health outcomes during the continent's unique development experience. This focus on macroeconomic factors provides insights that are critical for designing sustainable and targeted interventions to address the obesity crisis in Africa, offering policymakers the tools needed to mitigate its health and economic impacts. Precisely, the obesity crisis in Africa in this case refers to the rapid rise in obesity rates, which have tripled in some regions, driven by a shift towards calorie-dense diets and reduced physical activity due to urbanization and economic transitions. This trend coexists with undernutrition, creating a double burden of malnutrition that strains healthcare systems and contributes to rising communicable diseases like diabetes and hypertension. Trade liberalization and economic growth further exacerbate this issue by increasing access to unhealthy imported foods.

The following is the arrangement of the study's succeeding sections: Sect. 2 features the Methods; Sect. 3 centers on the presentation of the study's Results; Sect. 4 on the other hand handles the Discussions of the results obtained; Sect. 5 provides the Conclusion and Policy recommendations whereas the final section (Sect. 6) highlight the and limitations and future research direction of the study.

Methods

Study design, setting and study units

The rising prevalence of obesity has emerged as a significant public health concern globally particularly in developing nations such as those in Africa. Understanding the factors contributing to this phenomenon is crucial for developing effective interventions. To achieve the study's objective, a quantitative research design specifically panel data design, which is ideal for analyzing multiple countries over time is employed. This approach allows the examination of how obesity rate evolves in relation to economic growth and other factors over an extended period. The panel data design ensures that the analysis can capture both cross-sectional (across different countries) and temporal (over time) variations in obesity rates and the factors influencing them. The study's design spans 20 years (from 2000 to 2020), which is significant for capturing long-term trends and understanding the temporal dynamics between economic development and obesity. The time period was chosen because it captures a period of rapid change in many African countries. Economic growth, trade liberalization and urbanization accelerated during this time, creating a shift in dietary patterns and lifestyle choices, both which are major contributors to rise in obesity rates. A key feature of the design is the regional panel structure, where data is divided into four distinct regional groupings: Eastern, Western, Central and Southern Africa.[1] This regional breakdown is crucial because each part of Africa has different socio-economic, cultural and environmental contexts that may influence obesity prevalence in different ways. The study specifically tests the OKC hypothesis, which posits an inverted U-shaped relationship between economic growth and obesity prevalence. This hypothesis suggests that, as countries become wealthier, obesity rates initially rise due to an increase in food availability and lifestyle changes, but eventually decrease once a certain threshold of economic development is reached, where people adopt healthier diets and lifestyles. This framework is applied across the four regions to examine whether this pattern holds true in Africa. To analyze the data the study uses recent panel econometric techniques which are particularly well-suited to the study because they account for cross-sectional dependence and heterogeneity in the panel data—two issues that are common when working with data from multiple countries that may be influenced by similar global or regional factors. Additionally, the study incorporates gender-specific analysis,

[1] The lack of data from Northern Africa (except Algeria) excludes this region from the analysis, but the study still provides comprehensive insights into the rest of the continent.

Table 1 Variables description and data sources

Variable	Symbol	Measurement description	Source
Response variables			
Obesity prevalence (Both sexes)	OB_B	Percentage of the population (aged 18 +) (both sexes)	WHO Health Observatory Database, 2024
Obesity prevalence (Males)	OB_M	Percentage of the population (aged 18 +) (males)	WHO Health Observatory Database, 2024
Obesity Prevalence (Females)	OB_F	Percentage of the population (aged 18 +) (females)	WHO Health Observatory Database, 2024
Explanatory variables			
Economic growth	GDP	Per capita gross domestic product at constant 2015 US dollars	WDI, 2024
Urbanization	URB	Urban population total	WDI, 2024
Trade Openness	TRD	Sum of exports and imports of merchandise, current US$ as per GDP	WDI, 2024
Food Production	FP	Food production index (2014–2016 = 100)	WDI, 2024

separating the data on obesity prevalence for both sexes jointly together with males and females separately. These distinctions are vital because obesity patterns often vary between men and women due to factors such as differing socio-cultural pressures, lifestyle habits, and biological differences in weight gain and fat distribution. This approach thus ensures a nuanced understanding of how economic growth and other factors affect obesity prevalence differently for men and women across Africa.

Moreover, the setting of the study focused on African nations. This focus on Africa is significant given the rapid economic transitions and urbanization occurring in many African countries, which are contributing to increasing rates of obesity. The African continent provided a unique setting for this study, as it is home to a growing middle class, an expanding urban population, and changing food systems, all of which may influence the rising prevalence of obesity. By focusing on Africa, the study addresses the unique socio-economic and public health challenges faced by the region. African countries are in varying stages of economic development, and while some experiencing rapid growth and urbanization, others are still grappling with poverty and undernutrition. As such, the study aims to shed light on how these divergent trajectories affect the prevalence of obesity, particularly in the context of the double burden of malnutrition—where undernutrition and obesity coexist. Notably, the study units consist of African countries analysed within the framework of regional groupings and differentiated by gender for obesity prevalence. Specifically, the study uses data from 46 African nations that meet the criteria for inclusion based on data availability, particularly regarding obesity prevalence and other socio-economic indicators which includes economic growth, trade openness, urbanization, and food production. As already indicated, the sample of African countries utilized are grouped into four regional panels within the Western Africa panel consisting of 16 countries, Eastern panel containing 10 countries whereas the Central and Southern regional panels consist of 8 and 12 countries correspondingly.[2] This classification ensures that the study captures regional variations in obesity trends which are influenced by different levels of economic development, urbanization, trade patterns and food systems. Overall, the study does not focus on individual-level data (such as personal health surveys or household-level surveys) but instead analyses an annual national-level data aggregated by region. This approach allows the study to identify macro-level trends and patterns that are influenced by national policies, economic shifts, and public health interventions. By aggregating the data at the regional level, the study is able to highlight structural and policy-driven factors that contribute to obesity such as trade policies, food production systems and urbanization patterns, which affect large populations across these regions.

Data

This study utilized a panel time series data of African countries which spans from 2000 to 2020. The study utilised strongly balance panel data with no missing values sourced from updated international sources. The main data sources are the World Health Organization (WHO), Global Health Observatory Database and the World Bank Development Indicators (WDI). These sources ensure the reliability and consistency of the data across countries and over time, providing a robust foundation for the analysis. Specifically, the data extracted

[2] The list of countries of each regional panel are provided in Table A1 in the appendix which can be found in the supplementary file.

from the mentioned sources are with respect to the variables which includes, obesity prevalence, economic growth, trade openness, food production and urbanization. To ensure data quality, the data underwent a thorough review by the authors, who cross-checked the variables used to ensure consistency across different time periods and countries. Internal consistency checks were also conducted to confirm that the variables were logically related and that there were no contradictions in data across the countries selected. In terms of tools used for data verification and quality control, statistical software which include STAT 17.0 was employed. This tool enabled us to perform data consistency checks and ensure that the data met the necessary assumptions for dynamic panel data analysis. Furthermore, given the panel nature of the data, additional checks to ensure that the data was suitable for econometric modelling was conducted. These included that testing for stationarity, and cointegration of variables as well conducting cross-sectional dependence test to ensure that the data met the assumptions required for dynamic panel data models. By following these steps for the data verification and employing the appropriate tools, the study ensured that the data used in the analysis was both reliable and robust. This process not only strengthens the credibility of the results but also provides confidence that the findings are based on accurate, well-verified data that is appropriately transformed for the analysis.

Variables description and Measurement

The primary variable of interest is obesity prevalence, which is measured as the percentage of the population aged 18 years and older classified as obese, based on a body mass index (BMI) of 30 or higher. The obesity data is specifically sourced from the WHO Global Health Observatory Database. From the mentioned database from WHO, obesity prevalence is segregated in to three categories: both sexes jointly, then males and females separately. This segmentation allows the study to explore the gender-specific trends, recognizing that men and women may experience different influences due to socio-economic, biological and cultural factors. Economic growth, which is the main exposure variable is measured by gross domestic product (GDP) per capita, adjusted to constant 2015 US dollars to account for inflation. The WDI provides the data for GDP, which is an essential economic indicator for assessing the overall economic development of a country. GDP per capita is GDP divided by the midyear population. It is calculated without making deductions for depreciation of fabricated assets or for depletion of natural resources. GDP per capita reflects the average income of the population and is used in the study to understand the link between income growth and obesity based on the OKC hypothesis. The study further conditioned for additional covariates which includes urbanization, trade openness and food production. Particularly, urbanization is measured in terms of urban population total as provided by the WDI. This measurement reflects the total number of people living in urban areas within a country. Urban areas are typically defined based on national criteria, which can include factors such as population density, infrastructure and administrative boundaries. Urbanization is a key factor in obesity trends because urban areas often feature more sedentary lifestyles, greater access to processed foods and fewer opportunities to physical activity, all of which contribute to higher obesity rates. Further trade openness is measured as the sum of exports and imports of merchandise as a percentage of GDP. The proposition is that, greater trade openness increases the availability of imported, often unhealthy processed foods, which can contribute to rising obesity rates. This variable is particularly relevant in understanding how changes in food systems and global trade agreements can affect the dietary habits of populations. Finally, the study includes food production, measured by the food production index which reflects the total food produced domestically in a country relative to the base period 2014–2016 (with a value of 100). This variable is as well important because, food production influences the availability of food and can affect dietary patterns. An increase in food production, particularly if it leads to the production of calorie-dense foods, could contribute to higher obesity rates, especially in urbanized or economically growing countries.

Summarily, the description of variables together with their respect measurement and data source are outlined in Table 1.

Rationale for variables selection

The selection of variables in this study was guided by multiple theoretical frameworks that provide a comprehensive understanding of the relationship between obesity prevalence and economic growth, as well as the role of urbanization, trade, and food production in shaping the relationship. These frameworks include the OKC hypothesis, urbanization and lifestyle theory, theory of globalization and trade, together with food systems and nutritional transition theory. Each of these frameworks offers insight into how various economic and environmental factors interact with economic growth to influence obesity prevalence. The primary theoretical framework driving the study is the OKC hypothesis, which posits a non-linear (inverted U-shaped) relationship between economic growth and obesity prevalence. According to this hypothesis, as country's economy grows and incomes increases, obesity rates initially rise due to greater access to calorie-dense foods, more sedentary lifestyles and lifestyles changes that often accompany urbanization. However, after a certain level of economic development is reached, obesity rate begins to decline as people adopt healthier lifestyles, diets and behaviors, often driven by better access to healthcare, public health interventions and more opportunities for physical activity. In the context of this study, economic growth was selected to test the central tenet of the OKC hypothesis and explore how increases in economic development correlated with changes in obesity prevalence across the African regional panels employed. By examining this relationship, the study aims to assess whether Africa countries follow the expected pattern of rising obesity rates with increasing income, followed by potential decline as wealthier nations adopt healthier habits.

Moreover, urbanization plays a crucial role in shaping obesity trends and the theory of urban lifestyle transitions are central to understanding how urban environments impact health outcomes. As populations move from rural to urban areas, they undergo a transition from traditional, often more physically active lifestyles to more sedentary behaviors [20]. This shift is accompanied by increased access to processed, energy-dense foods, less physical activity, and lifestyle changes that favour convenience over nutritional value [10],Bixby, 2022). Urbanization is also linked to changes in food availability, with urban areas offering greater access to fast food, processed foods and sugary beverages, all of which contribute to rising obesity rates [27]. The variable urbanization, was thus selected to capture the impact of this lifestyle transition. By analysing how urbanization influences obesity rates, the study seeks to understand the degree to which urban living contributes to the rise of obesity in African nations. Given the rapid urbanization occurring across much of the continent, this variable is critical to understanding how changing living conditions influence health behaviors and outcomes such as obesity.

Further, globalization through trade openness, has transformed food systems globally. Trade openness is related to obesity on the theory of globalization and nutrition transition, which links increased international trade to changes in dietary patterns and lifestyles[28, 58]. As countries open their markets, there is greater availability and accessibility of imported processed food and calorie-dense foods, often at lower costs than locally-produced, nutrient-rich alternatives [25]. Increased trade openness also facilitates the expansion of global food industries, including fast food and sugary beverage companies, which further accelerates dietary changes that contribute to obesity. In African economies, trade openness has significantly transformed food systems, making obesogenic foods more widely available [21]. The study thus aims to understand how these changes relate with economic growth, and other factors like urbanization and food production in driving obesity trends. By incorporating trade openness, the study provides insight into how international trade contribute to obesity beyond local economic growth, emphasizing the need for polices that regulate unhealthy food imports and promote healthier dietary options. Finally, food systems and nutritional transition theory is central to understanding how changes in food production impact obesity trends. The theory suggests that, as countries industrialize and urbanize, they shift from traditional diets that are low in fat and high in fibre to more Westernize diets that are calorie-dense and nutrient-poor. This transition is often accompanied by an increase in consumption of processed foods, sugary beverages, and fats, all of which are linked to rising obesity rates (An et al., 2020). The variable food production was selected to provide insights into the availability of food and the shift in dietary habits. An increase in food production, particularly energy-dense foods, is expected to influence dietary choices and contribute to the rising prevalence of obesity, especially in urban and economically growing regions. By including food production, the study aims to examine the role of national food systems in shaping dietary behaviours and their link to obesity.

Summarily, the combination of the afore-discussed theoretical foundations guided the essence of selecting the study variables (economic, urbanization, trade openness, and food production) to examine how they are related to obesity prevalence in African regions. These theories ensure that the study captures the complexity of obesity trends, considering the role of economic growth, urbanization, trade openness and food production. By using these diverse theoretical perspectives, the study offers a comprehensive analysis of the factors that contribute to the obesity epidemic in African countries, providing valuable insights for policy makers and public health officials seeking to address the rising prevalence of obesity.

Model specification

This study aligns with existing empirical literature by examining the non-linear relationship between obesity and economic growth through the lens of OKC hypothesis proposed by Grecu and Rotthoff (42). Nonetheless, the study extends the traditional framework by modeling the inverted U-shaped relationship between economic growth and obesity while incorporating trade openness, urbanization, and food production into a multivariate context, reducing potential biases from omitted variables. As noted earlier, this study analyzes obesity prevalence based on three distinct groups: obesity prevalence among males, obesity prevalence among females, and the combined prevalence in both sexes. This specific classification enables the study to examine how the relationship between obesity and factors such as economic growth, urbanization, trade openness and food production may differ between the mentioned groupings. Based on this, our suggested augmented OKC multivariate panel models are structured in Eqs. (1a-1c). Specifically, in order to mitigate heterogeneity and heteroskedasticity concerns, the data related to the research variables must be converted into natural logarithms [19, 43, 45, 49, 88].

Econometric analysis

To analyse the non-linear relationship between obesity prevalence and income (economic growth), while accounting for the effect of urbanization, trade openness and food production in a panel setting, the empirical estimation process must involve standard econometric procedures. Specifically, the first step is to conduct a cross-sectional dependence (CD) test on the residuals to determine whether there are potential issues of strong or weak interdependence among the cross-sectional residuals with respect to the cross-sections (countries) within the regional panel employed. Practically, the CD test is essential to identify whether shared factors across countries within a panel influence the results, which is a common issue in panel data involving multiple nations. Thus, the Pesaran [73] PCD-test, the weighted CD (CD_w) test by Juodis and Reese [47], and the power enhanced ($CD_W{}^+$) test by Fan et al. [32] are utilized. The mentioned CD-tests employed assess the null hypothesis of weak cross-sectional dependence. Weak cross-sectional dependence in this case means the correlation between the cross-section units at each point converges to zero as the number of cross-sections goes to infinity.

$$lnOB_{Bi,t} = \alpha_o + \alpha_1 lnGDP_{i,t} + \alpha_2 lnGDP^2{}_{i,t} + \alpha_3 lnURB_{i,t} + \alpha_4 lnTRD_{i,t} + \alpha_5 lnFP_{i,t} + \mu_{i,t} \tag{1a}$$

$$lnOB_{Mi,t} = \beta_o + \beta_1 lnGDP_{i,t} + \beta_2 lnGDP^2{}_{i,t} + \beta_3 lnURB_{i,t} + \beta_4 lnTRD_{i,t} + \beta_5 lnFP_{i,t} + \mu_{i,t} \tag{1b}$$

$$lnOB_{Fi,t} = \theta_o + \theta_1 lnGDP_{i,t} + \theta_2 lnGDP^2{}_{i,t} + \theta_3 lnURB_{i,t} + \theta_4 lnTRD_{i,t} + \theta_5 lnFP_{i,t} + \mu_{i,t} \tag{1c}$$

where $lnOB_B$, $lnOB_M$, $lnOB_F$ represents natural log-transforms of obesity prevalence (both sexes), obesity prevalence (males) and obesity prevalence (females); $lnGDP$, $lnURB$, $lnTRD$, $lnFP$ respectively stands for the natural logarithms of gross domestic product (economic growth), urbanization, trade openness and food production; α_o, β_o and θ_o represent the constant terms in the corresponding equations; $\alpha_i\prime s$, $\beta_i\prime s$ and $\theta_i\prime s$ $(i = 1, \ldots, 5)$, denotes the parameter estimates of the respective explanatory variables; $\mu_{i,t} = \lambda_i + \epsilon_{it}$ symbolizes the idiosyncratic error term assumed to follow the normal distribution with mean of zero and constant variance, $\mu_{i,t} \sim N(0, \sigma^2)$ with λ_i and ϵ_{it} representing individual-specific effects (time-invariant) and idiosyncratic shocks (time-varying).[3]

Notably, transforming the mentioned study variables into natural logarithm help reduce the concerns of heterogeneity and heteroskedasticity by compressing the scale of data. This compression reduces the impact of large values, stabilizing variance across observations. In the case of heteroskedasticity, where the variance of the error term changes with the magnitude of the independent variables, logging makes the relationship more proportional leading to a more constant variance. For heterogeneity, logarithmic transformations improve comparability across units by normalizing skewed data, making relationships easier to mode. This approach is particularly effective in panel and times series data, where variability across units and time can be pronounced.

Second, it is important to test the unit root before operating for further scrutiny. The fundamental purpose of the unit root tests is to clarify the integration order of the incorporated variables. According to Sandusky (2013), unit root tests that assume cross-sectional residual independence can have low power if estimated on data that is characterized by residual cross-sectional dependencies. This study hence utilized the Pooled Modified Sarghan-Bhargava (PMSB) test by Bai and Ng [13], the cross-sectional Augmented Dickey-Fuller (CADF) test together with the Cross-sectional Im, Pesaran, and Shin (CIPS) by Pesaran [72]. The stationarity qualities of the variables are analyzed based on constant via trend in order to exploit potential hidden features such as selecting appropriate methods, understanding relationships, and assuring the stability of variances and covariances. Specifically, each panel unit root test, assumes the null hypothesis that variables are non-stationary against the alternative that the series are stationary across individual panels or units.

[3] The Individual-specific effect (time-invariant), capturing unobserved heterogeneity specific to each cross-sectional unit (e.g., a country) whereas Idiosyncratic shocks (time-varying), representing random shocks or deviations that are not explained by the model.

In the **third phase** of the econometric analysis, we examined the existence of cointegration relationships among the variables utilized in the study using the Westerlund and Edgerton (W-E) (2007) cointegration test and the Durbin-Hausman (D-H) test of cointegration by Westerlund [85]. The W-E test of cointegration deals with four separate panel-cointegration measures which focus on error correction. These measures include the group statistics ($G_\tau andG_\alpha$) which explores the alternate theory of cointegration for the whole group whereas the second type is the panel statistics ($P_\tau andP_\alpha$) which notes that, at least one cross-section of the panel is cointegrated. Comparatively, the D-H cointegration test ensures that independent variables vary in stability ranks. It takes into account two separate test statistics which includes panel statistics (DH_P) and group statistic (DH_G). Notably, both the W-E and D-H panel cointegration methods are based on the null hypothesis of no cointegration as against the alternative hypothesis of cointegration existence. The null hypothesis is thus rejected on the basis that, the group or panel statistics of the mentioned cointegration tests are statistically significant.

Also, slope coefficients, which quantify the elasticities of the explanatory variables, must be examined to determine whether they are homogeneous or heterogenous prior to estimating the existing long-run relationship (cointegration). Thus, at the **fourth stage** of the analysis, Pesaran and Yamagata (P-Y) (2008) homogeneity test is employed. The P-Y test also examines the null hypothesis of homogeneous slopes against an alternative hypothesis of slope heterogeneity using the test values of the delta_tilde $\left(\widetilde{\Delta}\right)$ and adjusted delta_tilde $\left(adj\widetilde{-\Delta}\right)$ adj) statistics which are estimated based on the Swamy (1978) approach. The null hypothesis of slope homogeneity can only be rejected on the basis that the $\widetilde{\Delta}$ and $adj\widetilde{-\Delta}$ are respectively significant.

Finally, a novel proposed estimator known as the Bias-Corrected Method of Moments (BCMM) by [17] is used to estimate the long-run equilibrium relationship among the study variables. Specifically, the BCCM estimator according to Breitung et al., [17] is used for estimating parameters within dynamic panel models with fixed or random effects. The BCCM technique is designed to enhance the accuracy and efficiency of estimates in dynamic panel data models, especially in the presence slope heterogeneity and residual cross-sectional dependence. Specifically, in panel data, units may exhibit different characteristics, leading to unobserved individual-specific effects. Thus, incorporating fixed or random effects to control for unobserved heterogeneity, ensures the estimators remain consistent and unbiased. Additionally, residual cross-sectional dependence arises when error terms across cross-sectional units (countries) are correlated. The BCMM approach accounts for this by using robust standard errors, enabling the model to provide consistent and efficient estimates even when cross-sectional dependence exists. By applying method of moments to estimate the parameters, the BCMM, ensures that, the estimates are both consistent and efficient, converging to the true value as the sample size increase exhibiting the smallest possible variance among unbiased estimators. Consequently, the BCMM improves the reliability of dynamic panel data models, by addressing bias from unobserved heterogeneity and inefficiencies due to residual cross-sectional dependence. Since the BCMM estimator relies on random and fixed effect dynamic panel models for parametric estimations, the study's proposed models (specified in Eq. 1a-1c) are re-specified in the dynamic effect framework as,

$$lnOB_{Bi,t} = \sum_{j=1}^{p} \psi_j lnOB_{Bi,t-j} + \alpha_o + \alpha_1 lnGDP_{i,t} + \alpha_2 lnGDP^2{}_{i,t} + \alpha_3 lnURB_{i,t} + \alpha_4 lnTRD_{i,t} + \alpha_5 lnFd_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{2a}$$

$$lnOB_{Mi,t} = \sum_{j=1}^{p} \delta_j lnOB_{Mi,t-j} + \beta_o + \beta_1 lnGDP_{i,t} + \beta_2 lnGDP^2{}_{i,t} + \beta_3 lnURB_{i,t} + \beta_4 lnTRD_{i,t} + \beta_5 lnFd_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{2b}$$

$$lnOB_{Fi,t} = \sum_{j=1}^{p} \varnothing_j lnOB_{Fi,t-j} + \theta_o + \theta_1 lnGDP_{i,t} + \theta_2 lnGDP^2{}_{i,t} + \theta_3 lnURB_{i,t} + \theta_4 lnTRD_{i,t} + \theta_5 lnFd_{i,t} + \lambda_i + \varepsilon_{i,t} \tag{2c}$$

where,ψ_j δ_j and $\varnothing_j$ are estimates of lagged obesity prevalence in both sexes ($OB_{Bi,t-j}$), lagged obesity prevalence in males ($OB_{Mi,t-j}$) and lagged obesity prevalence in females ($OB_{Fi,t-j}$), λ_i is the individual-specific effect

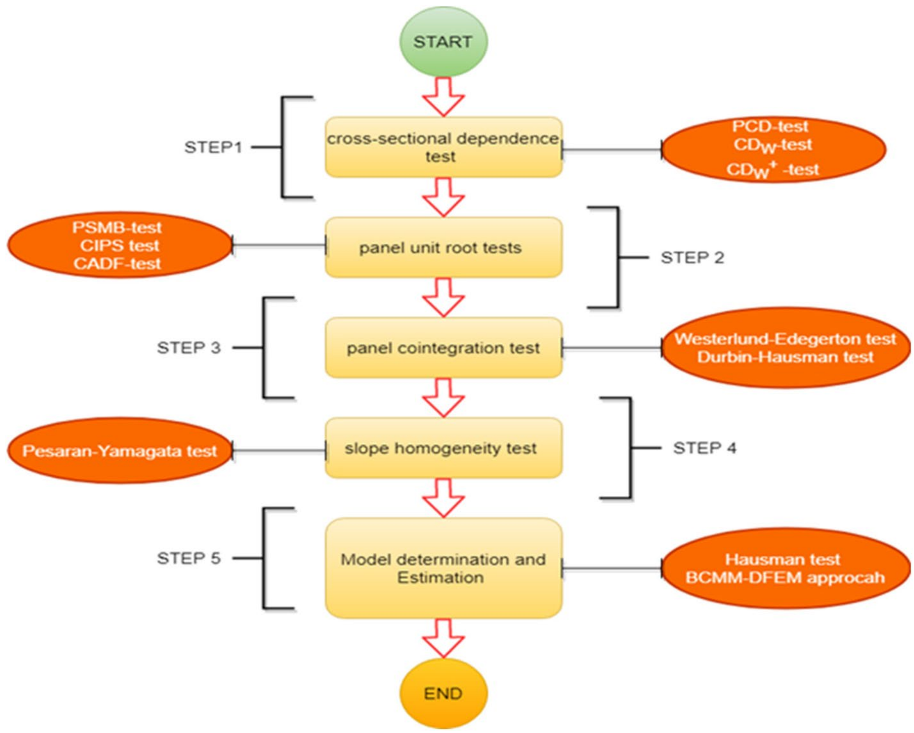

Fig. 2 Methodology flow chart

(time-invariant) and ϵ_{it} is the idiosyncratic shocks (time varying).

Specifically, the GDP coefficient estimate and its square are assumed to be positive and negative, respectively, in order for the OKC **conjecture** to be verified [6, 42], Mathieu-Bolh, 2022; [21]. Accordingly, the positive and negative signs of α_1 and α_2, β_1 and β_2, θ_1 and θ_2 correspondingly will suggest that obesity prevalence increases throughout early development but finally drops once income reaches a certain crucial level. This suggests that before the conundrum concerning the predominance of obesity can be resolved, an economy must reach a certain economic level. In light of Ayidin's (2019) research, the point of economic saturation is therefore calculated through the following with respect to the parameter in each dynamic model:

$$GDP^* = exp\left(\frac{-\alpha_1}{2\alpha_2}\right) \tag{3a}$$

$$GDP^* = exp\left(\frac{-\beta_1}{2\beta_2}\right) \tag{3b}$$

$$GDP^* = exp\left(\frac{-\theta_1}{2\theta_2}\right) \tag{3c}$$

More importantly, the models specified in Eqs. (2a-2c) can either be dynamic fixed or random-effect models depending on λ_i. In dynamic panel data models, where lagged dependent variables are included as regressors,

Table 2 Dynamic Fixed-Effect model estimation (Whole panel Analysis)

Whole panel					
OB_B-Model		OB_M-Model		OB_F-Model	
Variable	**Estimates**	**Variable**	**Estimates**	**Variable**	**Estimates**
Lag- OB_B	0.817 ***	Lag-OBE_M	0.810 ***	Lag- OB_F	0.819 ***
GDP	2.415 ***	GDP	2.518 ***	GDP	2.383 ***
GDP^2	−0.171***	GDP^2	−0.166***	GDP^2	−0.164 ***
FPI	0.189 ***	FPI	0.194***	FPI	0.187 ***
URB	−0.164***	URB	−0.179***	URB	−0.167 ***
TRD	0.054 ***	TRD	0.070 ***	TRD	0.051 ***
OKC hyp	Validated	Validated		Validated	
Peak-point level of GDP	1,166.081	1,967.143		1,429.734	
AR [2]	−0.351	−0.218		−0.394	
F-statistic	230.35 ***	378.870 ***		199.910 ***	

*** represents 1% significance, AR [2] means Arellano-Bond test of second order autocorrelation the choice between fixed and random effects become more critical, as biases can arise due to the endogeneity of the lagged terms. Thus, to confirm which of the dynamic linear models (random or fixed) to rely on in this extant research, the Hausman test is utilized. The Hausman test in this case relies on the hull hypothesis that the dynamic random effect model (DRM) is appropriate, meaning there is no correlation between the individual effect (unobserved heterogeneity) and the explanatory variables against the alternative hypothesis of the dynamic fixed effect model (DFM) being appropriate, meaning there is correlation between the individual effects and the explanatory variables. Notably, the null hypothesis of the Huaman test can only be rejected based on a statistically significant Chi-square statistic between the estimates of the DRM. Summary of the methodology flow chart is illustrated in Fig. 2.

Results

Descriptively, Table A.2 presents summary statistics for the variable utilized in the study. The prevalence of obesity, as well as trade openness, food production, and urbanization, vary greatly with respect to their average values throughout all the panels. Specifically, the aggregated panel averagely recorded a mean value of 8.667% as obesity prevalence for both sexes whereas female obesity prevalence and male obesity prevalence recorded respective average values of 13.092% and 4.339%. Regionally, Southern Africa on average had the highest obesity prevalence in terms of both sexes (12.598%), males (5.018%) and females (19.228%). This gives a clear indication that female obesity prevalence dominates on the African continent, specifically, Southern Africa region. Considering the case of the explanatory variables employed, Southern Africa region again recorded utmost mean value with respect to economic growth (3.45e +10), urbanization (42.215) and trade openness (0.728) while Western region of Africa recorded the maximum mean value of food production (95.446). In terms of normality checks, there is evidence of all variables not following the normal distribution since the Jarque–Bera test values are statistically significant leading to the rejection of the null hypothesis of variables following a normal curve.

Furthermore, results on correlation analysis and multicollinearity check are presented in Fig. 3 and Table A.3 respectively. The correlation analysis specifically shows that urbanization, food production and trade openness are positively correlated with obesity prevalence (both sexes), males obesity prevalence and females' obesity prevalence respectively among all the panel African economies. Nonetheless economic growth is positively related with all categories of obesity prevalence among all the regional panels except Eastern region where negative correlations are evidenced. On the side of the multicollinearity checks, the correlation coefficient among the explanatory variables (economic growth, urbanization, trade, and food production) are respectively less than the threshold of 0.7 with their respective variance inflation factor (VIF) test values all lesser than 10 across individual panels of African regions indicating no issues of multicollinearity. This is supported by the study of Dormman, (2013) and O'Brien, (2007). Further, Fig. 4 provides a geographical pattern of obesity prevalence across the regional panels in Africa. It is obvious that there are significant differences in the frequency of obesity between the regional panels, particularly when it comes to female obesity prevalence and male obesity prevalence. In the African context, it is evident that obesity prevalence in women is greater than in men, especially for countries in Southern and Central Africa where countries like South Africa on average recorded the highest level of obesity prevalence for females (35.1%) than males (11.3%) followed by Gabon also on average with obesity prevalence in females (17.1%) more than obesity prevalence in males (7.1%). Nonetheless, Algeria is characterized by the highest obesity prevalence in males (15.0%) compared to all other African countries.

Based on the econometric analysis, the cross-sectional dependence test results are outlined in Table A4. The results show that, the test values with respect to the PCD-test, weighted CD (CD_w), and the power enhanced ($CD_W{}^+$) test are statistically significant, leading to the rejection of the null hypothesis of weak cross-sectional dependence. This thus, indicates that, there exist issues of strong cross-sectional dependence among the residuals across all utilized panels. Moreover, the findings of the unit root test in the presence of strong cross-sectional residual dependence are presented in Table A5. The outcomes show that, the PMSB, CADF and the CIPS test values are insignificant across all the panels when the variables are at levels indicating the failure to reject the null hypothesis of non-stationarity. Nonetheless, the mentioned unit root tests values are respectively significant when the variables are first differenced leading to the rejection of the null hypothesis. This thus implies that; all the utilized variables have the same order of integration which indicates possible or potential cointegration as attested by Engle and Granger [30]. Further, the results of the panel cointegration tests (W-E and D-H tests) are summarized in Table A6. The cointegration checks unveiled that, the estimated values for the various test statistics ($G_\tau, G_\alpha, P_\tau, P_\alpha, DH_P$, and$DH_G$) are correspondingly significant indicating a strong validation that, there is an existence of cointegration (long-run relationship) among the research variables specified in each

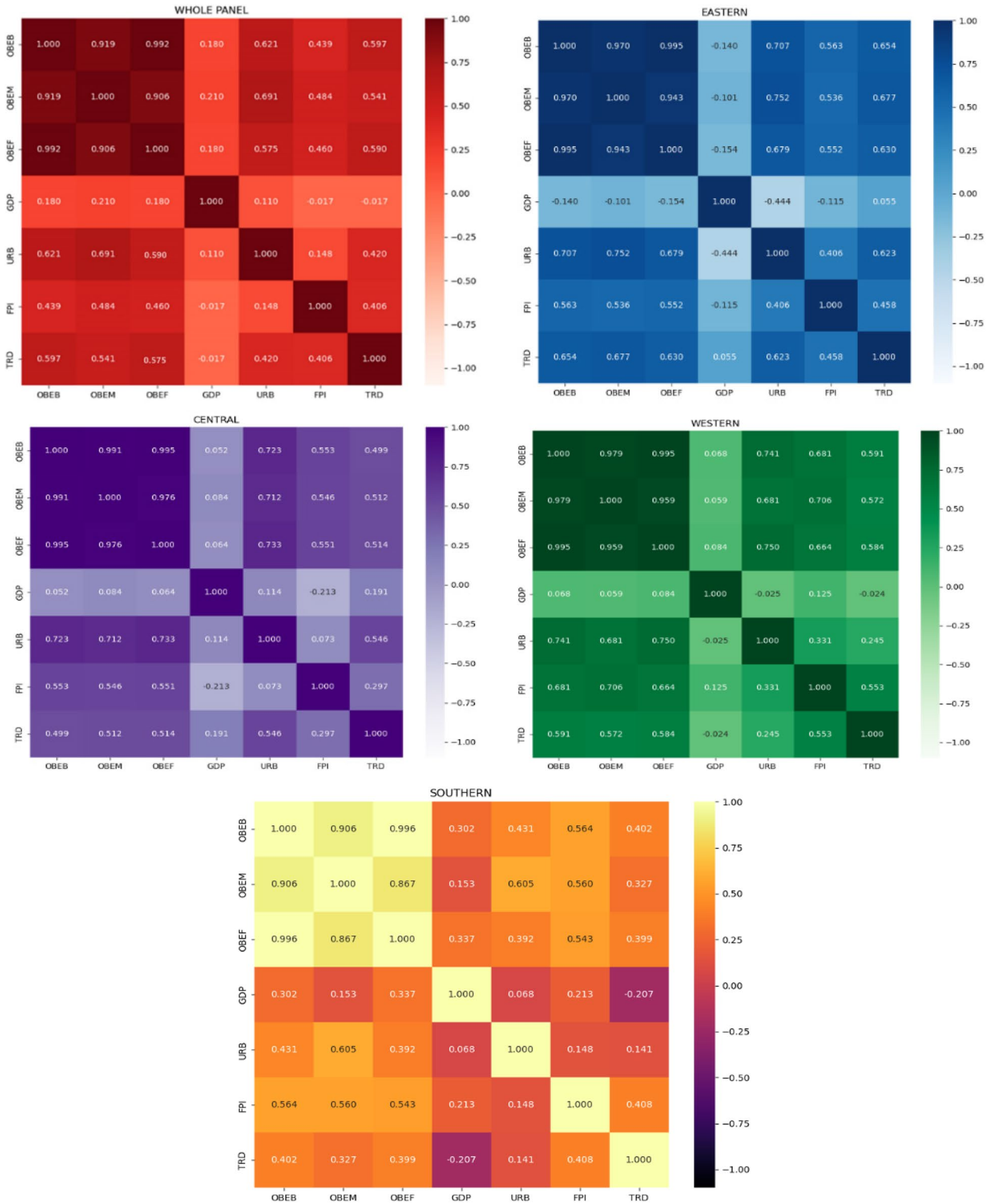

Fig. 3 Heat map correlation matrix among variables

Table 3 Dynamic fixed effect estimation (Regional Analysis)

Eastern Africa					
OB_B-Model		OB_M-Model		OB_F-Model OB_F	
Variable	Estimates	Variable	Estimates	Variable	Estimates
Lag- OB_B	0.788***	Lag- OB_B	0.767 ***	Lag- OB_F	0.789 ***
GDP	−0.569 ***	GDP	−0.552 ***	GDP	−0.494 ***
GDP^2	0.274 ***	GDP^2	0.271 ***	GDP^2	0.238 ***
FPI	0.146 ***	FPI	0.139 ***	FPI	0.148 ***
URB	−0.154 ***	URB	−0.157 ***	URB	−0.165***
TRD	0.067 ***	TRD	0.087 ***	TRD	0.066***
OKC hyp	Not Validated	Not Validated		Not Validated	
AR [2]	−0.573	−0.255		−0.487	
F-statistic	64.790 ***	117.37 ***		49.270 ***	
Western region panel					
OB_B-Model		OB_M-Model		OB_F-Model OB_F	
Variable	Estimates	Variable	Estimates	Variable	Estimates
Lag- OBE_B	0.836 ***	Lag- OBE_B	0.833 ***	Lag- OBE_F	0.834***
GDP	2.327 ***	GDP	2.372 ***	GDP	2.242 ***
GDP^2	−0.198 ***	GDP^2	−0.223***	GDP^2	−0.185***
FPI	0.155 ***	FPI	0.161 ***	FPI	0.157 ***
URB	0.103 ***	URB	−0.117 ***	URB	0.106 ***
TRD	0.055 ***	TRD	0.068 ***	TRD	0.052 ***
OKC hyp	Validated	Validated		Validated	
GDP peak-point level	356.475	204.054		428.144	
AR [2]	−0.236	−0.231		−0.227	
F-statistic	257.400 ***	223.920 ***		225.170 ***	
Central region panel					
OB_B-Model		OB_M-Model		OB_F-Model OB_F	
Variable	Estimates	Variable	Estimates	Variable	Estimates
Lag- OBE_B	0.812 ***	Lag- OBE_B	0.805***	Lag- OBE_F	0.817 ***
GDP	1.268 ***	GDP	1.381 ***	GDP	1.243 ***
GDP^2	−0.116 ***	GDP^2	−0.109 ***	GDP^2	−0.105 ***
FPI	0.147 ***	FPI	0.134 ***	FPI	0.189 ***
URB	−0.133 ***	URB	−0.173 ***	URB	−0.135 ***
TRD	0.049 ***	TRD	0.065 ***	TRD	0.044 ***
OKC hyp	Valid	Valid		Valid	
GDP peak-point level	236.398	563.892		372.372	
AR [2]	−0.086	−0.124		−0.098	
F-statistic	101.930 ***	109.530 ***		103.550 ***	
Southern Africa					
OB_B-Model		OB_M-Model		OB_F-Model OB_F	
Variable	Estimates	Variable	Estimates	Variable	Estimates
Lag- OBE_B	0.8000***	Lag- OBE_B	0.808 ***	Lag- OBE_F	0.805 ***
GDP	2.487***	GDP	2.560 ***	GDP	2.458 ***
GDP^2	−0.185***	GDP^2	−0.172 ***	GDP^2	−0.176 ***
FPI	0.138 ***	FPI	0.146 ***	FPI	0.135 ***
URB	0.052 ***	URB	0.103 ***	URB	−0.036 **
TRD	0.054***	TRD	0.077 ***	TRD	0.050 ***
OKC hyp	Valid	Valid		Valid	
GDP peak-point level	830.163	1,705.921		1,078.099	
AR [2]	−0.046	0.052		−0.219	
F-statistic	109.160***	95.720 ***		105.95 ***	

*** and ** represents 1% and 5% level of significance, AR [2] means Arellano-Bond test of second order autocorrelation obesity prevalence models across all panels. Moreover, the P-Y slope homogeneity test outcomes as outlined in Table A.7 disclose statistically significant $\widetilde{\Delta}$ and $\widetilde{adj-\Delta}$ -test values which give strong evidence to reject the null hypothesis of slope homogeneity. This thus implies that there exists heterogeneity among the slopes of the variables (economic growth, urbanization, trade openness and food production) specified in each obesity prevalence model. Additionally, findings from the Hausman test (Table A8) provides significant Chi-square test values concerning each obesity model across all study panels. This implies the null hypothesis of the obesity prevalence models being dynamic random effect models needs to be rejected. It can therefore be concluded that, the obesity prevalence models are rather dynamic fixed effect models.

With the evidence of cross-sectional dependence, together with stationary, cointegrated and slope heterogenous variables, Table 2 and Table 3 presents the summary of the estimation results of the dynamic fixed effect models using BCMM estimator. Results for the entire panel (Table 2) indicate that for the prevalence of obesity in all individuals (both sexes), men and females, respectively, the coefficients of economic growth and its square are significantly positive and negative. This finding provides compelling evidence of an inverse U-shaped link between the prevalence of obesity and per capita income, when the sexes are combined and separated respectively. The findings also indicate that men anticipated peak income levels are greater than those of women. Further, except urbanization, it is evident that the conditioned variables economic growth, food production, and trade openness have positive relationships with the prevalence of obesity for both sexes, males and females separately. Unwaveringly, the aforementioned factors lead to a greater rise in obesity in African men compared to women. Moreover, the estimates of the lags concerning both sexes obesity prevalence, male obesity prevalence and female obesity prevalence are respectively positive and statistically significant.

Results from Table 3, are partly consistent and partly varies from the whole panel analysis. For instance, in Western, Central and Southern Africa, the OKC conjecture is validated except Eastern Africa, meaning in the former regions (Western, Central and Southern Africa), income-obesity nexus exhibits upturned U-shapes. Comparably, the peak-output level of economic growth is higher for males than females in Central and Southern Africa. For Western Africa, it is the opposite where the peak-income level for females is rather more than males. Pondering on the regions characterized by the OKC hypothesis, Southern Africa recorded the highest GDP peak level for both sexes, males and females correspondingly. Our predicted peak-income levels under the BCMM-dynamic fixed effect may not be exact and should only be used as a guide because the peak-output levels described heavily rely on the empirical techniques used and the model assumptions. Further, except Eastern Africa, GDP is seen to enhance obesity prevalence in males, females and both sexes respectively in Western, Central and Southern regions. Specifically, the level of obesity prevalence heightening from GDP is higher in males than females concerning the mentioned regions. Similarly, trade openness and obesity prevalence in males, females and both sexes are respectively characterized by positive estimates across the regional panels. Interestingly, varying findings are obtained in the case of urbanization and food production in their respective connections with obesity prevalence in males, females and both sexes correspondingly. For instance, though food production is seen to increase obesity prevalence in all classifications, the impact is higher from the side of females than males in Eastern and Central Africa whereas in situation is vice versa in the case of Southern and Western Africa nations. Moreover, urbanization is as well evidenced in Eastern and Central Africa to have negative associations with male obesity prevalence, female obesity prevalence, and obesity prevalence in both sexes distinctly whereas Western and Southern Africa portrayed a different picture. Particularly, in Western Africa, urbanization leads to surge in obesity prevalence in both sexes and females but from the side of males a declination effect is marked whereas for Southern Africa, the aforesaid variable increases obesity prevalence in both sexes and that of males but minimizes the prevalence in females. Similarly, the lags of male obesity prevalence, female obesity prevalence together with that of obesity prevalence in both sexes are respectively positive and significant across all the regional panels.

Summarily, the outcomes from the AR [2] and F-statistics post-estimations tests, shows a strong indication of fitness in the estimated dynamic fixed-effect models for each panel that make use of the novel BCMM estimator. Specifically, the results from AR [2] indicate that the null hypothesis of no second-order autocorrelation is not rejected, as the p-values for the respective AR [2] test values are insignificant across all models of obesity prevalence in each panel. This implies that there is no evidence of second-order autocorrelation in the residuals, confirming the cogency of the dynamic specification. Thus, the AR [2] results support the adequacy of the model structure in capturing the relationship between obesity prevalence and the explanatory variables. Also, the F-statistic tests the joint significance of the model's explanatory variables. The results reveal highly significant F-statistics indicating that the explanatory

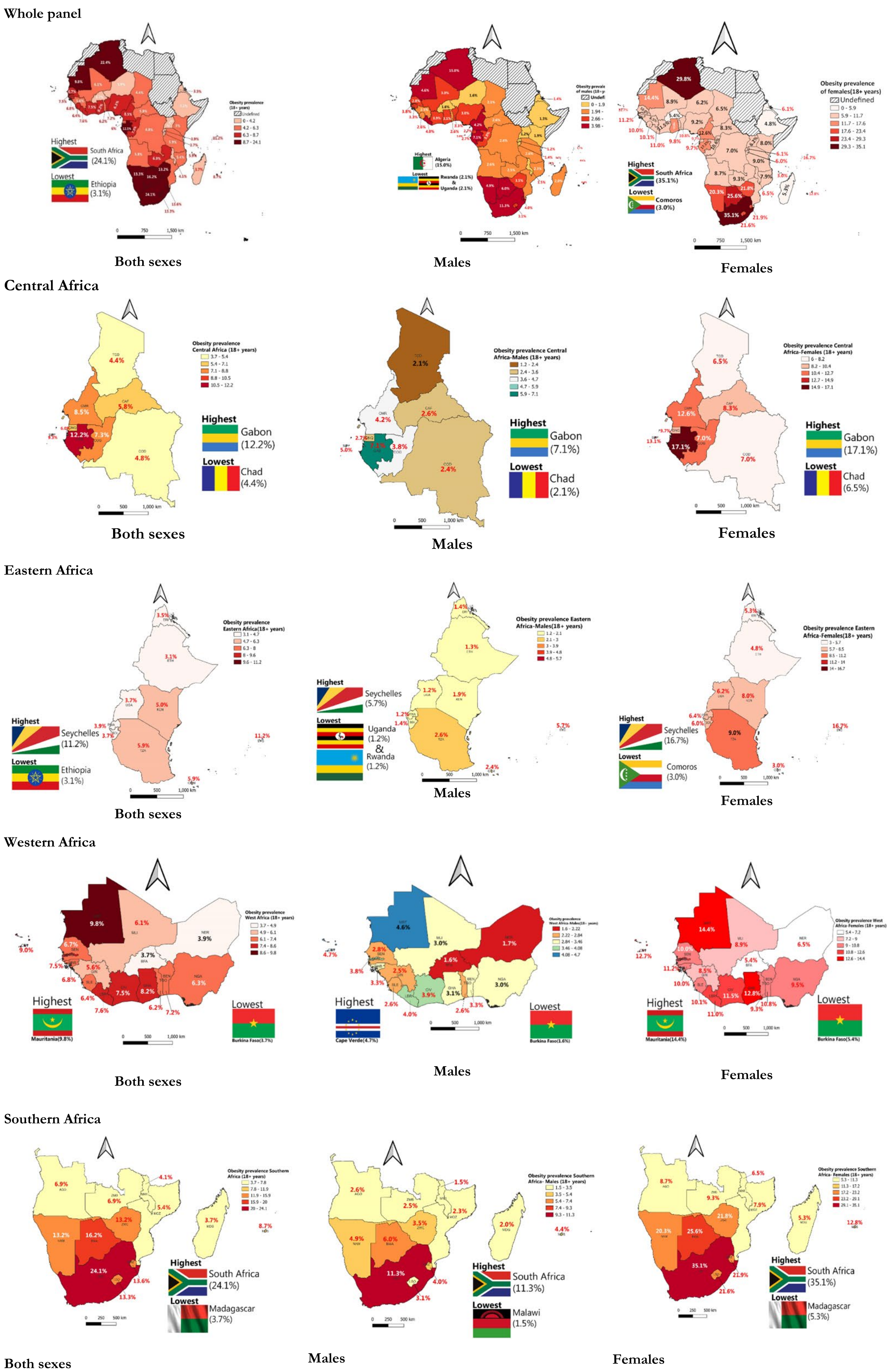

Fig. 4 Geographical distribution of obesity prevalence (2000–2020)

variables collectively explain substantial variations concerning obesity prevalence in males, females, and both sexes respectively across all panels. This thus suggests that, the models have a good overall fit and that the chosen variables which include economic growth, urbanization, trade openness and food production are relevant and meaningful predictors of obesity prevalence in males, females, or both sexes. In swift, the AR [2] together with the F-statistics results validate the reliability of the panel dynamic models estimated.

Considering the fact that there are some variations in results from the estimated obesity prevalence dynamic effect models from one regional panel to the other, a set of sensitivity analyses was further conducted to test the robustness of the validity of our findings across the specified models and covariate specification. These include the white noise test for residual using the panel Ljung-Box test together with the generalized method of moments (GMM). The results of the white noise test for residuals are thus summarized in Table A9. Based on the results of the white noise test for each obesity prevalence model, it was evident that all residuals are white noise which are independent and identically distributed (iid $(0, \sigma^2)$). This means the null hypothesis concerning the set of residuals being (iid)$(0, \sigma^2)$ or white noise was not rejected in each case since the white noise estimated values were statistically insignificant among the models for each panel of African countries. This thus suggests that our regression estimation results from the dynamic fixed effect models via the BCMM estimator are unbiased, consistent, and not spurious. In order to further test the robustness of our estimates an alternation estimation approach (GMM) is as well employed. The results from the GMM method (Ref. Table A10) interestingly are consistent with the main estimation outcomes though the estimated coefficients pertaining to the respective explanatory variables (economic growth, urbanization, trade openness and food production) varied in weights and significant levels. The GMM method also comes with AR [2] test of second-order autocorrelation and a Sargan post-estimation test of over-identification restrictions which indicates that all the estimated proposed panel models in the study show good signs of model fitness across all the utilized panels of African countries. Overall, this gives a corollary that the results obtained from estimating the proposed obesity prevalence dynamic fixed effect models via the BCMM method is accurate and reliable.

Discussions

The assertion that various factors have a significant impact on the diversity of obesity prevalence among nations has been examined in this current research. This study evaluated the nonlinear correlation between obesity prevalence and economic growth with the focus on the OKC hypothesis whiles considering the influence of urbanization, food production, and trade openness. Specifically, this research relied on the sex and gender based regional analysis to assess the OKC hypothesis using a panel data from African countries. The results revealed a distinct trend of an inverted U-shaped relationship between income and obesity prevalence in males, females and both sexes distinctly, across regional panels except the Eastern regional group. Essentially, this suggests that an upsurge in income prompts individuals in Africa, particularly in Central, Western, and Southern regions, to consume excess nutrients due to economic advancement during the initial phases of a nation's economic progress. Consequently, individuals in these African sectors tend to increase their caloric intake as they can financially afford more food, resulting in weight gain and eventually obesity. However, when a certain income threshold is attained, consistent with the OKC hypothesis, dietary habits shift towards a more balanced and healthier diets as purchasing power grows and health awareness increases. At this juncture, individuals exhibit a heightened awareness of health issues and a greater willingness to invest in personal well-being, ultimately leading to a decline in the prevalence of obesity. These findings are consistent with the research conducted by Go et al. [39], Öcal and Ergeç [69]), and Chen et al. [21]. As already indicated, only Eastern Africa exhibits a U-shaped relationship amid income and obesity prevalence in males, females and both sexes separately. In essence, this outcome in Eastern Africa is contrary to the OKC hypothesis where obesity rates are expected to rise to with increasing income during initial developmental stages of countries and then decline at higher income levels. The finding is intriguing because it indicates that economic growth in Eastern Africa might not be leading to the expected health benefits associated with higher incomes, such as improved access to healthy foods and better healthcare. In alignment with the research by Talukdar et al., [83], countries within the Eastern region are characterised by a condition where at lower income levels, economic growth initially leads to decline obesity rates, but as income rise beyond a certain point, dietary changes associated with economic development contribute to subsequent increase in obesity prevalence. This indicates that Eastern Africa is at an earlier stage of this dynamic, where rising income have not yet led to an anticipated plateau in obesity rates.

Moreover, the geographical pattern analysis on obesity prevalence carried out on the entire panel and the regional panels indicates variations in the pattern of obesity prevalence, with females exhibiting higher levels of obesity compared to males. This finding is supported by studies of Benli et al., [15] and Khan et al., [50]. However, the critical OKC threshold for males consistently exceeds that of females across the whole, Central, and Southern panels. This suggests that as countries in these regions develop economically, women tend to reach peak obesity levels earlier in the development process than men. Essentially, despite entering the obesity cycle sooner, females also tend to exit it earlier due to rising incomes. Consistent with the research of Benli et al., [15], this phenomenon may be attributed to the fact that women, with increasing incomes, place a higher priority on their health compared to men. Furthermore, males and females encounter distinct social pressures related to body image. Given that females are more likely to face societal pressures regarding obesity, their concerns about obesity prevalence are relatively pronounced (Costa-Font and Hernandez-Quevedo, 2018). Even when having similar body weights, females tend to strive harder to maintain a slimmer physique due to dissatisfaction with their weight [87]. Interestingly, Western Africa deviates from this trend, with the OKC income peak favouring females over males. This finding is noteworthy in OKC literature, particularly within the African context concerning gender disparities. It is plausible that women in Western Africa prioritize caregiving and household duties over personal health, leading to higher obesity rates among women at higher income levels compared to men.

Furthermore, the influence of economic growth on the prevalence of obesity shows that, prevalence of obesity in males, female and both sexes correspondingly rise with income across various regional panels, except for the Eastern region. This observation implies that, as income rise for individuals in Africa, particularly in Central, Western and Southern regions, their dietary habits initially increase in quantity and shift towards less healthy options, such calorie-dense processed foods, contributing to higher obesity prevalence [6]. This assertion is corroborated by Fernald [33], who noted that in developing nations, a larger body size is sometimes preferred due to its association with authority, attractiveness, and wealth. Notably, economic growth contributes more to the increase in obesity prevalence among males compared to females. This trend may be linked to the fact that economic growth often results in shifts in occupational structures. Consequently, men may be more inclined to take on sedentary roles as economies evolve, leading to higher obesity prevalence. Conversely, women might still be involved in physically demanding household chores or informal sector jobs that require greater physical exertion. Our findings align with the research of You and Henneberg [90] and Pisa and Pisa [76]. In the context of Eastern Africa, the study also uncovered evidence that at higher income levels, economic growth has begun to exhibit a negative relationship with obesity prevalence in males, females and both sexes respectively, which is consistent with the later stage of the U-shaped relationship where obesity rates initially decrease with rising income. This trend suggests that, in some areas or countries in Eastern Africa, rising income may eventually lead to a reduction in obesity rates, potentially due to improved access to healthier foods, better healthcare, and implementation of effective public health interventions [84].

Similarly, trade openness combined with gender-specific factors has been shown to be a noteworthy contributor to the increase in obesity prevalence ceteris paribus [9, 62]. This indicates that countries participating in free trade generally allow the import of foreign goods including processed and unhealthy foods, which can lead to dietary habits and contribute to higher obesity rates. For example, numerous African nations have endorsed a trade pact known as the African Continental Free Trade Area (AfCFTA), which aims to broaden economic activities, lessen dependence on exported goods, and enhance regional trade. Nevertheless, many African countries still heavily depend on imports from Western nations without considering the health implications for their populations [35],African Export–Import Bank (AFREXIMBANK), 2022). Fox et al. [34] highlighted that the trade agreements between African economies and Western countries have intensified the interest of individuals (both males and females) in Western dietary habits, influencing their preferences and increasing the demand for unhealthy food items, consequently leading to a high prevalence of obesity. Further, this research uncovers a complex connexion between urbanization and obesity prevalence in males, females and both sexes respectively across various African regions.

In Eastern and Central Africa, urbanization was linked to a negative relationship with obesity prevalence among all classifications, indicating that residing in urban areas in these regions might contribute to lower obesity levels. This suggests that urbanization could result in better health outcomes by providing improved access to healthcare services, varied food choices, and increased physical activity facilitated by urban infrastructure [71]. This finding, diverging from patterns in other sub-regions, underscores the complex context-dependent nature of health dynamic. This inverse relationship may also rise from synergistic factors unique to these regions, such as urban infrastructure that promotes physical activity through walkable layouts, accessible public transit, and green spaces, as seen in cities like Kigali, and Addis Ababa, where active commuting remains prevalent despite urban growth [98]. Additionally stronger ties to traditional food systems persist in these areas, with urban markets prioritizing fresh, locally sourced produce over processed alternatives —a trend documented in Kenya, where dietary diversity remains higher in urban compared to rural populations [99, 100]. Improved healthcare access to cities likely amplifies these benefits, enabling preventive care and nutritional education that mitigate obesity risks [100].

Moreover, the observed regional disparities in the relationship between urbanization and obesity prevalence across Western and Southern Africa, with contrasting gender-specific trends, underscore the multifaceted interplay of socio-cultural, economic and environmental factors shaping health outcomes in urbanizing contexts. In Western Africa, the positive association between urbanization and obesity prevalence in females, juxtaposed with a negative connexion in males, may reflect deeply rooted gender norms and occupational dynamics. Urban environments in this region often channel women into sedentary informal sector roles (for example petty trading or domestic work) while simultaneously exposing them with energy-dense processed foods through increasingly Westernized urban food markets [94]. Conversely, men in urban Western Africa may retain higher levels of occupational physical activity in sectors like construction or transportation, mitigating obesity risks (Ofori-Asenso et al., 2016). Additionally, cultural perceptions linking females body weight to socio-economic status or marital desirability may exacerbate dietary choices favouring caloric surplus among women [93]. In the Southern Africa, the inverse pattern — higher male obesity prevalence in urban area—can be attributed to the distinct structural and behavioural shifts. Urbanization in this region is often linked to male-dominated employment in formal sectors such as mining and manufacturing, which, despite providing economic stability, tend to encourage sedentary lifestyles (Steyn an Mchiza, 2014). Simultaneously, urban food environments in Southern Africa are characterized by men due to gendered dietary norms and social practices (Sodjinou et al., 2015). On the other hand, women in urban Southern Africa, meanwhile, may exhibit lower obesity rates due to higher participation in informal physical activities and stronger societal pressures toward weight management rooted in media-driven beauty standards [95]. These divergent trends are further complicated by regional variations in nutrition. Western Africa's urbanization has coincided with partial retention of traditional diets (for example fibre-rich staples like millet and sorghum), which may buffer men against obesogenic dietary shifts, whereas Southern Africa's longer history of urbanization has entered reliance on refined carbohydrates and fats [92]. Additionally, gendered access to resource plays a role: in Western Africa, women's limited control over household income may restrict their ability to purchase healthier foods, pushing them toward cheaper, calorie-dense alternatives [55]. In dissimilarity, Southern African men's higher disposable income in urban settings may facilitate greater consumption of obesogenic goods like sugary beverages and fast food, a pattern corroborated by studies linking economic empowerment to dietary shifts in urban males [61].

Furthermore, the relationship between food production and the prevalence of obesity was found to be positive across the entire panel and regional panels of Africa. This observation aligns with the findings of Go et al. [39], suggesting that an increase in food production may contribute to a rise in obesity rates. Our results are also in accordance with the research conducted by Poti et al. [78], indicating a direct link between the prevalence of obesity and food availability. Poti et al. [78] also noted the shift from traditional diets based on natural, unprocessed foods to modern diets centered around industrially processed food items. As a result of intricate processing techniques, alterations occur in the food structure and nutritional composition of the processed food. Specifically, the production of food items high in sugar and saturated fat has contributed to the issue of obesity in various regions of Africa. Moreover, the increase in food production improves food accessibility, potentially influencing dietary patterns. This shift, as suggested by Hall [44], offers a plausible explanation for the prevalence of obesity observed in Africa. Despite the existence of a positive relationship between food production and obesity prevalence across different demographics, the impact of the former on the latter is more pronounced in males compared to females in the overall population, as well as in Western and Southern Africa. Conversely, in Eastern and Central Africa, the situation is reversed. Based on the research conducted by Gebre and colleagues (2021), the observed disparity in gender representation may stem from disparities in the distribution of food within households, as well as cultural and societal beliefs regarding body image, and divergent reactions to the rise in food accessibility, coupled with the marketing tactics and advertising approaches employed by food manufacturers targeting both male and female populations across various African regions.

Notably, the finding that lagged estimates of obesity prevalence —for males, females and both sexes together —exhibit statistically significant positive associations with current obesity prevalence across all African regions underscores the persistence and path dependency of obesity as a public health challenge. This suggests that obesity trends in Africa regardless of the region, are not merely transient but are deeply embedded in structural and behavioural feedback loop, where historical prevalence reinforces current outcomes. For instance, once obesogenic environments, characterized by sedentary lifestyles, reliance on energy-dense processed foods, and reduced physical activity become attached, they create self-perpetuating cycles. Urbanization-driven shifts in dietary habits, such as increased consumption of imported ultra-processed foods, may establish long-term dietary norms that propagate obesity across generation. The regional consistency of this finding as well highlights the universality of obesogenic drivers across Africa's diverse contexts, despite variations in economic development or urbanization rates. The significance of the lagged effects also implies that interventions targeting obesity must account for temporal lags between policy implementations and observable outcomes.

The findings discussed in this study highlight critical intersections between economic growth, urbanization, trade, and food systems in shaping obesity trends, with significant implications for global health and Sustainable Development Goals (SDGs). Unlike prior works, which often centered on high-income nations or generalized findings across Africa, this research situates obesity with Africa's unique socio-economic transitions and introduces regional and gender-specific analysis. This nuanced approach enriches the global health theory by validating the OKC hypothesis in most African regions while challenging its applicability in others like Eastern Africa, where developmental trajectories diverge. Globally, the study advances the understanding of obesity as a systematic issue linked to macroeconomic factors rather than individual behaviors alone. It extends the discourse on trade liberalization or openness by demonstrating how the influx of processed foods into developing nations exacerbates obesity, a concern echoed in studies from other low- and middle-income countries. As well the integration of food production as a determinant underscore the broader role of the industrialized food system in driving dietary transitions, aligning with global findings but offering new insight specific to Africa's agriculture and economic landscape. In terms of policy contributions, the study advocates for structural interventions such as taxing ultra-processed foods, subsidizing healthy local procedures and integrating health objectives into urban planning. These recommendations align with the SDG3 (good health and well-being) and SDG2 (zero hunger) by addressing non-communicable diseases and the double burden of malnutrition. Summarily, the study advances global health frameworks by emphasizing the importance of context-specific, equity-driven policies that address structural drivers of health inequalities, offering a blueprint for integrated strategies in addressing obesity and related non-communicable diseases globally.

Conclusion and Policy recommendations

The global epidemic of obesity has been identified as a widespread disease, albeit with significant variations between nations. Africa, in particular, is grappling with an escalating obesity issue. This research conducted an analysis on the relationship between economic development and obesity prevalence within an OKC framework, considering the impact of urbanization, trade, and food production. Utilizing a dataset of 46 African countries sub-grouped into regional panels spanning from 2000 to 2020, a range of insightful findings emerged through the application of panel econometric methodologies that account for robust cross-sectional residual dependence and heterogeneity. The results of the analysis demonstrated a consistent trend of OKC across all regional panels, with a focus on gender disparities. Additionally, the conditioned impacts of trade openness, urbanization, and food production on the prevalence of obesity in men and women exhibited varying intriguing results among regional panels. The findings from this study provide several important policy recommendations for public health policymaking regarding obesity prevention efforts across Africa.

In Western, Central, and Southern Africa, the inverted U-shaped relationship between income and obesity prevalence underscores the need for stage-specific interventions. Policymakers should aim to mitigate the initial rise in obesity during early stages of economic growth and promote healthier lifestyles as incomes increase. To achieve this, governments could implement progressive taxes on ultra-processed foods and sugar-sweetened beverages, with revenues directed toward subsidizing fresh produce and supporting local farmers to increase the availability of affordable, nutritious foods. Such measures, as supported by Kaltenbrun et al. [48] and Popkin et al. [77] can result in coherent strategies aimed at reducing ultra-processed food consumption and encouraging healthier dietary habits.

In Eastern Africa, where a U-shaped relationship between income and obesity prevalence was observed, both extremely high and very low levels of economic development are linked to higher obesity rates. This highlights the importance of addressing the double burden of malnutrition (both undernutrition and obesity), focusing on preventing undernutrition while promoting balanced diets. Policymakers should emphasize the significance of maintaining a healthy diet even amidst the growing availability of processed foods and the shift toward more sedentary lifestyles.

The study also revealed notable gender disparities in obesity prevalence across regions. For instance, in

Western Africa, the obesity-income curve peaks higher for females than males, whereas the opposite trend is observed in Central and Southern Africa. In light of this, policymakers must ensure that healthcare services tailored to the unique needs of men and women are accessible and culturally appropriate. Specific strategies could include providing peer-support opportunities such as community-based fitness programs, sports teams, and support groups that encourage healthier lifestyles. For example, men in Central and Southern Africa and women in Western Africa should be empowered to improve their health through programs designed to foster engagement and motivation.

The mixed effects of urbanization on obesity prevalence also offer both challenges and opportunities for policymakers. In Eastern and Central Africa, where urbanization was associated with lower obesity rates, efforts should focus on preserving and enhancing aspects of urban living that promote healthy outcomes. This could involve improving access to diverse food options, health services, and urban infrastructure that encourages physical activity, such as pedestrian-friendly areas and recreational spaces. Conversely, in Western and Southern Africa, where urbanization had mixed effects on obesity prevalence depending on gender, targeted interventions are needed to address gender-specific challenges. Policymakers should promote active lifestyles and healthy eating habits, taking into account gendered occupational patterns and the unique challenges faced by men and women in urban settings.

The study also raises concerns about the impact of trade openness on obesity. Trade liberalization has increased the availability of ultra-processed and calorie-dense foods, contributing to rising obesity rates in Africa. Policymakers must monitor and regulate unhealthy food imports while encouraging the production and availability of healthier, locally produced foods. Public awareness campaigns should be launched to educate communities about the health risks associated with processed foods and to promote nutrition literacy.

Finally, the relationship between food production and obesity prevalence highlights the need for policies that promote not just increased food production, but also the availability of healthier food options. Governments should incentivize farmers to grow diverse, nutrient-rich crops and support local food production systems. Additionally, regulatory policies should encourage traditional diets and limit gender-specific advertising of unhealthy food products. Targeted efforts should focus on encouraging men in Western and Southern Africa to adopt healthier dietary practices and portion control, while promoting better nutrition education for women in these regions.

Aligning these recommendations with global development goals, such as SDG 3 (Good Health and Well-being) and SDG 2 (Zero Hunger), can enable policymakers to tackle obesity-related health challenges in African nations more effectively.

Limitations and Future Research Directions

While this study provides critical insights in the Obesity Kuznets Curve (OKC) hypothesis and its interplay with macroeconomic factors which includes urbanization, trade openness and food production, across African regions, several limitations must be acknowledged and guide future research. First, the analysis is constrained by selection bias stemming from the exclusion of countries with insufficient or inconsistent data, particularly in Northern Africa. This omission limits the representativeness of the findings, as excluded nations may exhibit unique socio-economic or cultural dynamics influencing obesity trends. For instance, Northern African countries, which often share Mediterranean dietary patterns and distinct urbanization trajectories, could alter regional comparisons if included. Second, the reliance on national-level aggregated data obscures subnational heterogeneity, such as disparities between urban and rural areas or variations across socio-economic strata. For instance, obesity driver in Lagos, Nigeria —a megacity with advanced food retail systems —may differ markedly from rural Nigeria, where traditional diets and physical labour persist. However, the regional panel approach aggregates these contexts, potentially masking critical localized dynamics.

Methodologically, while the novel BCMM estimator addresses residual cross-section dependence and heterogeneity, its assumptions —such as linearity in dynamic relationships, may not fully capture the complex, non-linear interactions between urbanization, cultural norms, and dietary transitions. For example, the model assumes uniform lag effects of past obesity prevalence across regions, yet behavioural responses to economic growth (example, dietary shifts) may vary non-linearly depending on education levels or health literacy, factors not explicitly modelled. Additionally, the use of percentage of the population aged 18 years and older are classified as obese, based on a body mass index (BMI) of 30 or higher as the sole obesity metric overlooks nuances in body composition and health risks. African populations often exhibit higher lean muscle mass and lower visceral fat at similar BMI levels compared to Western populations, potentially underestimating metabolic risks or over diagnosing obesity in certain demographics. Data limitations further constrain the analysis. Reliance on WHO and World Bank databases introduces potential inaccuracies, as obesity prevalence in low-source settings is frequently unreported due to fragmented health systems. For instance, rural areas with limited healthcare access may lack systematic BMI monitoring skewing urban-centric estimates. Similarly, food production indices prioritize caloric output over nutritional quality, failing to distinguish between nutrient-dense staples and processed commodities —a critical gap given the role of ultra processed foods in Africa's nutrition transition. The 20-year study period, while sufficient for capturing macroeconomic trends, may inadequately reflect long-term generational shifts in dietary habits or the delayed health impacts of obesogenic environments.

Contextual factors further complicate generalizability. Africa's demographic and economic transitions —such as urbanization rates exceeds 4% annually in countries like Tanzania —create evolving dynamics that static panel models may not fully encapsulate. Political instability for instance in Sudan or the DR Congo, disrupts data continuity, while cultural perceptions of body weight —such as the association of female adiposity with wealth in West Africa —introduce unmeasured confounders. Furthermore, the study's focus on macroeconomic variables neglects micro-level determinants, including genetic predispositions, intra-household food allocation, or marketing practice targeting gender-specific consumption patterns. For example, in Southern Africa, aggressive advertising of sugary beverages to men in mining communities may exacerbate obesity prevalence independently of broader trade policies. Finally, the temporal mismatch between independent variables (for example annual GDP growth) and obesity outcomes —which often manifest over decades —may obscure causal pathways. The OKC framework assumes immediate behavioural responses to income changes, yet lifestyle adaptations (for instance, reduced physical activity) may lag behind economic shifts. Similarly, the analysis does not account for time varying confounders like global food price fluctuations or climate-related agricultural shocks, which disproportionately affect African food systems.

The limitations identified in this research underscores the need for future research to adopt more nuanced and context-sensitive approaches to understanding obesity dynamics in Africa. Building on the methodological and data constraints highlighted, subsequent investigations should prioritize disaggregated data collection strategies that capture subnational, gender-specific, and ethnic variations in obesity prevalence. For instance, urban–rural disparities within countries like Nigeria —where megacities such a Lagos exhibit vastly different dietary and lifestyle patterns compared to rural hinterlands —warrant granular analysis to uncover localized drivers to obesity. Integrating mixed-method approaches could further enrich macroeconomic models by incorporating qualitative insights, such as community-level perceptions of body image or intra-household food allocation practices, which are often obscured in aggregated datasets. Expanding the geographical scope to include Northern African nations, would address regional gaps and enable cross-regional comparisons that account for Mediterranean dietary influences or distinct urbanization trajectories. Additionally, moving from BMI as the sole obesity metric to include alternative indicators like body fat percentage could better reflect metabolic risks in African populations, where body composition often diverges from Western norms. Finally, the gap between macro-level economic factors and micro-level determinants —such as targeted food marketing practices or generic predispositions —would provide a more holistic understanding of obesity drivers. By addressing these limitations, further research can generate actionable insights that align with Africa's unique socio-cultural and developmental contexts while advancing global health equity.

Supplementary Information

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Supplementary Material 1

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Authors contributions
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Data availability

The datasets used in the study are publicly available can be extracted from; The datasets used in the study are publicly available can be extracted from; •World Bank Development Indicators (https://databank.worldbank.org/source/world-development-indicators) • World Health Organization Health Observatory Database (https://aho.afro.who.int/ind/af?ind=21&dim=100&dom=Cardiovascular%20disease%20across%20NCDs&cc=af&ci=1&cn=Afro%20Region).
• World Bank Development Indicators (https://databank.worldbank.org/source/world-development-indicators)
• World Health Organization Health Observatory Database (https://aho.afro.who.int/ind/af?ind=21&dim=100&dom=Cardiovascular%20disease%20across%20NCDs&cc=af&ci=1&cn=Afro%20Region).

Declarations

Ethics approval and consent to participate

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Consent for publication

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Competing interest

The authors declare no competing interests.

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