The Health Economics of Obesity in Adult Populations in Ghana

by

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Statement of originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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We the undersigned agree with the above stated “proportion of work undertaken” for each of the above published (or submitted) peer-reviewed manuscripts contributing to this thesis:

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Statement of ethical conduct

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

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Andrew J. Palmer (Primary Supervisor)

Abstract

Background: Obesity, a known risk factor for non-communicable diseases, reduces quality-adjusted life years (QALYs) and life expectancy (LE), predicts all-cause mortality and imposes a high economic burden. Overweight and obesity have become epidemic in most regions of the world, including Ghana. Compared with other sub-Saharan African countries, the rapid transition toward an ageing population in Ghana makes it particularly vulnerable to the increased burden caused by an associated rise in the prevalence of obesity. Although epidemiological studies aid understanding of the distribution and determinants of obesity and inform prevention and intervention programs aimed at reducing the impact of obesity, questions on which programs should be funded using scarce health care resources remain unanswered. The application of health economics allows the prevention and intervention programs that represent best value for money to be identified. In Ghana, there are no data on the health economics of obesity. Therefore, this thesis examined the health economics of obesity in the Ghanaian population, particularly among older adults. The specific objectives of this thesis were:

1. to determine the prevalence and factors associated with obesity in the adult population;
2. to determine the prevalence of obesity at two time-points in older adults from 2007 to 2015;
3. to derive age- and sex-specific health state utilities (HSUs) and HSUs stratified by body mass index (BMI) status in the adult population;
4. to examine the associations between health services utilization and direct healthcare costs as a function of BMI status in the older adult population;
5. to estimate annual transition probabilities between healthy weight, overweight and obese in the older adult population; and

6. to quantify the long-term impact of overweight and obesity on remaining LE, years of life lost (YLL), QALYs and total direct healthcare costs in the older adult population.

Methods: Ghanaian data from the World health Organization (WHO) Study on global AGEing and adult health (SAGE) Wave 1 (2007/08, n=5573) and Wave 2 (2014/15, n=4735) were used. SAGE is a study on the health and well-being of the older adult populations aged ≥50 years that includes a smaller sample of adults aged 18–49 years. SAGE collected individual-level data using a stratified, multistage cluster design. Adult population was defined as those who were 18 years and above while older adult population was defined as those 50 years and above.

Results: At Wave 2, the prevalence of overweight was 25%, obesity was 13% and underweight was 7% in the adult population. In the seven years between SAGE Wave 1 and Wave 2, the prevalence of overweight increased by 25% from 20% in Wave 1 to 25% in Wave 2 and obesity prevalence increased by 47% from 10% in Wave 1 to 15% in Wave 2 among the older adults. Being female, having high socioeconomic status, or low physical activity were associated with higher odds of overweight and obesity. HSUs were negatively associated with obesity. Overweight and obesity were associated with additional health service utilization and healthcare costs. Findings in study five showed that the annual transition probability was 4.0% (95% CI: 3.4%, 4.8%) from healthy weight to overweight, and 4.9% (95% CI: 3.8%, 6.2%) from overweight to obesity; and the chances of remaining obese were higher especially among female. Using estimates from aims one to four as input parameters for Markov modelling in aim six, overweight and obesity were found to reduce the average remaining LE and QALYs while increasing direct healthcare costs and YLL.

Conclusion: These findings suggest that the prevalence of overweight and obesity has increased in the population; that overweight and obesity impose substantial health and economic burden in Ghana's older adults. Therefore, urgent sustainable and cost-effective interventions are needed to control and prevent overweight and obesity in Ghana.

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This thesis is based on the following original publications:

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2. Stella T. Lartey, Costan G. Magnussen, Lei Si, Godfred O. Boateng, Barbara de Graaff, Richard Berko Biritwum, Nadia Minicuci, Paul Kowal, Leigh Blizzard and Andrew J. Palmer. Rapidly increasing prevalence of overweight and obesity in older Ghanaian adults from 2007-2015: evidence from WHO-SAGE Waves 1 & 2. *PLoS ONE* 14(8): e0215045. August 2019.
3. Stella T. Lartey, Lei Si, Barbara de Graaff, Costan G. Magnussen, Hasnat Ahmad, Julie Campbell, Richard Berko Biritwum, Nadia Minicuci, Paul Kowal and Andrew J. Palmer. Evaluation of the association between health state utilities and obesity in sub-Saharan Africa: Evidence from WHO Study on global AGEing and Adult Health Wave 2. *Value in Health*. 2019; 22(9):1042–1049. September 2019.
4. Stella T. Lartey, Barbara de Graaff, Costan G. Magnussen, Godfred O. Boateng, Moses Aikins, Nadia Minicuci, Paul Kowal, Lei Si and Andrew J. Palmer. Health service utilization and direct healthcare costs associated with obesity in older adult population in Ghana. *Health Policy and Planning. 2019: czz147: 1–11*

5. Stella T. Lartey, Lei Si, Petr Otahal, Barbara de Graaff, Godfred O. Boateng, Richard Berko Biritwum, Nadia Minicuci, Paul Kowal, Costan G. Magnussen, and Andrew J. Palmer. Probabilities of changing between healthy weight, overweight, and obesity in older adults: the WHO SAGE older adults longitudinal study. *Social Science and Medicine*. 2020; 247(112821): 1-9.

List of Conference Presentations Arising from this Thesis

International

1. 2019 International Health Economics Association. Basel, Switzerland. "Obesity Is Associated with Increased Health Service Utilization and Direct Healthcare Costs in Older Adult Population in Ghana." (Oral presentation).

2. 2019 American Association of Public Health. Philadelphia, PA, USA. "Health service utilization and direct healthcare costs associated with obesity in older adult population in Ghana." (Oral and Poster presentation).

3. 2019 American Association of Public Health. Philadelphia, PA, USA. "Changes in the prevalence of obesity in older Ghanaian adults from 2007-2015: evidence from WHO-SAGE Waves 1 & 2." (Oral presentation).

4. 2018 International Society for Pharmacoeconomics and Outcomes Research (ISPOR) ASIA Conference, Tokyo, Japan. "Evaluation of the association between health state utilities and obesity in sub-Saharan Africa: Evidence from WHO Study on global AGEing and adult health (SAGE)." (Poster presentation).

National

5. 2018 Australian Health Economics Society (AHES), Hobart, Australia. "Determine the effects of high BMIs (overweight and obesity using healthy BMI

as a comparator) on health care utilization and health care cost.” (Oral presentation).

6. 2017 Graduate Research Conference, University of Tasmania, Hobart, Australia. “Prevalence and socio-correlates of Obesity in Ghana.” (Poster presentation).

Awards Resulting from the Thesis

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September 2018 College of Health and Medicine Graduate Research Conference and Research Travel Award, 2018.

September 2018 Semi-finalist best abstract award, 2018 International Society for Pharmacoeconomics and Outcomes Research (ISPOR) Asia.

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Abbreviations

BMI	Body Mass Index
CEA	Cost-effectiveness analysis
CLAD	Censored Least Absolute Deviation Model
CPI	Consumer price index
CUA	Cost-utility analyses
DALYs	Disability-adjusted life-years
FAO	Food and Agriculture Organization
FCUBE	Free Compulsory Universal Basic Education
G-DRG	Ghana Diagnosis Related Groupings
GHS	Ghana Cedis
GLLAMM	Generalized Latent Linear and Mixed Model
GPAQ	Global Physical Activity Questionnaire
HALYs	Health-adjusted life years
HRQoL	Health-related quality of life
HSUs	Health state utilities
HYE	Healthy years equivalent
ICC	Intra Class Correlation
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
IRR	Incidence rate ratios
ISPOR	International Society for Pharmacoeconomics and Outcomes Research
JSS	Junior High School
LE	Life expectancy

LMICs	Low-and middle-income countries
MET	Metabolic equivalents of task
NCDs	Non-communicable diseases
NHIA	National Health Insurance Authority
NHIS	National Health Insurance Scheme
OOP	Out-of-pocket
QALYs	Quality-adjusted life-years
SAGE	Study on Global AGEing and Adult Health
SES	Socioeconomic status
SHS	Senior high School
SSNIT	Social Security and National Insurance Trust
SSS	Senior Secondary School
WHO	World Health Organization
WHOQOL	World Health Organization Quality-of-Life
YLL	Years of life lost

Terminology Box

Term	Definition [1, 2]
Asymmetric information	Circumstances in which buyers and sellers have different levels of information.
Externality	The uncompensated, beneficial effect on a third person caused by the actions of a market. In relations to an intervention, it occurs as a result of the actions of first adopters of an intervention.
Moral hazard	The rational response to economic incentives as a result of price elasticity of demand. For example, this occurs when an individual increases their exposure to risk when they are insured.
Opportunity costs	The value of what is given up when a choice or decision is made, including the best foregone alternative.
Marginal analysis	Encompasses trading off the incremental costs against the incremental benefits at the margin; thus, the individual is considered as a rational economic agent who makes decisions at the margins.
Cost-effectiveness analysis	A type of economic evaluation in which the net costs of an intervention are compared with the benefits that arise as a consequence of applying that intervention using a single natural unit. The natural unit mostly refers to the primary clinical outcome measure for the interventions being compared.
Cost-utility analysis	A special form of cost-effectiveness analysis that introduces measures of benefit/effectiveness that reflect individuals' preferences over the health consequences of alternative interventions that affect them.
Cost-benefit analysis	A type of health economic evaluation in which the net costs of an intervention are compared with the benefits that arise as a consequence of applying that intervention measured in monetary units.

1 Introduction

1.1 Introduction to obesity

Obesity is medically defined as “a state of increased body weight, more specifically adipose tissue of sufficient magnitude to produce adverse health consequences” [3]. This aligns with the World Health Organization (WHO) definition of both overweight and obesity as “abnormal or excessive fat accumulation that may impair health” [4]. Overweight and obesity result from an imbalance between calorie intake and expenditure; and are commonly categorised based on body mass index (BMI). BMI is an index commonly used to classify adult overweight and obesity and defined as a person’s weight in kilograms divided by the square of his height in meters (kg/m^2) [4]. The WHO and National Institute of Health (NIH) classify BMI into the following: underweight- BMI $< 18.5 kg/m^2$; normal weight- 18.5 -24.9 kg/m^2; overweight- BMI 25.0-29.9kg/m^2; and obesity- BMI $\geq 30.0 kg/m^2$ [4, 5].

Since 1980, the prevalence of obesity has doubled and continues to significantly increase among adults in most parts of the world including sub-Saharan Africa [6-10]. In 2015, global adult obesity prevalence stood at 603.7 million [9]. A major challenge for most low-and middle-income countries (LMICs) in sub-Saharan Africa is that while the prevalence of overweight and obesity is rapidly increasing, it is co-existing with underweight [11, 12]. In Ghana, the prevalence of obesity in the general population has been rising steadily from as low as 0.9% in the 1980s to approximately 14 % in 2003 [11, 13, 14]. Increasing prevalence of obesity from 1980 to 2014 among individuals aged 15-49 years has been well-documented in Ghana [11, 15]. The Ghana Demographic and Health Surveys reported an increasing prevalence of obesity from 3.4% to 15.3% among Ghanaian women aged 15–49 years from 1993 to 2014 [11, 15, 16]. Based on the evidence of increasing obesity prevalence in those aged 15-49, the Ministry of Health identify the need to reduce obesity by 2% in this age group within five years starting from 2008 [17].

Obesity is one of the leading risk factors for non-communicable diseases (NCDs) and has become a major global health concern [9]. It is known to increase the risk of type 2 diabetes mellitus, hypertension, dyslipidaemia, osteoarthritis, gallbladder disease, strokes, cancers, heart attacks, obstructive sleep apnoea as well as overall mortality [18-22]. Thus, obesity substantially increases morbidity, disability and mortality, and poses significant economic burden on populations [6, 9, 23]. Aside from the strong associations between obesity and NCDs, obesity has also been associated with poor mental health especially among women [24, 25], poor school achievement and employment prospects, and suboptimal productivity [26, 27]. The combination of increasing prevalence of obesity, difficulties associated with its management [28], associated health challenges and cost burden, [7, 8, 10] presents major challenges to households, clinicians and especially, health policy decision makers when they allocate resources to prevent, manage or treat obesity [29] and obesity-related morbidities and disabilities [30]. An additional potential challenge for most low- and middle-income countries (LMICs) is the findings that underweight, overweight and obesity are regarded as risk factors for NCDs [11, 31, 32]. This is because increasing prevalence of obesity may co-exist with overweight and may contribute to an increased burden of NCDs.

Ghana is one of the LMICs in Africa experiencing both an ageing population transition and increasing obesity prevalence [8, 11, 33]. Ageing population transition, increasing obesity prevalence and longer life expectancy in Ghana are likely to have a combined effect which may lead to an increase in the prevalence of NCDs especially in older adults [6, 8, 33-35]. The ageing population transition is as a result of improved public health systems, faster fertility transitions, and increased life expectancy [33]. In the next 25 years, Ghana is projected to be one of the LMICs that will have higher numbers of old people [33]. Population growth and ageing transition are also closely associated with nutritional and epidemiological transition [36]. The increasing obesity prevalence has been attributed to increasing adoption of Western diets, lower physical activity, and the cultural promotion of obesity as an expression of beauty and affluence [37-39]. Thus, there is likely to be an ongoing increase in risk factors like obesity and a growing disease burden from NCDs [6], which is quite a shift from the usual communicable diseases mostly documented in Ghana [11]. In recent times, the prevalence of NCDs including type 2 diabetes and hypertension were reported to be increasing in Ghana [40-44]. A shift towards a growing burden of NCDs or a double burden of NCDs and communicable diseases will require health systems, policies and operational preparedness to meet these challenges. However, the lack of evidence of whether the country is experiencing an entire shift towards a growing burden of NCDs or a double burden of NCDs and communicable diseases means planning and preparedness activities are very challenging. As overweight and obesity are associated with increasing health and economic burden, increasing prevalence in most LMICs requires deliberate attention, and proactive and pragmatic actions to curb it.

In contrast to the evidence of increasing obesity prevalence in those aged 15-49 years, little is known about the trends in prevalence of obesity among populations of older adults aged 50 years and above in the Ghanaian population. However, the ageing and nutrition epidemiological transition, increasing obesity and NCDs prevalence may palpably affect the older adult population [11, 35]. Of note, the health and productivity of those aged 50 years and above is as vital as for the younger age groups, as they are also workers, taxpayers, business owners and mentors of younger colleagues. Furthermore, they form the majority of the labour force for agricultural productivity that is a key sector for sustainable development and poverty reduction in Ghana [45]. Besides, they are also consumers in the larger economy.

As preventing or controlling obesity in populations can be resource-intensive, monitoring trends and identifying factors that relate to obesity provide essential information that allows sustainable interventions to be appropriately and effectively targeted [46, 47]. However, such data on obesity among older adults are lacking in Ghana. Thus, the overarching aim of this thesis is to examine the health economics of obesity in the Ghanaian population, particularly among older adults. Through this thesis, I have generated the necessary evidence and developed a health economic obesity model for the older adult population in Ghana.

1.2 Ghana in context

Located in the west of sub-Saharan Africa, Ghana has a population of approximately 30 million people. Between the 1980s and 1990s, the total fertility rate fell significantly and has since stalled at around four children per woman in the last few years [48]. The fertility rate is projected to be three children per woman by 2035 and two children per woman by 2045 [49]. However, fertility rates remains higher in the northern regions compared to the Greater Accra Region, and urban residents who form approximately 57% of the total population, want fewer children than rural residents. Even though 57% of the total population are less than 25 years old, the reduced fertility rate has increased Ghana's proportion of elderly persons [48]. In addition, increased life expectancy since 1990 has also contributed to this trend [48, 49]. The proportion of persons aged 60+ is among the highest in sub-Saharan Africa [48-50]. Increased life expectancy has been attributed to improved health care, nutrition and hygiene, and overall economic conditions. Significant strides in economic development have contributed to improve household's economic circumstances. About 45% of the population in the Ghanaian labour force are engaged in agriculture, 25% in industry and 41% in the service sector. There are several ethnic groups in Ghana but predominantly 48% are Akans, 17% are Mole-Dagbon, 14% Ewes and 7% are Ga-Dangme. There are more than 30 spoken languages in Ghana.

1.3 Economics of public health

Economics applied to public health encompasses the allocation of scarce public resources to meet public health needs whilst ensuring value for money [2, 51, 52]. The processes and activities involved in economics of public health are considered as both the science and art that supports decision making. Policy makers have often had to deal with prioritizing resources due to scarcity of resource, but this has become more important in recent times due to international economic downturns. Therefore, as resources become increasingly scarce, much stronger evidence for investment into public health initiatives is required [53, 54]. More than ever, public health economics has been projected to the forefront in healthcare as governments and institutions have recognised health economic evaluations can lead to more efficient healthcare spending and increased sustainability of implemented programs [55]. Apart from using evidence from public health economics in decision making, it can also be used to ensure equity in health care. It is well-documented that inequalities exist in most human activities including health and healthcare [53, 54]. Rather than focus on economics of public health, this thesis focuses on health economics which utilizes concepts and methods from economics to understand and describe how people make decisions regarding health behaviours and use of health care [2, 56].

1.4 Introduction to health economics

Health economics is the study of issues related to scarcity, efficiency and effectiveness of health resource allocation, and the supply and demand of health and healthcare. Health economics draws on principles from welfare economics, agency theory, econometrics, and development economics [57, 58]. Kenneth Arrow's paper entitled "Uncertainty and the welfare economics of medical care" published in 1963 has been recognised as the major article that commenced the birth and creation of the health economics discipline [59]. In his paper, Arrow discusses how the operations of the 'medical-care industry and the efficacy with which it satisfies the society' differs from the norms of general economics [59]. The norms of general economics are based on the principles of competitive model. However, in the medical-care industry, he identified key distinguishing factors to include the extensive government interventions, asymmetric information, externalities and moral hazard. Health economics as a discipline has become important in the general economy due to the increasing size and budget of the health sector, increasing health consumer concerns resulting from the importance people attached to the economic problems encountered when seeking and maintaining their health, and the substantial economic elements attached to healthcare and healthcare industry [2].

Resources are generally scarce. Therefore, in meeting healthcare needs, planners, providers, consumers and those who pay for healthcare face a barrage of questions since choosing one course of action over another has consequences on health and healthcare resources with some spillover beyond healthcare [1]. The anticipated effects require a careful consideration of costs and benefits of the alternative actions. The evaluation using a systematic analysis of alternatives before a final decision is made on a choice action is called economic evaluation. Economic evaluations provide evidence of costs, benefits and effects of alternative course of actions to inform decision making in healthcare. Among others, they support the identification of clear relevant alternatives and increase the explicitness and accountability in decision making [1].

Economic evaluation provides evidence to inform decision making in health care [1]. As resources are scarce, we expect decision makers to be rational economic agents who reason at the margins. Drummond et al described two key features of economic evaluations. The first feature deals with inputs and outputs, thus costs and consequences of alternative actions [1]. Costs include both the explicit and the implicit (opportunity costs) costs. The consequences describe the benefits or otherwise of the course of action. Just like mainstream economics, health economic analysis uses reasoning at the margins and therefore includes incremental costs and benefits at the margin which constitute marginal analysis [2].

While identifying and measuring the type of costs is similar across most economic evaluations, the nature of the consequences (mostly benefits) differ and depends on alternative course of actions under examination. Thus, depending on the nature of consequences, there are different forms of economic evaluations. Three commonly used techniques in health economic evaluation are the cost-benefit analysis (CBA), cost-effectiveness (CEA) and cost-utility (CUA). While in all three types of economic evaluations the net costs of an intervention are compared with the benefits that arise as a consequence of applying that intervention, the unit for measuring benefits differ. CBA values benefits using monetary units, CEA uses a single natural unit and CUA measures of benefits that reflect individuals' preferences over the health consequences of alternative interventions that affect them.

The second feature focuses on choices due to scarcity of resources. Key players in health are faced with a range of outputs, each one of which has costs and consequences for which they must make a choice. Thus, economic evaluations establishes and uses explicit and systematic analysis to provide evidence to support prioritization and decision making which provides "value for money" among alternative choices. Economic evaluations requires that the costs and consequences of two or more alternatives are under consideration, and models are developed to characterize or depict the reality. As models are often abstract but must be representative of the reality, the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) recommends the use of locally driven input parameters to perform economic evaluations when available [60]. Such input parameters include costs, outcome measures such as disability-adjusted life-years (DALYs) or quality-adjusted life years (QALY- estimated from health state utilities (HSUs)), incidence or prevalence (if it is disease or risk factor), transition probabilities, etc. Models constructed for economic evaluations are first validated to ensure they depict the reality [61, 62].

Beside economic evaluations developed models can be used to predict the long-term impact of diseases or risk factor with results from this used for planning. To achieve the Universal Health Coverage (UHC) and other health objectives in the Sustainable Development Goal (SDG) 3, most countries including Ghana have identified the need to improve the quality and efficiency in its healthcare services to provide fair and equitable access to health [44, 63]. The overall aim of the SDG is to transform the world by 2030 through sustainable development. The SDG on health is the third of 17 goals and has nine objectives with 13 targets underpinning the broader health goal. SDG 3 aims at ensuring healthy lives and promoting well-being at all ages because it considers that health affects all facets of life [63]. This was built on the backdrop of targets from the Millennium Development Goals on health. However, the SDG 3 incorporates new targets on NCDs, mental health, substance abuse, injuries, UHC, health impact from hazardous chemicals, water and soil pollution and contamination, and the implementation of the WHO Framework Convention on Tobacco Control (WHO FCTC) [9, 63]. Nevertheless, the lack of the necessary parameters in most LMICs including Ghana, have been a major challenge hindering the course of conducting health economic evaluations [64] and measuring the achievement of SDG 3, hence the need to develop this evidence.

1.5 Evidence of long-term economic and health impact from obesity through health economic modelling

Development and evaluation of policies for the management and control of NCDs and their risk factors like obesity can be a complex process and poses a significant challenge as they impose short, medium and long term health and economic effects [65, 66]. While most studies are limited by time and therefore can provide evidence of short- to medium-term effects of NCDs and their risk factors, economic modelling is a method that can be used to provide estimates of likely long-term effects [1, 66]. Estimating the long-term effects of overweight and obesity are necessary to identify major differences in sub-populations, inform the development of and correctly target obesity preventive and control strategies, and allocation of health resources [67]. Constructing and validating a health economic model could form the basis for cost-effectiveness analysis (CEA) which is an essential tool and a common method used to develop and evaluate healthcare interventions. This method provides a broader context in which to make judgements about the value for money of using a intervention/drug for a particular health outcome. Constructing and validating a health economic model for obesity in Ghana requires the estimation of key parameters mostly from the population. Such parameters include establishing the incidence or prevalence of obesity, calculating BMI-specific health state utilities, costs and mortality rates.

Since results from modelling are used to inform health care decisions and resource allocation in specific populations, it is important that the parameters used are developed from the same or very similar population [68]. This is because circumstances like economic or political conditions, and how populations value their health differ. Economics and health systems differ in different countries; therefore, using parameters such as BMI-specific costs from different countries in economic evaluation and using the results to inform local health care decisions and resource allocation might lead to choosing unaffordable, inaccessible and unsustainable interventions.

1.6 Data Source for this thesis

Data from the World Health Organization's (WHO) 2007/8 (Wave 1) and 2014/15 (Wave 2) Study on global AGEing and adult health (WHO SAGE) were mostly used. WHO-SAGE is a study on the health and well-being of adult populations aged 50 years and older in six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa [69]. In Ghana, trained SAGE teams collected individual-level data from nationally representative households of adults using a stratified, multistage cluster design. The sampling method used in both 2007/08 and 2014/15 was based on the SAGE Wave 0 (2003) in which the primary sampling units were stratified by region and locality (urban/rural) [70, 71]. Data collected in 2007/08 had 5573 and 2014/15 had a total of 4735 survey respondents. Various aspects of the data (cross sectional or longitudinal) were explored depending on the objective for analysis. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). Further information on WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

This thesis utilizes both responses from the individual and the household questionnaire. The individual questionnaire responses used in the study covers the following domains: socio-demographic characteristics, work history and benefits; health state descriptions; anthropometrics, performance tests and biomarkers; risk factors and preventive health behaviour; chronic conditions and health services coverage; health care utilization; social cohesion; subjective well-being and quality of life; impact of caregiver; and the interviewer's assessment. The household questionnaire responses used include housing characteristics, assets and household income. The final samples for each analysis were determined after missing and biologically implausible weight, height and waist circumference measurements were excluded. Biologically implausible values were height <100cm or >250 cm, weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm [72, 73].

1.7 Justification for studies in this thesis

Globally, increasing prevalence of risk factors for NCDs such as obesity is a major concern particularly for older age groups [9]. This is likely to pose a major problem as the management of NCDs is more challenging in LMICs [35]. As an ageing population, Ghana is likely to experience an increasing burden of NCDs as the country is concurrently experiencing ageing, nutritional and epidemiological transitions [6, 11]. For the most part, epidemiological studies have provided insight on the distribution and determinants of obesity in Ghana but most of these studies neglected the older adult population. To some extent, they have proposed weight reduction intervention programs mostly in young adults [11, 15, 17, 74]. Notwithstanding, questions on which interventions represents best and real value for money remain unanswered.

Ghana in recent years has identified the need to improve the quality and efficiency in its healthcare services to be able to achieve Universal Health Coverage and the United Nation's Sustainable Development Goal 3 on health [63]. However, some of the parameters required for economic evaluations are lacking in Ghana. With the application of epidemiological methods and health economics tools, the necessary parameters can be developed. These parameters in turn can be used to develop a health economic model to identify strategies that represent best value for money. The paucity of information on obesity in the older adult population and the lack of systematic data on health economics of obesity convolutes the development of any cost-effective interventions. Therefore, through this PhD I systematically generate health economic parameters and apply the data to develop health economic model which can be used for economic evaluations. Thus, this thesis aimed to examine the health economics of obesity in the Ghanaian population, particularly among older adults. I used the outlined aims to generate the necessary parameters and develops a health economic obesity model for the older adult population.

1.8 Objectives of this thesis

The specific objectives of this thesis were to:

1. determine the current prevalence of obesity and the associations between current and lifetime markers of socioeconomic status and body mass index categories (underweight, healthy weight, overweight, obese) and central adiposity in Ghanaian adults;
2. examine recent changes in obesity prevalence and associated factors among older adults in Ghana between 2007/08 and 2014/15;
3. estimate age- and sex-specific health state utilities for Ghana, along with health state utilities (HSUs) by weight status; and examined the associations between HSUs and overweight and obesity;
4. examine the associations between health services utilization as well as direct healthcare costs and overweight and obesity among older adults;
5. estimated annual transition probabilities between three body mass index categories: healthy weight, overweight and obesity among older adults aged ≥50 years in Ghana to be used in future modelling studies; and
6. construct and validate a health economic model and use it to quantify the long-term impact of overweight and obesity on remaining life expectancy, quality-adjusted life years and total direct healthcare costs.

1.9 Structure of this thesis

Chapter 1 provides a background and justification for this study.

Chapters 2-4 are published and chapters 5-7 are under review. The outline of Chapters 2-7 follow the format of the peer-review journals in which the paper has been published or under review.

Chapter 2 presents the prevalence of obesity validated by measures of central adiposity in the general population. It also presents the associations between current and lifetime markers of SES and BMI categories and central adiposity in the population.

Chapter 3 focuses on the older adult population and presents findings on trends and factors associated with overweight and obesity in this population using the most current data.

Chapter 4 presents the first estimated age- and sex-specific health state utilities (HSUs) for Ghana, alongside with HSUs by weight status. It also presents the associations between HSUs and overweight and obesity

Chapter 5 provides estimates of health services usage and direct health care costs associated with overweight and obesity in the older adult population.

Chapter 6 presents the results for estimated annual transition probabilities between three body mass index (BMI) categories: healthy weight, overweight and obesity among older adults aged ≥50 years in Ghana, to be used in future modelling studies.

Chapter 7 describes the construction and validation of a new model for predicting the long-term impact of overweight and obesity using adults aged 50 years as the base case. This paper presents the remaining life expectancy, years of life lost, QALYs and direct healthcare costs of overweight and obesity in the population.

Chapter 8 summarises and discusses major findings presented in this thesis and the policy implications of the findings. It makes comments regarding the future research in this area.

2 The prevalence of obesity and the associations between current and lifetime markers of socioeconomic status (SES) and body mass index (BMI) categories (underweight, healthy weight, overweight, obese) and central adiposity in Ghanaian adults.

2.1 Preface

The most recently estimated prevalence of overweight and obesity was conducted only among those 15-49 years hence was not fully representative of the adult Ghanaian population [15]. This chapter presents a study in which measured weight, height and waist circumference taken in 2014/15 for those aged 18 years and above were used to estimate the prevalence of overweight and obesity. Characteristics of overweight and obesity may be the same in both high and low income countries but those affected may not follow typical socioeconomic status (SES)-related gradients seen in higher income countries. Thus, the study aimed to estimate the current prevalence of overweight and obesity in the adult population of Ghana. It also examined the associations between current and lifetime markers of SES and four body mass index (BMI) categories (underweight, healthy weight, overweight, obese) and central adiposity in Ghanaian adults.

The following text in this chapter has been published in PLoS One (Appendix 1).

Lartey, S.T., Magnussen, C.G., Lei, S., de Graff, B., Biritwum, R.B., Mensah, G., Yawson, A., Minicuci, N., Kowal, P., Boateng, G.O., & Palmer, A (2019). The role of intergenerational educational mobility and household wealth in adult obesity:

Evidence from wave 2 of WHO Study on Global Ageing and Adult Health. *PLoS ONE, 14*(1), e0208491.

2.2 Abstract

Background: Obesity has emerged as a major risk factor for non-communicable diseases in low and middle-income countries but may not follow typical socioeconomic status (SES)-related gradients seen in higher income countries.

Objective: To examine the associations between current and lifetime markers of SES and body mass index (BMI) categories (underweight, healthy weight, overweight, obese) and central adiposity in Ghanaian adults.

Methods: Data from 4,464 adults (2,610 women) who participated in the World Health Organization's Study on global AGEing and adult health Wave 2 were examined. Multilevel multinomial and binomial logistic regression models were used to examine associations. SES markers included parental education, individual education, intergenerational educational mobility and household wealth. Intergenerational educational mobility was classified: stable-low (low parental and low individual education), stable-high (high parental and high individual education), upwardly (low parental and high individual education), or downwardly mobile (high parental and low individual education).

Results: The prevalence of obesity (12.9%) exceeded the prevalence of underweight (7.2%) in the population. High parental and individual education were significantly associated with higher odds of obesity and central adiposity in women. Compared to the stable low pattern, stable high (obesity: OR=3.15; 95% CI: 1.96, 5.05; central adiposity: OR=1.75; 95% CI: 1.03, 2.98) and upwardly (obesity: OR=1.71; 95% CI: 11.13, 2.60; central adiposity: OR=1.60; 95% CI: 1.08, 2.37) mobile education patterns were associated with higher odds of obesity and central adiposity in women, while stable high pattern was associated with higher odds of overweight (OR=1.88; 95% CI: 1.11, 3.19) in men. Additionally, high compared to the lowest household wealth was associated with high odds of obesity and central adiposity in both sexes.

Conclusion: Stable high and upwardly mobile education patterns are associated with higher odds of obesity and central adiposity in women while the stable high pattern was associated with higher odds of overweight in men.

2.3 Introduction

Overweight and obesity have reached epidemic proportions in most regions of the world, including sub-Saharan Africa [6, 8]. With increasing prevalence of overweight and obesity in low-and middle-income countries (LMICs), the World Health Organization (WHO) has indicated that a double burden of communicable and non-communicable diseases in the near future in LMICs is imminent [75]. Since increasing prevalence of overweight and obesity could differ based on several factors including sex, biosocial, sociocultural, economics, biological, and environmental factors, it is crucial to understand the factors that contribute to their occurrence in LMICs in order to tailor efficient and cost-effective preventive programmes and policies in their prevention [37, 76].

Socioeconomic status (SES), is a consistent predictor of population morbidity and mortality [77, 78]. Some SES markers include education, intergenerational education mobility and income/wealth [77, 79, 80]. Education has been cited as one of the most important markers of SES that affect individuals' health [77-80]. However, the effect of intergenerational educational mobility on individuals' health is scarcely examined in many LMICs settings. Intergenerational educational mobility is largely defined as the change in the level of education between parent(s) and their children and describes individuals' experiences in relation to an achieved position compared to their parents [79, 81]. Previous studies have shown that different childhood or initial socioeconomic circumstances might influence current and future health outcomes and inequalities [78, 79, 81, 82]. Studies conducted mostly in high-income countries that used education to define lifetime SES found individuals with high levels of education compared with their parents had better health outcomes than those who had lower education compared with their parents [79, 81, 82]. Wealth has been found to be inversely associated with obesity in developed countries [37, 83], but has shown to be positively associated with obesity in developing countries [8, 36, 37].

Few studies have explored the mechanism by which intergenerational education mobility influences health risks in low and middle-income countries, and Ghana is no exception [13, 84]. However, these studies have used body mass index (BMI) as a continuous variable, which limits the ability to differentiate between categories of BMI. Hence, the associations for overweight or obesity have not been distinctively made. Furthermore, categorizing BMI into obese and non-obese where underweight and overweight are grouped as non-obese could be problematic as the two categories may produce different health effects [38, 85]. Waist circumference is found to be an important marker of central adiposity and could be used independently to predict cardiometabolic diseases in different populations [86, 87]. Thus, previous studies usage of only BMI to determine obesity may limit the appropriate capturing of central adiposity. Lastly, previous studies have used sub-populations that often do not represent the population of interest and limits the generalizability of the findings. To fill the gap in these previous studies, this study uses Wave 2 data of the WHO-SAGE to examine the association between markers of current and lifetime SES and different BMI categories in a representative sample of adult men and women in Ghana. We also conduct sub-analyses using current sub-Saharan Africa population waist circumference optimal cut-offs for which individuals are at increased risk of cardiometabolic diseases [86].

2.4 Methods

Study Population

Data from the World Health Organization's Study on global AGEing and adult health (WHO SAGE) Ghana Wave 2 (2014-2015) was used. This is a longitudinal dataset on the health and well-being of adult populations aged ⩾50 years for six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa [88]. For comparison, the study also collects sample data from younger adults aged 18–49 years. In Ghana, SAGE collected individual-level data from a nationally representative sample of households including older adults using a stratified, multistage cluster design. The primary sampling units were stratified by region and location of residence of a household (urban/rural) and the samples were selected from 250 enumeration areas. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). Further information on WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

The individual questionnaire responses used in the study covered the following domains: socio-demographic characteristics, work history and benefits; health state descriptions; anthropometrics, performance tests and biomarkers; risk factors and preventive health behaviour; chronic conditions and health services coverage; health care utilization; social cohesion; subjective well-being and quality of life; impact of caregiver; and the interviewer's assessment. Of the 4,735 survey respondents, 229 had missing data for height, 227 for weight and 228 for waist circumference. Also, biologically implausible values (BIV) (height <100cm or >200 cm and weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm) were excluded using the listwise deletion [72, 73]. In total, 246 (5.2%) and 25 (0.5%) observations were excluded due to missing anthropometric measurements and BIVs of height. Consequently, data from 4,464 participants who had complete responses formed the analytical sample for the study.

Outcome variables

In the WHO SAGE data, anthropometric measurements of body weight, height, and waist circumference of respondents were taken by trained assessors using standard protocols [70, 71]. Pregnant women were exempted from weight and waist circumference measurements [71]. Respondents' height was converted from centimeters to meters, and BMI was calculated as a person's weight in kilograms divided by the square of their height in meters (kg/m^2). BMI was classified into four categories and weighted prevalence estimated: underweight, BMI <18.50kg/m^2; healthy/healthy BMI, BMI ⩾18.50-24.99 kg/m^2; overweight, 25.00-29.99kg/m^2; and obesity as BMI ⩾30.00 kg/m^2 [5, 89]. We determined central adiposity using the current waist circumference optimal cut-offs for which individuals would be at increased risk for cardiometabolic diseases within the sub-Saharan Africa (SSA) population [86]. Thus, waist circumference (WC) cut-off of WC ⩾ 81.2cm for men, WC ⩾80.0cm for women and population WC ⩾81.1cm were categorized as central adiposity otherwise, healthy.

Explanatory variables

SES Variables

The selection of SES measures follows previous literature [77, 79, 81, 90]. These were parental and individual education, intergenerational educational mobility, and household wealth status. SAGE collected information on the respondent (individual) and parental highest level of education. The structure of the Ghanaian Educational System before and after independence in 1957 has been subjected to several structural and funding changes with significant debates around the number of years students should spend in the Senior Secondary/High School (SSS/SHS) [91]. In addition to reducing the number of years spent in pre-tertiary education, improving the quality of education and creating universal access to education, another principal aim of the SSS/SHS educational structural reforms was to enhance economic growth by ensuring that SSS/SHS school leavers would develop skills to secure jobs in the labour market when they exited the school system before tertiary education [91, 92]. Thus, the SSS/SHS would act as a better and preferable education level for entry into the labour market. Many structural reforms have occurred between 1961 and 1995. In 1995, the Free Compulsory Universal Basic Education (FCUBE) was introduced to improve the quality of education with basic education consisting of nine years. Universal Basic Education is made up of six (6) years of primary school education and three (3) years of Junior Secondary School (JSS) [91]. Between 2002 and 2008, this was changed to 11 years of free basic education to include two years of kindergarten education, and then four years of senior secondary school education. Since 2017, Ghana has embarked on free education from kindergarten to SHS [93]. While male participation in education has consistently been high, that of females has gradually increased, although with some major barriers [94].

On the basis that SSS/SHS would act as the minimum level of education required for entry into the labour market [92], and also due to fewer data observations for college or tertiary education, we divided the highest education completed into two groups. Thus, both parental and individual educational levels were grouped into low education where the highest level of education was less than a secondary or high school, and high education where a person completed secondary/ high school and above.

We used education to define the lifetime SES variable: intergenerational educational mobility was selected as studies have shown that education is reliable and vital in determining long-term social class when studying health risk factors [77-79]. Intergenerational educational mobility was assigned and coded as follows: 1) stable low if both parents and individual education were low; 2) stable high if both parents and individual education were high; 3) upwardly mobile if parents had low education and individual education was high; and, 4) downwardly mobile if parents had high education and individual education was low (Fig 2.1).

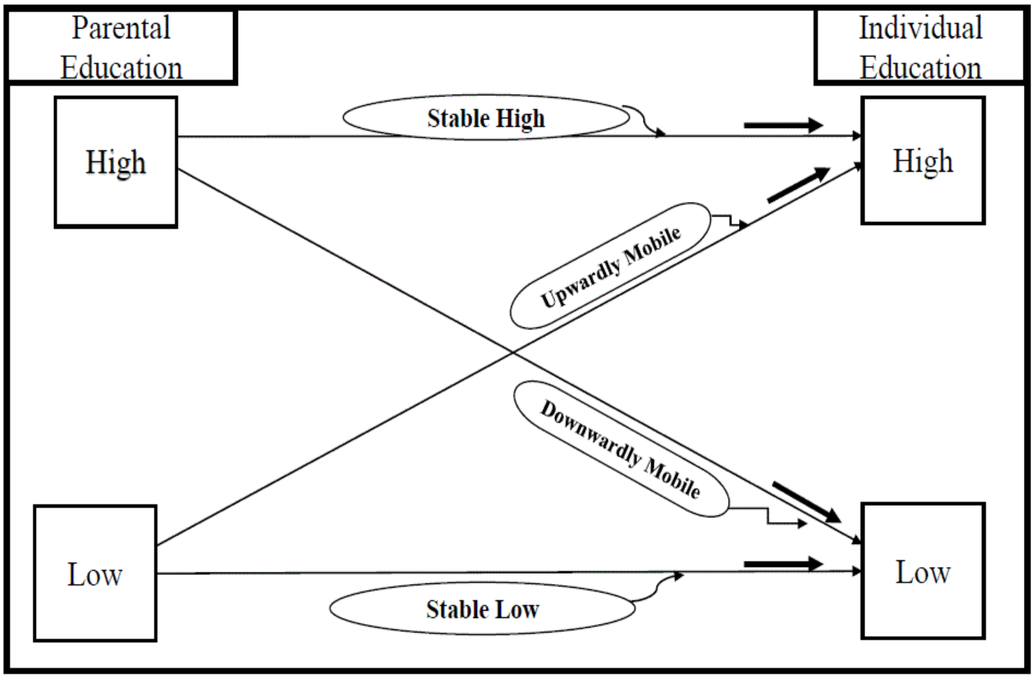


Figure 2. 1. Schematic representation of intergenerational education mobility tracking possibilities from parental education to respondents' education in the SAGE study.

Household wealth index was constructed using principal component analysis from a total of 22 assets/ characteristics/ items converting these into wealth quintiles [95, 96]. The items included household ownership of durable assets (example; radio, television, and refrigerator), dwelling characteristics (example; type of floor and wall material) and access to utilities (example; electricity, improved water and having improved sanitation facility). Quintile one was the lowest quintile; two represented low; three for moderate; four was high, and five was the highest quintile representing highest household wealth status. This served as a proxy for household economic status [95-97].

Covariates

Covariates included age, place of residence, marital status, alcohol intake, smoking status, daily fruit and vegetable intake, and weekly physical activity levels. In this study, age was specified in 10-year intervals except for ages 18-29 due to fewer observations based on the stated sampling strategy where the younger adult population was selected for comparison purposes, not to be nationally representative of these younger age groups. Rural/urban residence was defined by localities, where population size less than 5,000 was classified as rural and any larger localities classified as urban. Marital status was coded as (1) for single, (2) for married/ cohabiting and (3) for divorced/ separated/ widow/ widower. Respondents' smoking status was coded as (1) for "current smoker", (2) "former smoker" and (3) for "never smoked before"; and alcohol consumption status was also coded as (1) for "current alcohol drinker", (2) "former alcohol drinker" and (3) for "never drunk alcohol before".

Daily fruit and vegetable servings were categorized according to the NCD Global Monitoring Framework specifications and recommended by the joint WHO/FAO Panel on Diet, Nutrition and Chronic Disease Prevention [98]. Following these recommendations, a serving of fruit or vegetables was equivalent to 80 grams. Respondents were determined to have met the standard recommendation if they ate five or more servings of fruits and vegetables per day (equivalent to 400 grams). The level of physical activity was determined by the total metabolic equivalents of task (MET) minutes per week using the Global Physical Activity Questionnaire (GPAQ) built into the SAGE interview instrument [99]. Meeting the recommended total physical activity was defined as engaging in activities including work, during transport and leisure time for at least 150 minutes of moderate-intensity activity per week or 75 minutes of vigorous-intensity activity per week. The Cronbach's alpha for the 15 items covering work, travel to and from places, and recreational activities that measured physical activity was 85.4% in this sample.

Statistical analysis

The prevalence estimates for each BMI category and central adiposity were computed as percentages using the total sample size separately for men, women and the total population as the denominator. In the estimation process, we used post-stratified person weights to account for the differential probabilities of selection, nonresponse, and non-coverage/under-coverage. Using these weights, we were able to estimate prevalence that reflects the true distribution of the BMI categories and central adiposity in the population aged 50 years and older [100]. Due to the categorical nature of the outcome variables in this study, we used Pearson chi-squared test or Fisher's exact test where appropriate, to examine the associations between all BMI categories, the two categories of waist circumference and the mediators.

Taking the post-stratified person weights into account, we fitted multilevel multinomial and binomial logistic models using the Generalized Latent Linear and Mixed Model (GLLAMM) to determine the association between all the SES factors with the four-level outcome variable of BMI category (underweight, healthy weight, overweight, and obese) [101]. healthy/healthy weight category was used as the base/reference group. We estimated the exponentiated form of the coefficients and therefore presented the results in terms of multinomial and binomial log-odds (logit) instead of relative risk ratios [102]. Thus, we estimated the odds of being underweight, overweight, obese or having “at risk” WC compared to having healthy BMI.

Ignoring the post-stratified sampling weights, inability to account for both unobserved variables and dependence among observations are major identification problems, which could lead to biased estimations in this study. GLLAMM accounting for the sampling weights of the observation and the latent trait in GLLAMM helps to account for unobservable variables leading to unbiased estimates. The SAGE has a hierarchical structure, in which participants were nested within survey clusters. To adjust for dependence because of the clustering in the multivariable analyses, we used GLLAMM and included individual random effects in the model to estimate the magnitude and determine the significance of clustering using Intra Class Correlation (ICC). We determined the ICC as the ratio of the variance at the cluster level to the sum of the variance at the individual and the cluster levels [85]. All analyses were performed using STATA v.15 (Stata Corp., College Station, Texas, USA).

Two models for each sex and each SES factor were developed and were adjusted for covariates that were identified as confounders. Confounders were determined to be covariates if they were associated with the outcome and when included in the model resulted in a change in the parameter estimate by 10% or more [103]. Confounders were age, ethnicity and marital status (included in model 1 for each sex), while location, physical activity, alcohol, and smoking status, as well as fruit and vegetable intake, were used as potential mediators [90]. Both confounders and potential mediators were included in the final model (model 2) for each sex. We reported the results of a third model (Model 3 in Supplementary Table 2.1) in which household wealth status was included in model 2 separately for parental and individual education, and intergenerational education mobility, to test which of these SES factors remained associated with the categories of BMI. We assessed multicollinearity using variance inflation factors. There was no variance inflation factor higher than 10, suggesting no multicollinearity in both models 1 and 2 [104].

2.5 Results

Table 2.1 presents the characteristics of the study population. In this sample, there were more women (58.5%) compared to men (41.5%). The mean age (standard deviation, SD) of the population was of 57.1 years (SD: 16.5) with a mean height of 1.63m (SD: 8.63), weight of 65.3kg (SD: 14.2), waist circumference of 83.4cm (15.9) and BMI of 24.5kg/m^2 (SD: 5.4). While about 40% of men had high education, only about 22% of women had the same level of education.

Table 2.1. Characteristics of the sample, by sex in WHO SAGE Ghana Wave 2 (2014/15)

		Men		Women		Population	
		(n)	**%**	**(n)**	**%**	**(n)**	**%**
Total Population		1854	41.5	2610	58.5	4464	100
Age [years (SD)]		58.1 (16.8)		56.4 (16.2)		57.1 (16.5)	
Mean Weight [kg (SD)]		64.5 (11.5)		66.0 (16.0)		65.3 (14.2)	
Mean Height [m (SD)]		1.68 (7.59)		1.59 (7.49)		1.63 (8.63)	
Mean Waist Circumference [cm (SD)]		79.7 (12.6)		86.6 (17.7)		83.4 (15.9)	
Mean BMI [kg/m^2 (SD)]		22.9 (3.7)		25.9 (6.1)		24.5 (5.4)	
BMI Categories	healthy Weight	1220	65.8	1248	47.8	2468	55.3
	Underweight	250	13.5	248	9.5	498	11.2
	Overweight	320	17.3	640	24.5	960	21.5
	Obese	64	3.5	474	18.2	538	12.1
‡Central Adiposity (WC ≥ optimal cut-point)		864	46.6	1898	72.7	2762	61.9
Age (years)	18-29	160	8.6	207	7.9	367	8.2
	30-39	107	5.8	216	8.3	323	7.2
	40-49	189	10.2	235	9.0	424	9.5
	50-59	443	23.9	805	30.8	1248	28.0
	60-69	485	26.2	577	22.1	1062	23.8
	≥ 70	470	25.4	570	21.8	1040	23.3
Parental Education	Low	1619	87.3	2205	84.5	3824	85.7
	High	235	12.7	405	15.5	640	14.3
Individual Education	Low	1111	59.9	2047	78.4	3158	70.7
	High	743	40.1	563	21.6	1306	29.3
Intergenerational Education Mobility	Stable Low	1071	57.8	1906	73.0	2,977	66.7
	Stable High	195	10.5	264	10.1	459	10.3
	Upward Mobility	548	29.6	299	11.5	847	19.0
	Downward Mobility	40	2.2	141	5.4	181	4.1
Household Wealth Quintile	Lowest	329	17.8	263	10.1	592	13.3
	Low	421	22.7	538	20.6	959	21.5
	Moderate	342	18.5	609	23.3	951	21.3
	High	390	21.0	615	23.6	1005	22.5
	Highest	372	20.1	585	22.4	957	21.4

‡ sub-Saharan African waist circumference (WC) cut-off point for men (WC⩾81.2cm); women (WC⩾80.0cm); population level (WC⩾81.1cm) [86]

The weighted prevalence across the four BMI categories and central adiposity are shown in Table 2.2. Accounting for sampling weights, 7.2% (95% CI: 6.0%, 8.7%) were underweight; 55.2% (95% CI: 52.1%, 58.2%) were healthy weight; 24.7% (95% CI: 22.3%, 27.2%) were overweight; 12.9% (95% CI: 11.2%, 14.8%) were obese by BMI measurement, and 61.9% (95% CI: 60.4%, 63.3%) had elevated central adiposity by waist circumference measurement. Thus, the prevalence of central adiposity that increases cardiometabolic risk was higher compared to the combined prevalence of overweight and obesity in both men and women (Table 2.2).

Table 2.2. Prevalence (%) of body mass index (BMI) categories and central adiposity (waist circumference ≥ cut-off point) with 95% Confidence Interval in Ghana's adult population (2014/15)

		Underweight	Healthy weight	Overweight	Obese	‡‡ Central Adiposity (WC ≥ optimal cut-point)
Men	‡Weighted	9.1 (6.9, 11.9)	66.2 (61.4, 70.7)	20.7 (17.1, 24.9)	3.9 (2.5, 6.2)	42.7 (38.7, 46.7)
	Unweighted	13.4 (12.0, 15.1)	65.8 (63.6, 67.9)	17.3 (15.6, 19.1)	3.5 (2.7, 4.4)	46.6 (44.3, 48.9)
‡ Parental Education	Low	9.5 (7.1, 12.5)	66.0 (61.1, 70.5)	20.7 (16.7, 25.3)	3.8 (2.4, 5.9)	42.6 (38.2, 47.2)
	High	8.0 (84.4, 14.0)	66.8 (56.2, 75.9)	20.8 (13.0, 29.8)	4.4 (2.0, 9.5)	42.8 (34.1, 51.8)
‡Individual Education	Low	5.6 (3.5, 8.9)	68.4 (61.4, 74.7)	20.6 (16.2, 25.7)	5.4 (2.9, 9.7)	42.6 (37.0, 48.4)
	High	5.6 (3.5, 8.9)	68.4 (61.4, 74.7)	20.6 (16.2, 25.7)	5.4 (2.9, 9.7)	42.6 (37.0, 48.4)
‡Intergenerational Education Mobility	Stable Low	12.1 (8.7, 16.6)	64.1 (58.1, .69.7)	21.1 (16.0, 27.2)	2.6 (1.3, 5.2)	43.7 (37.9, 49.7)
	Stable High	5.9 (2.9, 10.8)	67.7 (55.2, 78.1)	21.2 (13.6, 31.6)	5.1 (2.2, 11.6)	45.0 (35.6, 54.7)
	Upwardly	5.4 (3.3, 8.7)	68.9 (61.6, 75.5)	20.1 (15.0, 26.4)	5.6 (2.9, 10.4)	40.8 (34.1, 48.0)
	Downwardly	14.1 (8.0, 23.6)	64.1 (44.6, 79.8)	19.6 (12.0, 26.6)	2.1 (1.0, 6.9)	35.9 (18.8, 50.7)
‡Household Wealth Quintiles	Lowest	11.5 (7.0, 18.5)	74.0 (66.7, 80.2)	13.7 (8.5, 21.2)	0.8 (0.2, 3.5)	29.2 (21.1, 38.9)
	Low	8.6 (5.0, 14.3)	76.0 (68.5, 82.1)	12.6 (8.2, 19.0)	2.8 (1.0, 6.2)	41.0 (32.2, 50.5)
	Moderate	13.6 (8.7, 20.5)	62.0 (52.7, 70.4)	22.2 (14.7, 32.3)	2.2 (0.9, 5.6)	50.7 (40.7, 60.6)
	High	10.2 (6.2, 16.4)	65.2 (56.8, 72.7)	20.5 (14.3, 26.4)	4.1 (1.9, 8.6)	39.8 (32.1, 48.1)
	Highest	4.2 (1.5, 10.3)	60.2 (48.9, 70.6)	28.4 (21.4, 36.6)	7.1 (3.4, 14.2)	47.2 (38.5, 56.0)
Women	‡Weighted	9.0 (6.6, 12.1)	45.9 (42.6, 49.2)	28.0 (25.2, 31.0)	20.4 (17.8, 23.4)	70.9 (67.1, 74.4)
	Unweighted	9.5 (8.4, 10.7)	47.8 (45.9, 49.7)	24.5 (22.9, 26.2)	18.2 (16.7, 19.7)	72.7 (71.0, 74.4)
‡Parental Education	Low	5.3 (4.0, 7.0)	47.9 (44.2, 51.5)	26.9 (23.8, 30.3)	19.9 (17.1, 23.0)	71.7 (67.5, 75.6)
	High	6.8 (3.8, 10.9)	40.2 (33.5, 47.2)	31.0 (25.0, 37.7)	22.0 (16.5, 28.7)	68.3 (60.7, 75.0)
‡Individual Education	Low	5.7 (4.2, 7.5)	47.3 (43.4, 51.3)	27.8 (24.6, 31.3)	19.2 (16.1, 22.7)	71.6 (67.4, 75.5)
	High	5.7 (3.2, 9.9)	42.8 (37.0, 48.7)	28.4 (22.7, 34.8)	23.2 (18.3, 28.8)	69.2 (62.2, 75.4)
‡Intergenerational Education Mobility	Stable Low	6.0 (4.4, 8.0)	48.3 (44.2, 52.4)	26.3 (23.0, 29.9)	19.4 (16.2, 23.2)	70.9 (66.3, 75.1)
	Stable High	8.5 (4.3, 16.1)	40.2 (32.4, 48.5)	27.2 (20.1, 35.5)	24.2 (17.0, 33.3)	64.1 (54.5, 72.7)
	Upwardly	2.3 (1.0, 5.5)	45.9 (36.8, 55.2)	29.8 (20.9, 40.5)	22.0 (15.7, 29.9)	75.2 (65.4, 83.0)
	Downwardly	3.5 (1.1, 9.2)	40.2 (28.7,50.8)	38.8 (28.1, 48.7)	17.6 (11.2, 26.4)	76.9 (64.6, 85.8)
‡Household Wealth Quintiles	Lowest	6.9 (3.6, 13.1)	56.9 (45.5, 67.6)	28.8 (19.9, 39.7)	7.4 (2.8, 14.2)	55.9 (44.1, 67.1))
	Low	7.4 (4.3, 12.6)	53.0 (44.3, 61.5)	26.4 (19.2, 35.3)	13.1 (7.3, 20.2)	68.1 (60.2, 75.1)
	Moderate	5.4 (3.6, 8.2)	52.3 (45.2, 59.4)	27.4 (21.7, 33.8)	14.9 (10.5, 20.7)	73.4 (66.7, 79.3)
	High	7.9 (4.6, 13.3)	37.1 (31.1, 43.5)	32.2 (26.1, 38.9)	22.8 (17.9, 28.6)	73.4 (66.2, 79.5)
	Highest	2.2 (1.0, 5.1)	40.8 (34.0, 48.1)	25.4 (20.1, 31.4)	31.6 (25.2, 38.7)	73.6 (65.7, 80.3)
Total Population	‡Weighted	7.2 (6.0, 8.7)	55.2 (52.1, 58.2)	24.7 (22.3, 27.2)	12.9 (11.2, 14.8)	61.9 (60.4, 63.3)
	Unweighted	11.2 (10.3, 12.1)	55.3 (53.8, 56.7)	21.5 (20.3, 22.7)	12.1 (11.1, 13.0)	58.0 (54.8, 61.1)

‡Weighted Prevalence: - Post-stratified person weight applied. Only weighted prevalence is presented for parents and individual education, intergenerational education mobility and household wealth quintiles

‡‡ sub-Sahara waist circumference optimal cut-off point for men (WC⩾81.2cm); women (WC⩾80.0cm); population level (WC⩾81.1cm) [86]

Also, the prevalence of obesity exceeded that of underweight in the population. The prevalence of overweight, obesity and central adiposity was higher in women, particularly in all the high SES categories. Tables 2.3 (men) and 2.4 (women) show that all the SES markers were associated with BMI and central adiposity. In addition, SES status was found to be associated with covariates such as location and in some cases alcohol intake, low fruit and vegetable intake, and physical activity levels. These covariates were used as mediators in the regression analyses.

Table 2.3. Prevalence of covariates (mediators) by education categories and household wealth in men

	BMI			Central Adiposity	Urban Location	Smoking Status		Alcohol Status		Below recommended ‡ FV intake	Below recommended physical activity levels
	Underweight	Overweight	Obese	(WC≥81.2cm)		Current smoker	Former smoker	Current drinker	Former drinker		
Parental Education											
Low	231	265	52	752	506	155	73	589	128	864	887
High	19	55	12	112	137	15	18	89	22	120	118
P-*value*	<0.01			<0.01	<0.01	0.04		0.61		0.53	0.21
Individual Education											
Low	171	166	30	499	302	124	44	383	82	583	588
High	79	154	34	365	341	46	47	295	68	401	417
P-*value*	<0.01			0.08	<0.01	<0.01		0.01		0.54	0.18
Intergenerational Education Mobility											
Stable Low	165	160	29	485	284	121	41	370	78	562	569
Stable High	13	49	11	98	119	12	15	76	18	99	99
Upwardly	66	105	23	267	222	34	32	219	50	302	318
Downwardly	6	6	1	14	18	3	3	13	4	21	19
P-*value*	<0.01			0.18	<0.01	<0.01		0.15		0.68	0.14
Household Wealth Quintiles											
Poorest	59	38	4	100	21	61	14	127	21	161	160
Poor	63	50	7	194	55	37	17	148	20	237	221
Moderate	60	49	5	168	108	29	18	126	43	191	199
Rich	49	73	21	181	203	28	23	153	29	218	229
Richest	19	110	27	221	256	15	19	124	37	177	196
P-*value*	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.04

‡ FV: Fruits and vegetable intake

Table 2.4. Prevalence of covariates (mediators) by education categories and household wealth in women

	BMI			Central Adiposity	Urban Location	Smoking Status		Alcohol Status		Below recommended ‡ FV intake	Below recommended physical activity levels
	Underweight	Overweight	Obese	(WC≥80.0cm)		Current smoker	Former smoker	Current drinker	Former drinker		
Parental Education											
Low	232	517	352	1588	902	17	22	273	136	1158	1319
High	16	123	122	310	276	4	1	54	33	204	263
P-*value*	<0.01			0.03	<0.01	0.30		0.26		0.45	0.05
Individual Education											
Low	221	485	311	1462	815	19	22	263	130	1091	1236
High	27	155	163	436	363	2	3	64	39	271	346
P-*value*	<0.01			<0.01	<0.01	0.05		0.59		0.03	0.66
Intergenerational Education Mobility											
Stable Low	216	438	275	1353	733	16	22	237	114	1028	1136
Stable High	11	76	86	201	194	1	1	28	17	141	163
Upwardly	16	79	77	235	169	1	0	36	22	130	183
Downwardly	5	47	36	109	82	3	0	26	16	63	100
P-*value*	<0.01			0.01	<0.01	0.09		0.04		<0.01	0.06
Household Wealth Quintiles											
Poorest	31	50	14	152	22	0	6	28	9	132	155
Poor	71	106	39	363	112	4	5	76	28	311	338
Moderate	76	139	71	449	244	7	6	62	52	327	361
Rich	50	175	147	465	363	6	1	77	39	312	370
Richest	20	170	203	469	437	4	5	84	41	280	358
P-*value*	<0.01			<0.01	<0.01	0.11		0.03		0.01	0.74

‡ FV: Fruits and vegetable intake

Results of the multivariable analyses for the SES markers associated with the BMI categories and central adiposity are shown in Tables 2.5 and 2.6 for men and women, respectively. Model 1 in men showed that high parental education was associated with lower odds of underweight but higher odds of both overweight and obesity. In the fully adjusted model, the association was no longer significant except for those in the underweight (OR=0.40; 95% CI: 0.16, 0.97) and overweight (OR=1.66; 95% CI: 1.05, 2.65) categories. Parental education was not associated with central adiposity in men. In women, parental education was significantly associated with BMI and central adiposity. High parental education was significantly associated lower odds of underweight (OR=0.31; 95% CI: 0.12, 0.75), but higher odds of overweight (OR=1.84; 95% CI: 1.29, 2.62), obesity (OR=2.59; 95% CI: 1.72, 3.91) and central adiposity (OR=1.51; 95% CI: 1.04, 2.19) in the fully adjusted model.

Table 2.5. Odds ratios (95% confidence intervals, CI) of being underweight, overweight, or obese according to markers of socioeconomic status in men in Ghana (2014/15)

Men	[1]Model 1			[2]Model 2			[1]Model 1	[2]Model 2
	BMI (Ref: healthy/healthy BMI)						Central Adiposity ([3]WC⩾81.2cm)	
	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Central Adiposity OR [95% CI]	Central Adiposity OR [95% CI]
Parental Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.35 (0.14, 0.87) *	2.06 (1.31, 3.25) **	2.80 (1.16, 5.74) *	0.40 (0.16, 0.97) *	1.66 (1.05, 2.65) *	1.96 (0.82, 4.67)	1.30 (0.86, 1.97)	1.09 (0.72, 1.67)
Individual Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.70 (0.47, 1.03)	1.71 (1.21, 2.43) **	1.64 (0.86, 3.16)	0.79 (0.53, 1.17)	1.41 (0.99, 2.10)	1.28 (0.65, 2.52)	1.25 (0.94, 1.64)	1.09 (0.82, 1.45)
Intergenerational Education Mobility								
Stable Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stable High	0.28 (0.11, 0.77) **	2.52 (1.50, 4.23) ***	3.30 (1.27, 7.55) **	0.32 (0.12, 0.90) *	1.88 (1.11, 3.19) *	2.06 (0.80, 54.29)	1.40 (0.88, 2.23)	1.11 (0.69, 1.79)
Upwardly	0.82 (0.54, 1.23)	1.60 (1.09, 2.37) **	1.24 (0.61, 2.50)	0.91 (0.61, 1.37)	1.36 (0.92, 2.02)	1.04 (0.49, 2.22)	1.23 (0.91, 1.65)	1.11 (0.85, 1.50)
Downwardly	1.03 (0.19, 3.63)	3.70 (0.76, 7.00)	0.35 (0.04, 3.38)	1.16 (0.19, 3.10)	3.34 (0.85, 6.21)	0.35 (0.03, 1.88)	1.75 (0.57, 3.39)	1.70 (0.57, 4.06)
Household Wealth Quintile								
Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low	0.60 (0.38, 0.96) *	1.14 (0.56, 2.31)	1.00 (0.20, 3.12)	0.60 (0.48, 1.23)	0.93 (0.53, 1.67)	0.69 (0.13, 2.77)	2.21 (1.46, 3.33) ***	1.89 (1.15, 3.11) **
Moderate	0.57 (0.34, 0.94) *	1.32 (0.62, 2.81)	2.38 (0.51, 5.62)	0.67 (0.41, 1.04)	1.45 (0.84, 2.52)	2.03 (0.43, 5.07)	2.37 (1.59, 3.55) ***	1.92 (1.23, 3.00) **
High	0.49 (0.30, 0.82) **	2.20 (1.13, 4.30) *	4.28 (2.10, 9.78) ***	0.65 (0.38, 1.11)	1.52 (0.83, 2.82)	3.74 (1.53, 8.66) *	2.49 (1.58, 3.92) ***	2.06 (1.34, 3.15) ***
Highest	0.20 (0.11, 0.38) ***	3.06 (1.64, 6.85) ***	5.36 (3.30, 10.99) ***	0.24 (0.11, 0.49) ***	1.83 (1.01, 3,34) *	4.52 (2.51, 9.95) **	4.46 (2.87, 6.92) ***	2.98 (1.83, 4.83) ***

**p<0.05, **p<0.01, ***p<0.001*

[1]Model 1- Adjusted for confounders including age, marital status and ethnicity

[2]Model 2- Adjusted for confounders and potential mediators including rural/urban location, whether a respondent was current smoker, former smoker or never smoked, regularly/ currently drinks alcohol, former or has never drunk alcohol, met the recommended daily fruit and vegetable intake level, and met the recommended weekly level of physical activity.

[3]sub-Sahara waist circumference optimal cut-off point for men (WC⩾81.2cm) [86]

Table 2.6. Odds ratios (95% confidence intervals, CI) of being underweight, overweight, or obese according to markers of socioeconomic status in **women** in Ghana (2014/15)

Women	[1]Model 1			[2]Model 2			[1]Model 1	[2]Model 2
	BMI (Ref: healthy/healthy BMI)						Central Adiposity ([3]WC⩾80.0cm)	
	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Central Adiposity OR [95% CI]	Central Adiposity OR [95% CI]
Parental Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.28 (0.11, 0.71) **	2.04 (1.46, 2.84) ***	3.34 (2.19, 5.10) ***	0.31 (0.12, 0.75) **	1.84 (1.29, 2.62) ***	2.59 (1.72, 3.91) ***	1.77 (1.23, 2.54) **	1.51 (1.04, 2.19) *
Individual Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.50 (0.28, 0.89) *	1.52 (1.13, 2.05) **	2.71 (1.90, 3.87) ***	0.56 (0.32, 1.00)	1.34 (0.99, 1.83)	2.05 (1.45, 2.91)	1.87 (1.35, 2.59) ***	1.62 (1.16, 2.27) **
Intergenerational Education Mobility								
Stable Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stable High	0.18 (0.06, 0.52) **	2.16 (1.42, 3.31) ***	4.54 (2.77, 7.43) ***	0.21 (0.07, 0.61) **	1.87 (1.19, 2.93) **	3.15 (1.96, 5.05) ***	2.13 (1.31, 3.49) **	1.75 (1.03, 2.98) *
Upwardly	0.67 (0.17, 1.59)	1.32 (0.88, 1.98)	2.18 (1.44, 3.28) ***	0.73 (0.38, 1.38)	1.17 (0.78, 1.77)	1.71 (1.13, 2.60) **	1.80 (1.20, 2.69) **	1.60 (1.08, 2.37) *
Downwardly	0.43 (0.11, 1.63)	2.06 (1.22, 3.46) **	2.86 (1.61, 5.11) ***	0.42 (0.12, 1.45)	1.92 (1.11, 3.32) **	2.42 (1.30, 4.53) **	1.60 (0.91, 2.81)	1.43 (0.82, 2.50)
Household Wealth Quintile								
Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low	1.09 (0.64, 1.86)	1.26 (0.80, 1.99)	1.39 (0.56, 3.45)	1.01 (0.60, 1.72)	1.19 (0.75, 1.88)	1.19 (0.47, 2.98)	1.51 (1.01, 2.27) *	1.38 (0.92, 2.08)
Moderate	0.99 (0.59, 1.67)	1.61 (1.03, 2.51) *	2.94 (1.84, 7.03) *	1.21 (0.69, 2.11)	1.44 (0.91, 2.28)	2.02 (0.84, 4.89)	2.10 (1.35, 3.27) ***	1.79 (1.15, 2.79) **
High	0.96 (0.54, 1.70)	2.74 (1.74, 4.29) ***	4.91 (2.27, 10.15) ***	1.10 (0.60, 2.02)	2.30 (1.42, 3.71) ***	3.75 (1.93, 7.68) ***	2.36 (1.51, 3.69) ***	1.86 (1.18, 2.93) **
Highest	0.62 (0.31, 1.24)	4.31 (2.64, 7.06) ***	6.29 (2.85, 16.77) ***	0.76 (0.37, 1.58)	3.44 (2.02, 5.88) ***	4.48 (3.49, 9.59) ***	3.19 (1.96, 5.20) ***	2.34 (1.42, 3.85) ***

p<0.05, **p<0.01, ***p<0.001

[1]**Model 1-** Adjusted for confounders including age, marital status and ethnicity

[2]**Model 2-** Adjusted for confounders and potential mediators including rural/urban location, whether a respondent was current smoker, former smoker or never smoked, regularly/currently drinks alcohol, former or has never drunk alcohol, met the recommended daily fruit and vegetable intake level, and met the recommended weekly level of physical activity.

[3]sub-Sahara waist circumference cut-off point for women (WC⩾80.0cm) [86]

While no significant association was found between individual education and BMI or central adiposity in men, a significant association was found in women who were obese and women with central adiposity. High compared to low individual education was associated with higher odds of obesity (OR=2.05; 95% CI: 1.45, 2.91) and central adiposity (OR=1.62; 95% CI: 1.16, 2.27). When individual education was independently adjusted for parental education in the full model, high individual education was found to be associated with higher odds of obesity (OR=1.61; 95% CI: 1.13, 2.30) and central adiposity (OR=1.51; 95% CI: 1.07, 2.13) only in women (Table 2.7). The interaction terms between parental and individual education were not significant for either sex (Table 2.7).

Among men, being in the stable high compared to the stable low category of educational mobility was associated with lower odds of underweight (OR=0.32; 95% CI: 0.12, 0.90) but higher odds of overweight (OR=1.88; 95% CI: 1.11, 3.19). There was no significant association between educational mobility and obesity or central adiposity in men. Compared to the stable low category in women, all three other categories of educational mobility were associated with higher odds of obesity. Stable high (OR=1.75; 95% CI: 1.03, 2.98) and upwardly mobile (OR= 1.60; 95% CI: 1.08, 2.37) categories in women were associated with central adiposity. Household wealth status was significantly associated with all categories of BMI and central adiposity in both sexes. In men, high compared to lowest household wealth status was significantly associated with lower odds of underweight but high odds of overweight, obesity and central adiposity in both model 1 and 2. Similar odds and associations were observed in women; however, no significant association was found for underweight. Separately for parental and individual education, and intergenerational educational mobility, household wealth was added to the full models (Table 2.7). While only household wealth remained significantly associated with BMI and central adiposity in men, high parental education (OR=1.83; 95% CI: 1.24, 2.70), stable high (OR=1.90; 95% CI: 1.18, 3.08) and upwardly mobile (OR= 1.89; 95% CI: 1.04, 3.43) categories of educational mobility remained significantly associated with higher odds of obesity in women.

Table 2.7**.** Sub-analyses between SES variables and BMI as well as central adiposity in Model 3

Men	Parental and Individual Education controlled simultaneously in Model 2				Women	Parental and Individual Education controlled simultaneously in Model 2			
	BMI (Ref: healthy/healthy BMI)			Central adiposity (Ref: ‡WC <81.2cm)		BMI (Ref: healthy/healthy BMI)			Central adiposity (Ref: ‡ WC <80.0cm)
	Underweight	Overweight	Obese	WC ≥ 81.2		Underweight	Overweight	Obese	WC ≥ 80.0cm
	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]		OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]
Parental Education									
Low	1	1	1	1		1	1	1	1
High	0.42 (0.16, 1.08)	1.51 (0.93, 2.44)	1.89 (0.77, 4.65)	1.06 (0.67, 1.63)		0.35 (0.14, 0.89) *	1.74 (1.20, 2.54) **	2.08 (1.37, 3.15) ***	1.26 (0.86, 1.83)
Individual Education									
Low	1	1	1	1		1	1	1	1
High	0.88 (0.58, 1.32)	1.29 (0.99, 1.88)	1.09 (0.54, 2.19)	1.08 (0.81, 1.44)		0.69 (0.38, 1.25)	1.12 (0.81, 1.58)	1.61 (1.13, 2.30) **	1.51 (1.07, 2.13) *
	Parental and individual Education interaction in Model 2					**Parental and individual Education interaction in Model 2**			
Parental*Individual Education									
Low	1	1	1	1		1	1	1	1
High	0.30 (0.04, 2.28)	0.41 (0.09, 1.90)	3.70 (0.39, 5.47)	0.59 (0.57, 5.06)		0.68 (0.12, 3.90)	0.83 (0.36, 1.93)	0.76 (0.35, 1.64)	0.76 (0.82, 2.50)
	SES variables controlled independently for household wealth in Model 2					**SES variables controlled for household wealth in Model 2**			
Parental Education									
Low	1	1	1	1		1	1	1	1
High	0.47 (0.19, 1.18)	1.43 (0.88, 2.31)	1.62 (0.67, 3.94)	0.98 (0.64, 1.49)		0.32 (0.13, 0.76) **	1.45 (1.02, 2.06) *	1.83 (1.24, 2.71) **	1.36 (0.92, 2.00)
Individual Education									
Low	1	1	1	1		1	1	1	1
High	0.98 (0.65, 1.49)	1.08 (0.73, 1.60)	0.82 (0.40, 1.67)	0.92 (0.69, 1.23)		0.60 90.34, 1.07)	1.01 (0.72, 1.41)	1.35 (0.94, 1.93)	1.46 (1.02, 2.08) *
Intergenerational Education Mobility									
Stable Low	1	1	1	1		1	1	1	1
Stable High	0.42 (0.15, 1.21)	1.40 (0.79, 2.47)	1.30 (0.48, 3.48)	0.90 (0.55, 1.48)		0.22 (0.08, 0.66) **	1.31 (0.81, 2.11)	1.90 (1.18, 3.08) **	1.56 (0.90, 2.71)
Upwardly	1.40 (0.25, 4.09)	3.04 (0.67, 6.78)	0.28 (0.02, 3.16)	1.53 (0.50, 4.69)		0.41 (0.12, 1.36)	1.61 (0.93, 2.79)	1.89 (1.04, 3.43) *	1.33 (0.76, 2.33)
Downwardly	1.13 (0.73, 1.73)	1.07 (0.71, 1.61)	0.66 (0.30, 1.44)	0.94 90.70, 1.27)		0.75 (0.39, 1.42)	0.92 (0.60, 1.42)	1.17 (0.76, 1.80)	1.46 (0.97, 2.19)

‡ WC: Waist circumference

2.6 Discussion and Conclusion

This study sought to examine associations between key markers of current and lifetime SES and categories of BMI, as well as central adiposity in Ghanaian adults using the most recent data collected by WHO SAGE in Ghana. We found that in men, high parental education and stable high category of intergenerational education mobility were significantly associated with lower odds of underweight but with higher odds of overweight. In women, high compared to low parental and individual education; stable high and upward educational mobility compared to the stable low category were significantly associated with higher odds of obesity and central adiposity. High household wealth status was significantly associated with higher odds of overweight, obesity and central adiposity in both men and women. At the same time, wealthier households were significantly associated with lower odds of underweight making household wealth a protective factor against underweight, especially in men. Finally, accounting for the post-stratified person weights, the prevalence of central adiposity was higher compared to the combined prevalence of overweight and obesity in both men and women, and the prevalence of overweight and obesity separately exceeded that of underweight in this population.

Significant findings made in this study were that the prevalence of central adiposity was high, and the prevalence of overweight and obesity separately exceeded underweight in both men and women. The later corroborates previous studies that showed that overweight/obesity exceeded underweight in some developing countries [38]. Historically, the prevalence of obesity in Ghana's population was as low as 0.8% in 1980 [105, 106], it gradually increased to 5.5% in 2003 [107] and 9.8% in 2008 [70]. Findings in this study showed a weighted obesity prevalence of 12.9% and unweighted obesity prevalence about 12% at the time of data collection (2014/2015). In 2003, the weight and height measures used to estimate BMI prevalence were self-reported (as part of SAGE Ghana Wave 0). Weight and height were then objectively measured in 2008 as part of SAGE Ghana Wave 1 (9.8% obese) impeding the ability to compare the prevalence rates in the two waves in 2003 and 2008 [108]. However, the current obesity rate estimated in this study also used objectively measured weight and height, making the current rate comparable to that of Wave 1 from 2008; and this shows an increase even in the case of unweighted prevalence. The increasing obesity rates could be due to several factors such as increased economic growth, rapid urbanization, changing food preference, and availability of healthy foods in Ghana over the past 15 years [109-111]. There is evidence of rapid urbanization in Ghana that has been accompanied by changes in dietary patterns, increase in sedentary lifestyles, increased commuting times due to traffic congestion hence commuters spend long sitting hours in traffic, the loss or lack of open and safe places for physical activities because these spaces are converted into residential or commercial building spaces, and less engagement in physical activities [109, 110]. Changes in dietary patterns could be associated with the readily available fast-foods as evidenced by almost a doubling of the hospitality sector (which includes restaurants and food services) from 2.9% to 5.5% from the year 2000 to 2010 in Ghana [110]. The combined effect of such conditions could serve as a platform for households to adopt lifestyles that make individuals prone to obesity as has been observed in other settings [38, 112]. However, as a major risk factor for non-communicable diseases, the high prevalence of obesity in this study compared to the historical prevalence emphasizes the need for deliberate actions to prevent obesity, a point which is supported by WHO's position that an increasing prevalence of obesity may contribute to the rising burden of non-communicable diseases in Africa [6, 75, 85].

Another significant finding in this study is the result that especially in women, high compared to low parental and individual education levels were associated with higher odds of overweight and obesity. This finding is consistent with findings in most developing economies where overweight and obesity have been associated with high SES [36, 84, 113-115]. However, this finding is in contrast with results from countries such as Australia, Germany, the United States and Malaysia in which parental or an individual's high educational attainment has been associated with low BMI, low central adiposity and good health outcomes [79, 81, 116-118]. The situation in Ghana suggests that high education which begins with the completion of SSS/SHS and above is an economic tool for resource acquisition through the generations. Hence, those whose parents had high education were likely to possess the resources needed to afford the 'westernized' lifestyle: increase consumption of fast foods, high sodium diets, and high caloric drinks which are associated with westernized diets and perceived to be major dietary changes that promote obesity [38, 119].

This phenomenon could also be explained by the potentially low level of awareness of the positive effect of maintaining healthy body weight especially among women and thus, suggests the need for nutritional education [39]. Furthermore, this may also be as a consequence of cultural influence, which portrays overweight and obesity instead of healthy/healthy BMI as a sign of affluence and high social standing observed in some developing countries [37-39]. The finding that high parental education is associated with lower odds of underweight in women supports the notion culture confers on body size and socio-economic status.

In this population and especially among women, having a stable high or upward educational mobility were significantly associated with higher odds of obesity (both defined by BMI and waist circumference). This finding, especially regarding central adiposity, confirms that high SES potentially affected obesity in Ghanaian women [84]. Results in this study, however, contradict findings in some previous studies conducted mostly in developed countries [79, 81, 82, 116]. For instance, Kuntz and Lampert found no significant increase in the risk of obesity among respondents with potentially upward educational mobility [81]; Gall et al found upward educational mobility was associated with higher healthy life scores that included low BMI in young Australians [79]; Albrecht and Gordon-Larsen reported upward education mobility was associated with low adult mean BMI [116]; Adina et al found high parental and high personal education levels were associated with lower odds of large waist circumference [117]. Thus, the association between educational mobility and obesity seem to differ based on the culture, social location, and economy from which a sample is drawn.

Evidence in this study that high household wealth increased the odds of overweight and obesity is consistent with findings from some developing economies [36, 38, 113]. For example, using educational attainment as an SES marker in 36 countries, Mendez et al [38] found a strong positive association between high SES and overweight/obesity in developing countries; but this association reduced or reversed for developed countries [113].

Another interesting finding in this study is that downward mobility in women compared to the stable low category was associated with higher odds of obesity, although such association was not seen with central adiposity. The sample of downwardly mobile populations overall was small, which is a positive result but may contribute to a relative underestimation of associations in this analysis. Given that, we have accounted for all possible observable factors, included the sampling weights, and used STATA's GLLAMM multilevel multinomial logistic regression that adjusted for clustering and any latent variable, we could, therefore, rule out that this is not a spurious relationship. The finding is consistent with results in other studies in which positive associations were found between downward intergenerational education mobility and health risk outcomes [79, 81, 116].

Significantly low levels of education in women may have affected their food choices, preference, and understanding of the health implications of having unhealthy BMI or central adiposity. For many years to many children, SSS/SHS education was an "elusive dream" mainly due to the cost of obtaining this level of education and girls were mostly affected [94]. However, with increased general and nutrition education, a population is more likely to reduce such health inequalities [120], suggesting the need for increased general, health and nutrition education in the population. Alternatively, the results in this study suggest that education may be protective in reducing health inequalities in the population and thus, an improvement in education enrolment rates, especially in women, may reduce underweight in the population. Consequently, the overall results call for a balance in the implementation of management and preventive measures for all categories of BMI or waist circumference in the population. This notwithstanding, high prevalence of overweight/obesity and the identified associations in this study coupled with the “obesogenic environment” created due to urbanization, makes it imperative that the public health system is well-resourced to prevent and manage, and further be ready to bear the burden overweight/ obesity may impose on the system.

This study has some limitations. First, the use of cross-sectional data prevented the determination of temporality, and therefore we were unable to discount the possibility of bias due to reverse causality. Second, the use of education to measure mobility for two different generations should be interpreted with caution since the applicability of education and education completion rates may differ in different generations. However, as the educational level is accurately recalled, it is more stable over time compared to other SES markers such as occupation; and the education gradient in health is considered robust when there are preventive and treatment methods for the health risk/outcome such as obesity [77-79]. Also, although the data is representative of the older adult population, analyses omit those observations with missing information such as height and weight, and this may have introduced selection bias which may affect internal validity even though the missing data were relatively minimal (less than 5%). Additionally, the small sample of younger adults aged 18-49 included in the study precludes strong conclusions about the relationship in younger adult ages. Finally, there are a few objective based measures we could not account for, like fast food diet, and occupation due to the scope of this paper and data limitations. Although there were respondents’ occupation in the data, it was not included for the following reasons: with regards to socio-economic factors that contribute to risk factors for health, education has shown to be the strongest and most consistent measure [77]; hence, the focus on education first and not occupation. Furthermore, the relationship between occupation and obesity are normally considered in the light of the income earned from such occupation, as well as, whether an individual's occupation makes him/her active or sedentary. Although previous studies did not include factors such as physical activities [79, 84], we included both the level of physical activity determined using the GPAQ [121] which captures various activities including those at work, and household wealth which is a proxy for economic status of the household from which the individual originates. Thus, although occupation is not captured in this model, its significance is captured by adjusting for physical activity and household wealth.

We recommend that future studies should adjust for measures such as individual genetic composition, availability of fast food diet, and household composition, which have the potential to influence obesity.

The study also has many strengths. First, we use waist circumference determined by the current sub-Saharan Africa optimal cut-off which accounts for central adiposity hence obesity definition was not limited to only BMI. Secondly, we use the most current national dataset that is representative of a wide age group ($\geqslant$18 years) in both sexes and the use of objectively measured anthropometric data that facilitates the ability to make inferences to the broader population. Finally, the ability to examine the relationship between intergenerational educational mobility and the different BMI categories and central adiposity fills a gap that has rarely been tested in LMICs.

In conclusion, findings in this study showed that the prevalence of central adiposity was higher compared to the combined prevalence of overweight and obesity; and the prevalence of obesity was higher than that of underweight in the Ghanaian adult population. In contrast to studies from high-income countries, we found that high current and lifetime SES were associated with higher odds of overweight, obesity and central adiposity, and with lower odds of underweight in the population.

2.7 Postscript

Chapter two aimed to estimate the prevalence of overweight and obesity in a nationally representative adult population of Ghana. It also to examine the associations between current and lifetime markers of SES and four BMI categories and central adiposity in this population. The main finding from this chapter two was that the prevalence of obesity exceeded the prevalence of underweight in the population. Regarding associations, the finding showed that high SES was significantly associated with higher odds of overweight, obesity and central adiposity, particularly in women. High SES included having individual and/or parental education, being an individual with stable high or upwardly mobile education patterns and coming from a household with high or higher household wealth. The contrary of the association found in this chapter is observed in most high income countries.

The pattern observed in this chapter is a phenomenon documented as countries are increasingly becoming wealthy. This might imply that robust weight reduction strategies in high income countries may not necessarily be useful in low income countries. This is because the underlying SES gradient may differ for different countries and those affected by overweight and obesity might not necessarily be the same. Thus, in a concerted effort to reduce or prevent overweight and obesity, countries could learn from others but would have to develop locally sensitive, affordable, sustainable and workable strategies. As there has been a paucity of information on obesity in those 50 years and above, Chapter 3 aimed to examine the changes in the prevalence of overweight and obesity in this population. In the same chapter, we examined if factors associated with the overweight and obesity changed over time.

3 Recent changes in obesity prevalence and associated factors among older adults in Ghana between 2007/08 and 2014/15

3.1 Preface

An increasing prevalence of obesity, a major risk factor for non-communicable diseases (NCDs), is of particular importance in older adults and in any ageing populations [9]. Whilst the Ghanaian population is ageing however, the Ministry of Health's strategic policy guideline to reduce and prevent an increasing obesity prevalence completely neglects the older adult population [17]. This is likely to be due to the lack of evidence on obesity in the older adult population. Thus, Chapter 3 presents a study that aimed to examine the trends in overweight and obesity prevalence in the older adult population. We analysed repeated cross-sectional data measuring secular changes and associations between obesity and factors previous studies purported to influence obesity. The estimated prevalence of the various BMI categories were used as input parameters for developing the health economic model presented in Chapter 7.

The following text in this chapter has been published in PLoS One (Appendix 2).

Lartey, S.T., Magnussen, C.G., Si, L., Boateng, G.O**.,** de Graff, B., Biritwum, R.B., Minicuci, N., Kowal, P., Blizzard, L., & Palmer, A (2019). Rapidly increasing prevalence of overweight and obesity in older Ghanaian adults from 2007-2015: evidence from WHO-SAGE waves 1 & 2. *PLoS ONE, 14(8): e0215045.*

3.2 Abstract

Background: Studies on changes in the prevalence and determinants of obesity in older adults living in sub-Saharan Africa are scarce. We examined recent changes in obesity prevalence and associated factors for older adults in Ghana between 2007/08 and 2014/15.

Methods: Data on adults aged 50 years and older in Ghana were drawn from the World health Organization's Study on global AGEing and adult health (WHO SAGE) 2007/08 (Wave 1; n=4158) and 2014/15 (Wave 2; n=1663). The weighted prevalence of obesity, overweight, healthy weight and underweight, and of high central adiposity were compared in 2007/08 and 2014/15. Multinomial and binomial logistic regressions were used to examine whether the determinants of weight status based on objectively measured body mass index and waist circumference changed between the two time periods.

Results: The prevalence of overweight (2007/08=19.6%, 95% CI: 18.0-21.4%; 2014/15=24.5%, 95% CI: 21.7-27.5%) and obesity (2007/08=10.2%, 95% CI: 8.9-11.7%; 2014/15=15.0%, 95% CI: 12.6-17.7%) was higher in 2014/15 than 2007/08 and more than half of the population had high central adiposity (2007/08=57.7%, 95% CI: 55.4-60.1%; 2014/15=66.9%, 95% CI: 63.7-70.0%) in both study periods. While the prevalence of overweight increased in both sexes, obesity prevalence was 16% lower in males and 55% higher in females comparing 2007/08 to 2014/15. Female sex, urban residence, and high household wealth were associated with higher odds of overweight/obesity and high central adiposity. Those aged 70+ years had lower odds of obesity in both study waves. In 2014/15, females who did not meet the recommended physical activity were more likely to be obese.

Conclusion: Over the 7-year period between the surveys, the prevalence of underweight decreased and overweight increased in both sexes, while obesity decreased in males but increased in females. The difference in obesity prevalence may point to differential impacts of past initiatives to reduce overweight and obesity, potential high-risk groups in Ghana, and the need to increase surveillance.

3.3 Introduction

Obesity is a significant global public health challenge because it is a major risk factor for most non-communicable diseases (NCDs) and independently predicts overall mortality [6, 9, 122]. In adults 25 years or older, epidemiological data have been used to establish a causal relationship between high body mass index (BMI, defined in this study as overweight and obesity) and some chronic diseases such as cardiovascular disease, diabetes mellitus, chronic kidney disease, many cancers and musculoskeletal disorders [9, 34, 123]; increased all-cause mortality; and reduced life expectancy [67, 122, 124-126]. For instance, pooled data from four large cohort studies found that the relative risk for each 5 kg/m^2 higher BMI was 2.32 (2.04–2.63) for diabetes and 1.44 (1.40–1.48) for ischaemic heart disease among those aged 55–64 years [123]. Additionally, high BMI has been associated with poor mental health, reduction in quality-adjusted life-years (QALYs), and a high economic burden due to the associated medical and treatment costs [24, 127-132]. In 2015 alone, a total of 603.7 million adults globally were classified to be obese [9]. From 1980 to 2014, obesity has almost doubled among adults in most parts of the world including sub-Saharan Africa [6-8, 133]. Among urban residents in West Africa, the prevalence of obesity has doubled and has consistently increased in both men and women over a period of 15 years from 1992 to 2007 [8, 134].

In Ghana, the increasing prevalence of obesity from 1980 to 2014 among individuals aged 15-49 years has been well-documented [11, 15] and the Ministry of Health found the need to reduce obesity by 2% in the same age group within five years starting from 2008 [17]. However, little is known about the trends in the prevalence of obesity among populations of older adults aged 50 years and above. As a result of improved public health systems, faster fertility transitions, and increased life expectancy, Ghana's population is rapidly transitioning into an ageing population [33]. This is occurring concurrently with improved nutrition but increased availability of energy-dense foods and increasing sedentary lifestyle that has led to recent increases in obesity prevalence and NCDs [11, 35]. The health and productivity of those in the 50-65 years age range are important as they mentor younger colleagues and form the majority labour force for agricultural productivity that is a key sector for sustainable development and poverty reduction in Ghana [45]. Monitoring trends and identifying factors that relate to obesity provide information that allows interventions to be appropriately and effectively targeted [46, 47] but such data among older adults are lacking in Ghana. Thus, this study aimed to investigate recent changes in the prevalence of obesity among Ghana's older adult population and identify contributing factors.

3.4 Methods

Study Population

Data from the World Health Organization's Study on global AGEing and adult health (WHO SAGE) 2007/8 (Wave 1) and 2014/15 (Wave 2) were used. WHO SAGE is a longitudinal study on the health and well-being of adult populations aged 50 years and older in six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa [69]. In Ghana, trained SAGE teams collected individual-level data from nationally representative households of adults using a stratified, multistage cluster design. The sampling method used in both 2007/08 and 2014/15 was based on the SAGE Wave 0 (2003) in which the primary sampling units were stratified by region and locality (urban/rural) [70, 71]. Weight, height and waist circumference were measured, exempting pregnant women from weight measurements in both surveys [28].

Final sample and missing data

Data collected in 2007/08 had 5,573 and 2014/15 had 4,735 total survey respondents. The final analytical sample at each level of analysis is shown in Fig 3.1. The final samples for analysis were determined after missing and biologically implausible weight, height and waist circumference measurements were excluded. Biologically implausible values were height <100cm or >250 cm, weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm, and were excluded [72, 73]. Additionally, to examine data in a repeated cross-sectional framework and to meet the assumption of independency, all individuals in 2014/15 who participated in 2007/08 were excluded from the analysis [135-137]. A comparison of the “dropped” subjects with the new respondents in terms of BMI and central adiposity was performed and results suggested that the issue of the representativeness should not represent a potential bias. Individuals aged 50+ years with complete responses were 4,158 (2007/08) and 1,663 (2014/15).

Caution is required when interpreting Fig 1. The exempted values presented were those identified in the initial sample for each variable. As there are overlaps/double-counting of some of the exempted responses, subtracting the sum of all the exempted from the total sample will not yield the presented final sample size. The analysis omits 13% of observations with missing data in 2007/08 and 4.8% in 2014/15. This could introduce selection bias that might have affected external validity. Using the law of large numbers [138], it was assumed that the final sample was large enough to override any effect of percentage of missing data on the estimates. Moreover, the use of the survey method and the post-stratified persons' weight that extrapolates the sample to the entire older adult population reduce the effect of the percentage of missing data in this analysis.

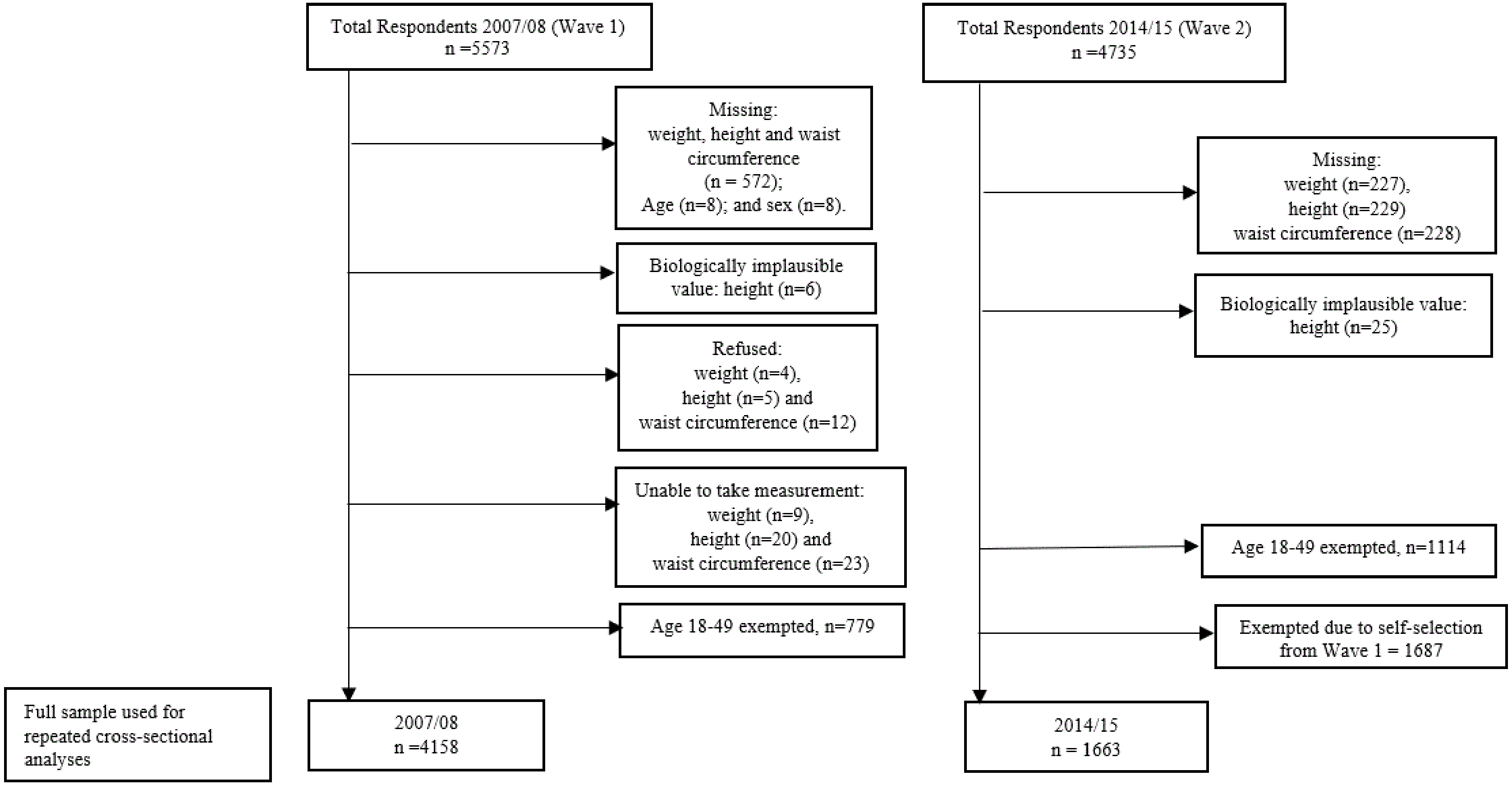


Figure 3. 1. Flowchart showing samples included in the analysis. Sample extracted from 2007/08 and 2014/15 of the WHO Study on global AGEing and adult health.

Measures

Explanatory factors

The definition of explanatory variables used in this study followed the ecological framework developed by Scott *et al* [90] and adapts the causality continuum model[1] for obesity in sub-Saharan Africa [139]. In their ecological framework, Scott *et al* indicated that factors influencing obesity could be situated in the distant, intermediate and proximate tiers. In the framework, the three tiers are found to interact and overlap with each other, and all influence the health outcome. Distant factors include globalization and urbanization, which affect factors such as lifestyle, food habits, and occupation. The intermediate factors include household and community level characteristics (e.g. household income and cultural perception about weight). Finally, the proximate factors include individual factors that directly affect the health outcome such as a genetic composition of the individual, food habits, and physical activity.

Distant factor: The distant factor included in this study was the location of participants' residence, i.e. rural or urban residence. Rural or urban residency, the two main types of localities used were defined based on the populations size. A population size less than 5,000 was classified as rural, and larger than 5,000 classified as urban. Intermediate factors: Household wealth, a proxy for household income representing the economic status of the household [140], was used as an intermediate factor. Even though household wealth is sometimes seen as a poor index for household consumption or expenditure, there has been a consistent lack of data in most low-and middle-income countries to measure the long-term economic status [85, 140-142]. In

[1] This model differentiates between the "degree of directedness of effect for various etiologic factors affecting health."

this study, household wealth was constructed using principal component analysis from 22 items that considered assets and the derived variable was indexed into five quintiles [143].

Proximate factors: These included sex, age, level of education completed and marital status. We also included smoking status, alcohol consumption, fruit and vegetable servings per day and level of physical activity per week. For estimation of age-specific prevalence, age was classified into 10-year intervals. The level of education was grouped into high education (completion of secondary/high school or higher) and low education (highest level of education completed was less than secondary or high school). Marital status was categorized as (1) single, (2) married/cohabiting and (3) divorced/separated/widowed. Respondents' smoking status was coded as (1) "never smoked", (2) "quitter" and (3) "current smoker". Alcohol consumption status was coded as (1) "never", (2) "quitter" and (3) "current drinker". We categorized responses about fruit and vegetable intake according to international standards [98]. Respondents met the recommendation if they consumed ≥5 servings of fruits and/or vegetables per day (equivalent to 400 grams). The level of physical activity was categorised as meeting or not meeting the recommended level of total physical activity per week [99, 144]. Using the Global Physical Activity Questionnaire (GPAQ) instrument that was included in the SAGE, physical activity was estimated by the total metabolic equivalents of task (MET) minutes per week. The analysis guide and STATA syntax was provided by the WHO STEPwise approach to Chronic Disease Risk Factor Surveillance (STEPS) [144]. Meeting the recommended level of total physical activity was defined as engaging in activities including work, during transport and leisure-time for at least 150 minutes of moderate-intensity activity per week or 75 minutes of vigorous-intensity activity per week [99].

Outcome variables

In WHO SAGE, anthropometric measurements of body weight, height, and waist circumference of respondents were taken by trained interviewers using a weighing scale, stadiometer and Gulick measuring tape following standard protocols [71]. BMI was calculated as a person's weight in kilograms divided by the square of their height in meters and obesity was defined using cut-offs following the WHO classification. BMI was classified into four categories and weighted prevalence estimated: underweight, BMI<18.50 kg/m^2; healthy/healthy weight, BMI≥18.50<25.00 kg/m^2; overweight, 25.00<30.00 kg/m^2; and obese as BMI≥30.00 kg/m^2 [145]. From the measured waist circumference, high central adiposity was determined using sub-Saharan Africa standards as waist circumference ≥81.2 cm for men, and ≥80.0 cm for women [86].

Statistical Analysis

Accounting for the complex survey design, survey weights were used to estimate age- and sex-specific prevalence of obesity and of high central adiposity. From the cross-sectional datasets, we tested whether the frequency of distribution of the categories of BMI and central adiposity were identical in each wave using the survey Pearson's chi-squared (X^2) test. The absolute and percentage differences in the frequency of each category of BMI and central adiposity between the two waves were calculated for males, females, and both sexes. The categories of BMI and central adiposity were cross-tabulated against the socio-demographic and behavioral factors in 3.2 and 3.3 Figs. We fitted survey multinomial and binomial logistic models to estimate odds ratios (OR) and their 95% confidence intervals (CI) of the weight status outcome with sociodemographic and behavioural factors.

The characteristics of the sample are presented in Table 3.1. Table 3.2 shows the prevalence, absolute and percentage differences in prevalence. In Tables 3.3 and 3.4, the univariable and multivariable regression results are presented in a corresponding manner. BMI categories and central adiposity were the outcome variables whiles the explanatory variables included were age, sex, educational and marital statuses, location of residence, household wealth, smoking and alcohol consumption statuses, fruit and vegetable intake, and total physical activities. Statistical analysis was performed in STATA 15, and a two-tailed *p value*<0.05 was determined as statistically significant.

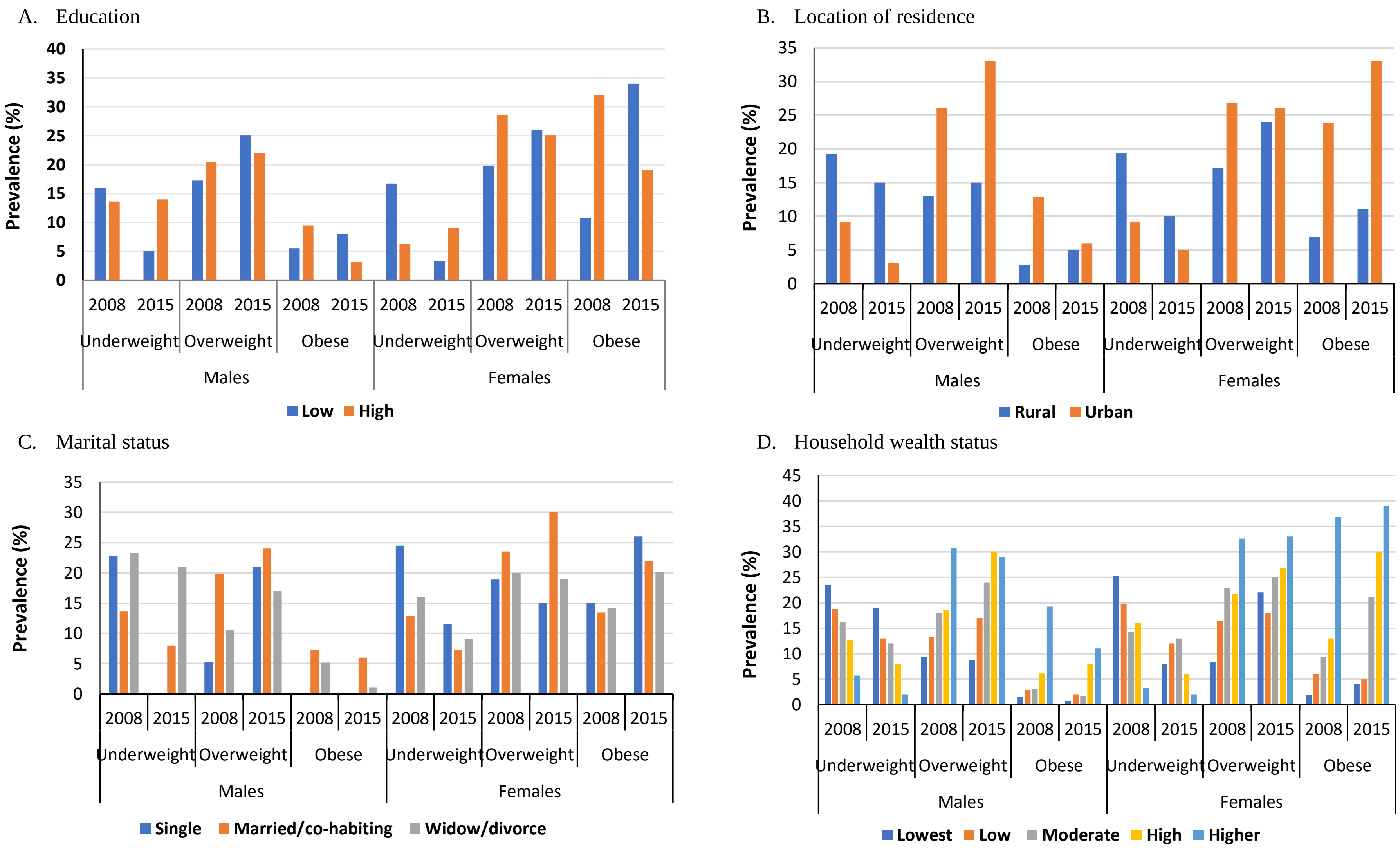


Figure 3. 2. (A-D). Distribution of underweight, overweight and obesity by socio-demographic factors in the older adult population of Ghana in 2007/08 and 2014/15.

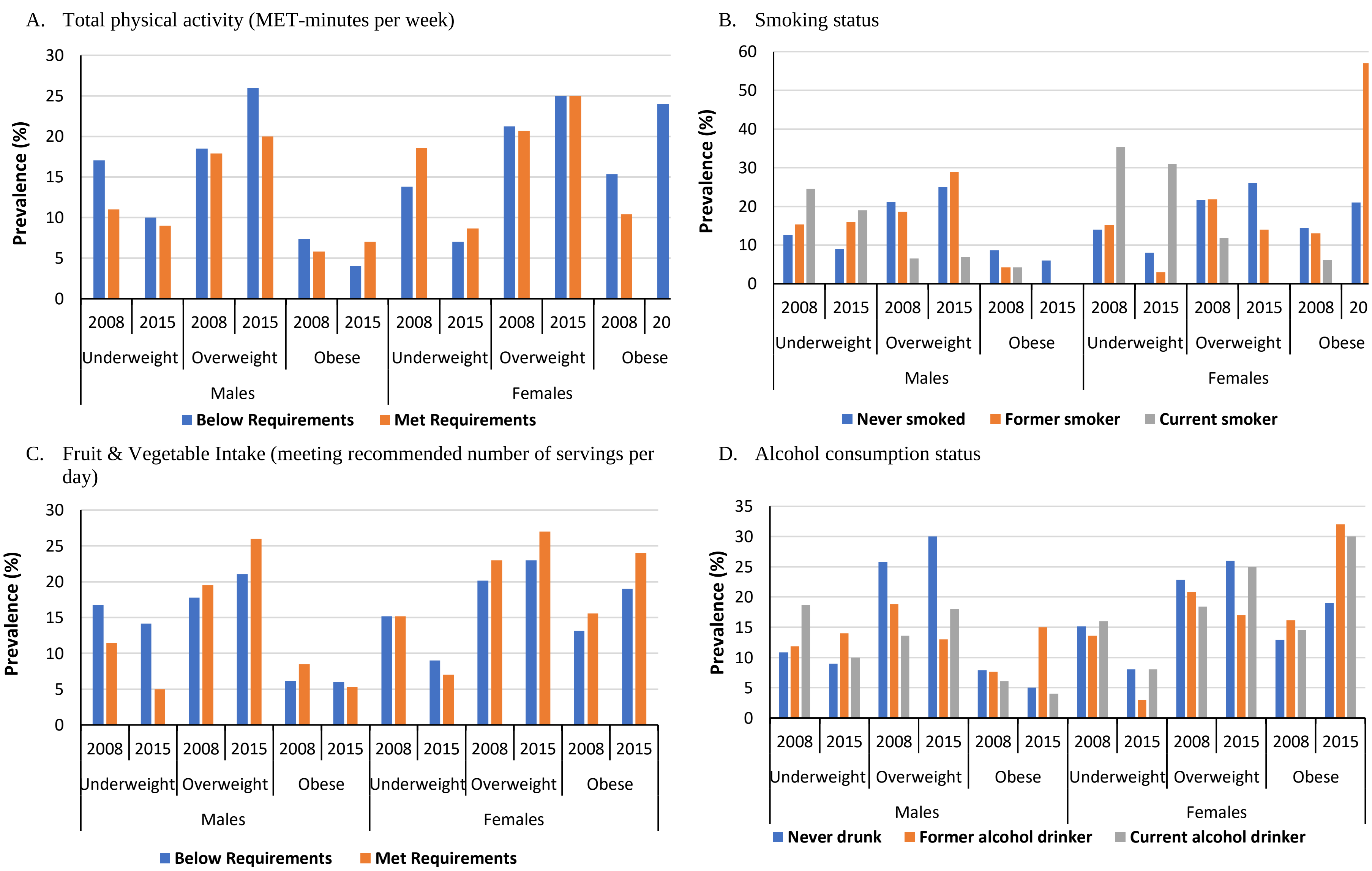


Figure 3. 3. (A-D). Distribution of underweight, overweight and obesity by behavioral factors in the older adult population of Ghana in 2007/08 and 2014/15

3.5 Results

In total, 4,158 persons (52% males) provided complete data in 2007/08 whilst 1,663 new persons (41% males) did so in 2014/15. Table 3.1 presents the estimated frequencies of the characteristics of the study population in 2007/08 and 2014/15. The population in 2014/15 was estimated to be around five years younger and 3.1kg heavier. Particularly for women, the proportion in the overweight/obese and high central adiposity categories were also higher in 2014/15.

Table 3.1. Characteristics of older people (50+ years) with complete responses in repeated cross-sectional data from WHO SAGE 2007/08 & 2014/15

		Males	Females
2007/08 (n=4158)			
n		52.7% (2191)	47.3% (1967)
Mean age, y		64.3 (10.8)	64.2 (10.5)
Mean weight (kg)		62.5 (13.8)	59.7 (15.8)
Mean height (m)		1.66 (8.42)	1.58 (7.42)
Mean waist circumference (cm)		83.3 (12.0)	86.4 (13.5)
‡Central Adiposity (WC ≥ optimal cut-point)		50.0% (1090)	66.6% (1317)
Mean BMI (kg/m^2)		22.8 (5.1)	24.0 (6.0)
BMI Categories	Underweight	15.1% (329)	15.2% (301)
	healthy BMI	59.7% (1302)	49.8% (985)
	Overweight	18.3% (399)	21.1% (417)
	Obese	6.9% (150)	13.9% (275)
2014/15 (n=1663)			
n		41.0% (682)	59.0% (981)
Mean age, y		58.2 (8.4)	59.5 (9.1)
Mean weight (kg)		64.6 (11.5)	64.1 (16.3)
Mean height (m)		1.67 (7.78)	1.58 (7.51)
Mean waist circumference (cm)		82.4 (12.9)	89.7 (18.6)
‡Central Adiposity (WC ≥ optimal cut-point)		54.4% (370)	75.6% (742)
Mean BMI (kg/m^2)		23.1 (3.8)	25.8 (6.7)
BMI Categories	Underweight	9.7% (66)	7.9% (77)
	healthy BMI	61.2% (418)	45.4% (446)
	Overweight	23.5% (160)	25.2% (247)
	Obese	5.6% (38)	21.5% (211)

All are weighted estimates. Data are mean (standard deviation) for continuous variables and percentages (sample, n) for categorical variables. BMI indicates body mass index; and WC, waist circumference. ‡ sub-Sahara waist circumference optimal cut-off points for men (WC≥81.2cm) and women (WC≥80.0cm).

The overall age- and sex-specific weighted prevalence of each BMI category and of high central adiposity in the repeated cross-sectional data are shown in Table 3.2. Relative to 2007/08, the 2014/15 prevalence of overweight (2007/08 =19.6%; 95% CI: 18.0-21.4%; 2014/15 =24.5%; 95% CI: 21.7-27.5%) and obesity (2007/08 =10.2%; 95% CI: 8.9-11.7%; 2014/15 = 15.0%; 95% CI: 12.6-17.7%) was higher. Obesity increased by about 47% while overweight increased by approximately 25% in the population. More than half of the population had high central adiposity in both waves (2007/08 =57.7%; 95% CI: 55.4-60.1%; 2014/15 =66.9%; 95% CI: 63.7-70.0%) with about a 16% increase over the 7 to 8-year period. Underweight reduced by about 43% in the population. In 2014/15, despite a decline in the prevalence of obesity for males (2007/08 =6.7%; 95% CI: 5.6-8.4%; 2014/15 =5.6%; 95% CI: 3.4-8.8%), the prevalence of overweight was high for males (2007/08 =18.3%; 95% CI: 16.2-20.6%; 2014/15 =23.5%; 95% CI: 18.6-29.2%); and the prevalence of both overweight (2007/08 =21.1%; 95% CI: 18.9-23.5%; 2014/15 =25.2%; 95% CI: 22.4-28.2%) and obesity (2007/08 =13.9%; 95% CI: 11.8-16.4%; 2014/15 =21.5%; 95% CI: 18.3-25.2%) were higher for females. The prevalence of high central adiposity was higher in 2014/15 for both males and females (Table 3.2).

Table 3.2. Age- and sex-specific prevalence (95% confidence interval) of body mass index (BMI) categories and high central adiposity (WC ≥ optimal cut-off point) for older people in Ghana

		Underweight	Healthy weight	Overweight	Obese		‡High Central Adiposity	
		*Pr (95% CI)	Pr (95% CI)	Pr (95% CI)	Pr (95% CI)	*P* Value	Pr (95% CI)	*P* Value
Total Sample	2007/08	15.2 (13.6, 16.8)	55.0 (52.8, 57.2)	19.6 (18.0, 21.4)	10.2 (8.9, 11.7)	<0.001	57.7 (55.4, 60.1)	<0.001
	2014/15	8.6 (7.1, 10.3)	51.9 (48.8, 55.0)	24.5 (21.7, 27.5)	15.0 (12.6, 17.7)		66.9 (63.7, 70.0)	
Absolute difference (95% CI)		-6.6 (-8.6, -4.4)	-3.1 (-6.7, -1.0)	4.9 (1.6, 8.1)	4.8 (2.0, 7.6)		9.2 (5.5, 12.8)	
% difference (95% CI)		-43.4 (-52.9, -31.2)	-5.6 (-11.8, 1.0)	25.0 (9.1, 42.7)	47.1 (21.6, 76.9)		15.9 (10.0, 22.0)	
Males: Age, y -specific prevalence (2007/08, n=2180; 2014/15, n=682)								
50-59	2007/08	11.2 (9.0, 13.9)	60.3 (56.3, 64.1)	21.0 (17.9, 24.5)	7.5 (5.8, 9.8)	0.155	51.0 (46.9, 55.1)	0.252
	2014/15	6.7 (4.3, 10.5)	61.4 (54.9, 67.5)	25.5 (19.5, 32.7)	6.3 (3.6, 10.8)		55.0 (48.6, 61.3)	
60-69	2007/08	14.1 (11.2, 17.7)	62.3 (57.8, 66.5)	16.7 (13.6, 20.4)	6.9 (4.9, 9.5)	0.326	48.7 (43.8, 53.7)	0.323
	2014/15	18.2 (11.5, 27.6)	58.0 (48.1, 67.4)	20.3 (13.3, 29.6)	3.5 (1.5, 8.1)		54.2 (44.3, 63.8)	
≥ 70	2007/08	21.0 (17.0, 25.5)	56.7 (51.9, 61.4)	16.3 (12.8, 20.4)	6.1 (4.0, 9.1)	0.607	49.2 (43.9, 54.7)	0.158
	2014/15	16.0 (9.4, 25.9)	65.5 (54.4, 75.1)	14.8 (8.9, 23.5)	3.8 (1.6, 8.8)		50.9 (41.0, 60.7)	
Total Male sample	2007/08	15.1 (13.3, 17.2)	59.7 (57.0, 62.3)	18.3 (16.2, 20.6)	6.7 (5.6, 8.4)	0.022	49.8 (46.8, 52.8)	0.117
	2014/15	9.7 (7.4, 12.8)	61.2 (56.2, 66.1)	23.5 (18.6, 29.2)	5.6 (3.4, 8.8)		54.4 (49.2, 59.5)	
Absolute difference (95% CI)		-5.4 (-8.6, 2.2)	1.5 (-4.0, 7.1)	5.2 (-0.5, 10.8)	-1.1 (-4.4, 1.7)		4.6 (-1.1, 10.4)	
% difference (95% CI)		-35.8 (-52.2, -13.4)	2.5 (-7.0, 13.3)	28.4 (2.4, 64.1)	-16.4 (-51.0, 33.0)		9.2 (-2.3, 22.1)	
Females: Age, y -specific prevalence (2007/08, n=1398; 2014/15, n=981)								
50-59	2007/08	9.7 (7.1, 13.2)	45.7 (40.8, 50.6)	24.7 (20.7, 29.1)	20.0 (16.0, 24.6)	0.012	70.6 (66.5, 74.5)	0.014
	2014/15	5.2 (3.7, 7.2)	42.6 (38.2, 47.2)	26.3 (22.7, 30.3)	25.8 (21.6, 30.6)		77.7 (73.3, 81.5)	
60-69	2007/08	12.2 (9.2, 16.1)	53.3 (48.1, 58.5)	22.1 (18.5, 26.2)	12.3 (9.8, 15.5)	0.125	69.6 (64.1, 74.6)	0.389
	2014/15	8.5 (5.3, 13.2)	51.1 (43.6, 58.5)	21.5 (16.6, 27.3)	18.9 (13.0, 26.8)		73.5 (65.7, 80.1)	
≥ 70	2007/08	24.3 (13.0, 19.3)	51.8 (47.4, 56.1)	15.9 (13.0, 19.3)	8.0 (5.8, 10.8)	0.042	59.1 (54.1, 63.9)	0.017
	2014/15	17.9 (12.6, 24.7)	49.1 (41.4, 56.8)	25.5 (18.5, 33.9)	7.6 (4.3, 13.1)		69.8 (62.1, 76.6)	
Total Female Sample	2007/08	15.2 (13.1, 17.5)	49.8 (46.7, 52.8)	21.1 (18.9, 23.5)	13.9 (11.8, 16.4)	<0.001	66.6 (63.6, 69.4)	<0.001
	2014/15	7.9 (7.9, 10.8)	45.4 (41.7, 49.1)	25.2 (22.4, 28.2)	21.5 (18.3, 25.2)		75.6 (71.9, 78.9)	
Absolute difference (95% CI)		-7.3 (-10.0, -4.7)	-4.4 (-8.9, 0.1)	4.1 (0.3, 7.9)	7.6 (3.7, 11.5)		9.0 (4.7, 13.3)	
% difference (95% CI)		-48.0 (-59.4, -34.0)	-8.8 (-16.7, -0.1)	19.4 (2.5, 39.1)	54.7 (26.8, 88.3)		13.5 (7.7, 19.6)	

*Pr (95% CI) means prevalence (95% confidence intervals). All are weighted estimates. ‡High central adiposity measured using sub-Sahara high waist circumference cut-off point for men (WC≥81.2cm) and women (WC≥80.0cm). Data were used from the 2007/08 (n=4150) and 2014/15 (n=1663) WHO SAGE (All subjects with complete responses used from the repeated cross-sections).

The distribution of prevalence of the BMI categories by socio-demographic and behavioral factors in 2007/08 and 2014/15 are shown in Figures 3.2 and 3.3. Generally, the prevalence of obesity was high in individuals who resided in urban areas and those from households with high/higher wealth status in both waves. While obesity was high in 2007/08 among those with high education, in 2014/15 it was rather high among both males and females with low education. Obesity was low among females who met the recommended physical activity level in both waves.

Results from the univariable analyses are presented in Table 3.3. In the multivariable analyses in 2007/08, being female (overweight: OR=1.47, 95% CI: 1.15-1.89; obesity: OR=2.49, 95% CI: 1.74-3.55; and high central adiposity: OR=2.03, 95% CI: 1.64-2.51), living in an urban area (obesity: OR=2.01, 95% CI: 1.41-2.86; and high central adiposity: OR=1.51, 95% CI: 1.19-1.92) and those from households with moderate, higher or higher wealth (overweight: OR=4.42, 95% CI: 2.84-6.89; obesity: OR=4.91, 95% CI: 2.41-10.17; and high central adiposity: OR=3.70, 95% CI: 1.22-6.85) were associated with higher odds of overweight, obesity and central adiposity (Table 3.4). However, being in age group 70+ years (overweight: OR=0.70, 95% CI: 0.54-0.90; obesity: OR=0.54, 95% CI: 0.36-0.80), currently smoking status (overweight: OR=0.54, 95% CI: 0.35-0.83; and high central adiposity: OR=0.69, 95% CI: 0.53-0.90), and current alcohol drinking (overweight: OR=0.64, 95% CI: 0.50-0.82) were associated with lower odds of overweight/obesity. Also, being in the 70+ years age group (underweight: OR=2.21, 95% CI: 1.73-2.84) and currently smoking status (underweight: OR=1.63, 95% CI: 1.18-2.25) were associated with higher odds of underweight while the odds of underweight was low among those with high/higher household wealth. In 2014/15, most associations found in 2007/08 remained the same with minimal changes in magnitude.

Table 3.3**.** Univariable regressions: Factor associated with BMI categories and central adiposity in year WHO-SAGE 2007/08 and 2014/15

		Year 2007/08 Underweight	Overweight	Obese	Year 2014/15 Underweight	Overweight	Obese	Year 2007/08 High Central Adiposity	Year 2014/15 High Central Adiposity
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age Groups, y	50-59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	60-69	1.17 (0.88, 1.53)	0.78 (0.62, 0.98) *	0.66 (0.48, 0.89) **	1.95 (1.21, 3.16) **	0.77 (0.55, 1.07)	0.73 (0.45, 1.18)	0.94 (0.79, 1.12)	0.94 (0.70, 1.26)
	≥ 70	2.11 (1.66, 2.69) ***	0.70, (0.56, 0.87) **	0.51 (0.36, 0.74) ***	2.76 (1.70, 4.49) ***	0.79 (0.53, 1.18)	0.35 (0.20, 0.60) ***	0.77 (0.65, 0.93) **	0.84 (0.63, 1.12)
Sex	Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female	1.20 (0.97, 1.49)	1.39 (1.13, 1.68) **	2.42 (1.84, 3.20) ***	1.09 (0.75, 1.58)	1.45 (1.05, 2.00) *	4.22 (3.14, 8.70) ***	2.01 (1.72, 2.34) ***	2.59 (1.97, 3.40) ***
Educational Status	Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	High	0.80 (0.62, 1.03)	1.38 (1.10, 1.74)	2.14 (1.61, 2.84)	2.43 (1.42, 4.14) **	0.98 (0.67, 1.43)	0.80 (0.53, 1.21)	1.57 (1.30, 1.91)	0.76 (0.55, 1.06)
Marital status	Single	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Married/ cohabiting	0.56 (0.27, 1.17)	1.65 (0.78, 3.49)	1.11 (0.41, 2.98)	1.14 (0.21, 3.31)	1.84 (0.69, 4.85)	0.87 (0.28, 2.73)	1.07 (0.64, 1.80)	0.98 (0.49, 1.96)
	Widow/divorce	0.79 (0.39, 1.60)	1.59 (0.75, 3.38)	1.72 (0.69, 4.31)	1.65 (0.29, 4.45)	1.18 (0.44, 3.18)	0.95 (0.29, 3.08)	1.48 (0.89, 2.46)	0.98 (0.50, 1.93)
Location	Rural	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Urban	0.62 (0.47, 0.82) **	2.32 (1.82, 2.97) ***	4.06 (2.56, 7.20) ***	0.47 (0.29, 0.78) **	1.89 (1.36, 2.61) ***	3.47 (2.14, 5.62) ***	2.61 (2.05, 3.32) ***	2.35 (1.73, 3.19) ***
Wealth Index	Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Low	0.84 (0.60, 1.16)	1.73 (1.20, 2.51) **	2.76 (1.29, 5.89) **	1.08 (0.65, 1.79)	1.13 (0.64, 1.99)	1.43 (0.43, 3.73)	1.60 (1.27, 2.02) ***	1.49 (0.99, 2.23)
	Moderate	0.70 (0.52, 0.95) *	2.56 (1.76, 3.72) ***	3.25 (2.04, 6.82) ***	1.43 (0.78, 2.63)	2.00 (1.18, 3.40) *	3.72 (1.98, 6.87) **	2.06 (1.59, 2.66) ***	2.24 (1.44, 3.48) ***
	High	0.70 (0.48, 1.01)	2.66 (1.81, 3.91) ***	3.92 (2.32, 7.44) ***	0.88 (0.46, 1.65)	2.56 (1.53, 4.28) ***	4.26 (2.81, 8.25) ***	2.40 (1.84, 3.12) ***	2.78 (1.75, 4.41) ***
	Higher	0.34 (0.21, 0.54) ***	4.26 (2.33, 7.05) ***	4.94 (2.46, 9.54) ***	0.28 (0.31, 0.60) **	3.27 (1.92, 5.58) ***	5.17 (3.07, 10.10) ***	3.95 (2.80, 6.90) ***	3.84 (2.37, 6.22) ***
Smoking status	Never Smoked	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	0.99 (0.71, 1.40)	0.77 (0.57, 1.05)	0.37 (0.23, 0.60) ***	1.58 (0.50, 3.01)	1.08 (0.40, 2.92)	1.84 (0.31, 4.98)	0.97 (0.76, 1.25)	1.02 (0.36, 2.91)
	Currently smoke	1.78 (1.33, 2.38) ***	0.32 (0.22, 0.47) ***	0.34 (0.17, 0.68) **	1.87 (0.88, 3.97)	0.18 (0.07, 0.48) **	0.18 (0.04, 0.81) *	0.67 (0.55, 0.80) ***	0.23 (0.13, 0.41) ***
Alcohol Consumption Status	Never drunk alcohol	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	0.88 (0.64, 1.21)	0.76 (0.56, 1.03)	1.00 (0.70, 1.44)	0.90 (0.43, 1.91)	0.54 (0.30, 0.98) *	1.57 (0.82, 3.01)	0.59 (0.47, 0.73) ***	1.84 (1.03, 3.27) *
	Currently Drinks	1.18 (0.93, 1.51)	0.57 (0.45, 0.71) ***	0.75 (0.55, 1.02)	0.94 (0.58, 1.51)	0.64 (0.42, 0.97) *	0.69 (0.38, 1.26)	0.37 (0.28, 0.47) ***	0.69 (0.49, 0.96) *
Fruit & Vegetable Intake	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.86 (0.66, 1.12)	1.17 (0.95, 1.42)	1.32 (1.02, 1.72) *	0.57 (0.39, 0.84) **	1.23 (0.91, 1.67)	1.32 (0.91, 1.92)	1.61 (1.32, 1.96) ***	1.27 (0.95, 1.71)
Total Physical Activity	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.85 (0.67, 1.08)	0.88 (0.71, 1.10)	0.64 (0.47, 0.87) **	1.05 (0.72, 1.54)	0.85 (0.62, 1.17)	0.81 (0.55, 1.19)	0.76 (0.63, 0.92) **	0.84 (0.63, 1.11)

**p<0.05, **p<0.01, ***p<0.001;* Fruit & Vegetable Intake (serving per day); Total Physical Activity (Minutes per week); Year is the year for completion of data collection

Table 3.4. Multivariable regressions: predictors of overweight, obesity and central adiposity in year WHO-SAGE 2007/08 and 2014/15

		Year 2007/08			Year 2014/15			Year 2007/08	Year 2014/15
		Underweight	Overweight	Obese	Underweight	Overweight	Obese	High Central Adiposity	High Central Adiposity
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age Groups, y	50-59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	60-69	1.17 (0.88, 1.55)	0.79 (0.61, 1.10)	0.67 (0.49, 0.91) *	1.94 (1.19, 3.18) **	0.77 (0.55, 1.09)	0.59 (0.36, 0.97) *	1.01 (0.83, 1.23)	0.93 (0.71, 1.22)
	≥ 70	2.21 (1.73, 2.84) ***	0.70, (0.54, 0.90) **	0.54 (0.36, 0.80) **	2.45 (1.49, 4.04) ***	0.87 (0.57, 1.31)	0.34 (0.18, 0.62) **	0.86 (0.70, 1.07)	0.94 (0.68, 1.29)
Sex	Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female	1.23 (0.88, 1.71)	1.47 (1.15, 1.89) **	2.49 (1.74, 3.55) ***	0.81 (0.52, 1.26)	1.70 (1.16, 2.49) **	4.65 (2.65, 9.09) ***	2.03 (1.64, 2.51) ***	3.36 (2.42, 4.68) ***
Educational Status	Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	High	1.34 (1.02, 1.78) *	0.97 (0.73, 1.28)	1.15 (0.83, 1.60)	1.86 (1.00, 3.42)	1.22 (0.80, 1.86)	0.94 (0.61, 1.46)	1.17 (0.93, 1.47)	0.74 (0.49, 1.14)
Marital status	Single	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Married/ cohabiting	0.60 (0.29, 1.23)	2.00 (0.92, 4.35)	1.60 (0.64, 3.96)	1.17 (0.17, 2.93)	2.25 (0.81, 4.21)	1.61 (0.63, 4.11)	1.25 (0.69, 2.25)	1.54 (0.69, 3.43)
	Widow/divorce	0.74 (0.37, 1.08)	1.50 (0.68, 3.31)	1.65 (0.69, 3.95)	1.39 (0.19, 3.94)	1.20 (0.44, 3.28)	1.11 (0.43, 2.84)	1.16 (0.67, 2.02)	1.10 (0.46, 2.23)
Location	Rural	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Urban	0.79 (0.57, 1.08)	1.44 (1.08, 1.92) *	2.01 (1.41, 2.86) ***	0.53 (0.32, 0.87) *	1.38 (0.96, 1.98)	1.73 (1.03, 2.89) *	1.51 (1.19, 1.92) **	1.91 (1.33, 2.74) **
Wealth Index	Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Low	0.87 (0.62, 1.21)	1.52 (1.05, 2.21) *	2.40 (1.13, 5.13) *	1.12 (0.65, 1.91)	1.13 (0.66, 1.95)	1.53 (0.45, 3.21)	1.31 (1.02, 1.69) *	1.43 (0.93, 2.20)
	Moderate	0.77 (0.51, 1.17)	2.01 (1.33, 3.04) **	3.17 (1.50, 6.68) **	1.91 (1.04, 3.50) *	2.03 (1.16, 3.55) *	3.17 (1.87, 6.31) **	1.56 (1.18, 2.07) **	1.66 (1.02, 2.69) *
	High	0.71 (0.51, 0.97) *	2.15 (1.46, 3.16) ***	3.79 (1.96, 7.93) ***	1.20 (0.68, 2.67)	2.57 (1.50, 4.42) **	3.76 (2.27, 7.28) ***	1.57 (1.16, 2.11) **	2.33 (1.42, 3.81) **
	Higher	0.40 (0.23, 0.68) **	4.42 (2.84, 6.89) ***	4.91 (2.41, 10.17) ***	0.52 (0.22, 1.21)	3.29 (1.89, 5.74) ***	4.67 (2.39, 8.53) ***	3.70 (3.22, 6.85) ***	2.45 (1.39, 4.32) **
Smoking status	Never Smoked	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	1.08 (0.74, 1.57)	0.92 (0.68, 1.26)	0.53 (0.30, 0.92) *	1.68 (0.50, 3.64)	1.73 (0.61, 4.95)	3.48 (0.86, 6.19)	0.77 (0.59, 0.10)	1.06 (0.43, 2.60)
	Currently smoke	1.63 (1.18, 2.25) **	0.54 (0.35, 0.83) **	0.88 (0.46, 1.69)	1.66 (0.69, 4.00)	0.31 (0.11, 0.90) *	0.48 (0.10, 2.23)	0.69 (0.53, 0.90) **	0.44 (0.22, 0.88) *
Alcohol Consumption Status	Never drunk alcohol	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	0.88 (0.63, 1.23)	0.71 (0.51, 0.97) *	0.85 (0.57, 1.29)	0.68 (0.32, 1.43)	0.56 (0.30, 1.06)	1.47 (0.64, 3.38)	0.96 (0.74, 1.24)	2.52 (1.38, 4.59) **
	Currently Drinks	1.19 (0.93, 1.54)	0.64 (0.50, 0.82) ***	0.95 (0.68, 1.31)	0.91 (0.56, 1.49)	0.78 (0.48, 1.27)	1.21 (0.70, 2.08)	0.86 (0.72, 1.03)	1.11 (0.78, 1.58)
Fruit & Vegetable Intake	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.98 (0.75, 1.27)	1.05 (0.85, 1.29)	1.16 (0.90, 1.49)	0.57 (0.37, 0.86) **	1.16 (0.85, 1.60)	1.25 (0.82, 1.90)	1.51 (1.23, 1.84) ***	1.27 (0.92, 1.72)
Total Physical Activity	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.81 (0.64, 1.02)	1.01 (0.80, 1.27)	0.78 (0.57, 1.08)	1.12 (0.73, 1.71)	0.82 (0.59, 1.14)	0.72 (0.49, 1.08)	0.82 (0.67, 0.99) *	0.89 (0.66, 1.20)

**p<0.05, **p<0.01, ***p<0.001;* Fruit & Vegetable Intake (serving per day); Total Physical Activity (Minutes per week); Year is the year for completion of data collection

An interaction term between the age categories and sex in a multivariable regression showed that the product of age and sex were not significantly associated with the BMI categories for all age groups in both 2007/08 and 2014/15 except for females between the age of 50-59 years in whom there was a significant association for higher odds of obesity (OR=2.67; 95% CI: 1.34-5.30) in 2007/08. The same interaction using central adiposity as the outcome also revealed significantly higher odds of high central adiposity among females aged 50-59 years (OR=1.69; 95% CI: 1.10-2.58) and 60-69 years (OR=1.54; 95% CI: 1.06-2.25) only in 2007/08. We also examined whether respondents sex modified the association between physical activity and BMI categories and central adiposity. No significant associations were found in 2007/08. However, in 2014/15, not meeting the recommended physical activity level among females was associated with higher odds of obesity (OR=3.23; 95% CI: 1.13-6.23) and high central adiposity (OR=2.19; 95% CI: 1.32-3.63).

3.6 Discussion

This study estimated changes in the prevalence and determinants of BMI and central adiposity in the older adult population of Ghana between year and 2007/08 and 2014/15. We found that over the 7 to 8-year period the prevalence of obesity had increased by 47%, overweight by 25%, but underweight reduced by 43%. However, we found heterogeneity by sex with females showing a 55% increase in the prevalence of obesity compared with a 16% reduction among males over the same period. While we provide estimates of the temporal change in BMI categories and high central adiposity for the total population (males and females combined), there are reasons why the sex-stratified estimates should be prioritised. First, as the ratio of males to females reduced between waves, the estimates for the secular changes at the population level are weighted toward females. Second, we observed a sex difference in the temporal change in obesity where males decreased, and females increased from 2007/08 to 2014/15. Being female, living in an urban area and having high household wealth were associated with higher odds of obesity/high central adiposity while those aged 70+ years was associated with lower odds of obesity. Additionally, in 2014/15, not meeting the recommended physical activity among females was associated with higher odds of obesity and central adiposity.

Findings in this study showed that while the prevalence of underweight reduced over the period, overweight, obesity and central adiposity increased over the same period. The increased prevalence of overweight, obesity (in females) and central adiposity could have a negative public health implication as obesity buttresses the increasing burden of NCDs in most low-and middle-income countries. Even though most previous studies in sub-Saharan Africa were cross-sectional studies, most of the studies found a higher prevalence of overweight/obesity in the female population compared to their male counterparts [8, 11, 36, 146]. This phenomenon has been attributed to the body preference of most females [8, 111, 115, 146, 147]. However, a recent study of African-Americans suggested that being male with West-African ancestry genes could be protective against obesity specifically, high central adiposity and hence could be a reason for the male/female disparities [148]. Furthermore, high odds of overweight/obesity among African females in many parts of sub-Saharan Africa and elsewhere, have also been largely attributed to general cultural preference in which overweight/obesity is regarded as a source of beauty and a sign of affluence [36, 115]. In Ghana, this could also be attributed to generally low levels of physical activities in the population [36, 109]. This corroborates this study’s finding that low physical activities in females was associated with higher odds of obesity and central adiposity suggesting that promotion of physical activity may support efforts to reduce obesity in females in Ghana as in other population [47, 149].

Overweight and obesity prevalence in both waves was high in females in all age groups with a decline noted after age 59 years. In males, we observed non-significant declines for obesity and increases for high central adiposity across all age groups. The observed difference in trends for obesity and high central adiposity in males was unexpected but could be attributed to the following reasons. First, the differences could reflect where the respective cut-offs for BMI and waist circumference lie on their distributions. As shown in Table 3.2, whereas about half of the male population had high central adiposity, less than 10% were obese in both waves. Second, this difference could also reaffirm that BMI may not be as sensitive to changes in excess adiposity compared with waist circumference [150].

While obesity prevalence was found to generally increase with age in some developed countries, in most developing countries, it was found to peak around age 50 years, then decline afterward [151]. In this study, a decline in obesity prevalence rates was found after age 59 years in females. Such trends may demand deliberate attention as those aged over 50 years supply the majority of the labour force for agricultural productivity, which has played a major role in sustainable development and poverty reduction in Ghana [45]. Increased obesity prevalence in this age group may lead to higher NCDs and consequently increase overall mortality as well as increasing the medical cost of care [129]. This can further lead to increased absenteeism from work and reduced work productivity, negatively impacting the economy [129, 152].

Urban residency was also associated with higher odds of overweight/obesity and central adiposity in both waves. Residing in an urban area has shown a similar association with obesity in previous studies in Africa and elsewhere [8]. Urban residency is mostly associated with changes in diets and food availability, increased dependence on mechanized transportation, especially in older people coupled with an increasingly sedentary lifestyle and the loss or lack of open and safe places for physical activities [90, 112]. Dietary transition from nutritious foods to the consumption of easily accessible cheap calorie-dense foods as well as longer hours spent on buses and in cars in traffic may have been key drivers of increasing obesity prevalence in urban areas [109, 110, 112], and this is likely to be the same in Ghana. Older people, especially those over the ages 65 years, tend to rely heavily on their children and grandchildren for activities of daily living [153]. These activities include food preparation and timely food supply. These children, who may be busy on the labour market, may be restricted in their ability to prepare home-made foods for them. They may, therefore, resort to purchasing calorie-dense fast-foods. It is also possible that the reliance on others for food sources/preparation amongst those aged over 70 years may contribute to loss of weight, which agrees with the finding in this study that those aged 70+ years had higher odds of underweight.

The finding that high household wealth is associated with higher odds of overweight/obesity and central adiposity in both waves in this population concurs with findings in other low-and middle-income countries [36, 114]. Finding in this study is the opposite of what is observed in most developed countries where individuals from socioeconomic disadvantaged households tend to be at increased risk of obesity [37, 154]. Household wealth, a proxy for household income, was expected to have a positive impact resulting in good health outcomes for the individuals within a household as it has been in most developed countries [37]. Findings in this study support Philipson and Posner's [114] argument that income has a positive impact on weight in less-developed economies; however, as economic development improves, this relationship tends to become negative in the long term. It is suspected that because rich households in LMICs can afford many varieties of foods, increased household wealth could potentially contribute to changes in food preference, increased food consumption and poor choices regarding dietary intake [155].

As part of lifestyle factors, the finding that smoking was associated with lower odds of overweight has been found in previous studies where current smokers were less likely to have increased body weight compared to those who have never smoked before [156]. In 2007/08 quitting smoking was associated with lower odds of obesity however in 2014/15, currently smoking was rather associated with lower odds of overweight which agrees with previous findings in a randomized control trial [157]. As findings in this study are from repeated cross-sectional studies, we are unable to confer causality. Further studies are necessary to confirm the strength and direction of the association.

This study has several strengths. First, missing from the extant literature is a study that tracks trends in obesity prevalence among older adults in Ghana. We used the most current data to measure prevalence, changes in prevalence and factors associated with overweight/obesity among older adults about whom little is known in sub-Saharan

Africa. Second, the prevalence estimates will be useful in establishing and predicting the future economic burden of obesity on health in this population. Third, the inclusion of waist circumference, a marker of central adiposity and a prime marker of cardiometabolic diseases, provides added confirmation of findings in this study. Finally, the use of a population-based data that is representative of the older adult population, and uses objectively measured rather than self-reported weight, height, and waist circumference to determine obesity in the population are major strengths.

This study had some limitations. First, given that this study uses data from cross-sectional studies, results focused on associations and not causality [36]. Second, the study focuses only on those who were 50 years and above and does not cover the entire population. Therefore, conclusions from this study is limited to the population of 50 years and above. Finally, although the data is representative of the population aged 50 years and over, the analysis omits observations with missing data (13% in 2007/08 and 4.8% in 2014/15) on variables such as weight, height and waist circumference. Hence, there is a chance for selection bias to be introduced that might have affected external validity. However, the analytical sample was large, and the use of the post-stratified persons' weight supported the analysis.

3.7 Conclusion

We found a decline in underweight among Ghanaian older adults, an increase in overweight among males and females, and an increase in obesity among females only. The Ghana NCDs management strategy 2012-2016 focused on reducing by 2% the overweight and obesity prevalence in females age 15-49years, neglecting those aged 50+ years. However, the exponential increase in the current estimates of overweight and obesity prevalence suggest the need for policy initiatives aimed at reducing overweight and obesity, especially among females aged 50+ years and the importance of advancing surveillance. This study also identifies some factors associated with high obesity prevalence such as being female, living in an urban area and having high household wealth that could inform prevention and intervention programs in improving the health and well-being of older adult populations in sub-Saharan Africa.

3.8 Postscript

Chapter 3 aimed to examine recent changes in the prevalence and determinants of obesity in older adults in Ghana between 2007/08 and 2014/15. In the seven years between Wave 1 and Wave 2, the prevalence of overweight increased by 25% from 20% in Wave 1 to 25% in Wave 2 and obesity prevalence increased by 47% from 10% in Wave 1 to 15% in Wave 2 among the older adults. Underweight decreased by 43% in the older adult population. While a 55% increase in obesity prevalence was observed in females, a 16 % decrease in obesity prevalence was observed in males. Female sex, urban residence, and high household wealth were associated with higher odds of overweight/obesity and high central adiposity in both Wave 1 and Wave 2. In Wave 2, females who did not meet the recommended physical activity were more likely to be obese.

As a population with little information on the issue of obesity, this study was critical to support the identification, development and targeting of weight reduction interventions. The difference in obesity prevalence may point to differential impacts of past initiatives to reduce overweight and obesity among potential high-risk groups in Ghana, and the need to increase surveillance. The impact of these past initiatives have not been formally evaluated and therefore, one can only refer to their potential impacts. Some of the initiatives in-country include the continual comprehensive behaviour change communication by the Ghana Health Services [158] and Ghana government promotion of the use of locally produced foods [159]. The main idea is to support obesity prevention. This initiative highlights the value of consuming "whole, fresh, and unprocessed ingredients". The estimated prevalence is also very essential in developing a model for cost-effectiveness analysis of strategies. Another key health economic parameter necessary for cost-effectiveness analysis is the HSUs. The development of HSUs specific to Ghana is described in Chapter 4.

4 Estimation of age- and sex-specific health state utilities (HSUs), along with HSUs by weight status; and the associations between HSUs and overweight and obesity

4.1 Preface

In recent times, Ghana has identified the need to improve the quality and efficiency in its healthcare services to be able to achieve Universal Health Coverage and the Sustainable Development Goal 3 on health [63]. However, some of the key effectiveness measures required for economic evaluations are lacking in Ghana, including HSUs. HSUs are used to calculate QALYs for use in cost-utility analyses (CUA), a commonly used methodology to inform more effective prioritisation of scarce healthcare resources. This chapter bridges this gap by deriving and reporting the first age- and sex-specific HSUs for Ghana, along with HSUs by BMI status. The HSUs stratified by BMI status were instrumental in developing the health economic model presented in Chapter 7.

The following text in this chapter has been published in Value Health (Appendix 3). **Lartey, S.T**., Si L., de Graaff, B., Hasnat, A., Biritwum, R.B., Minicuci, N., Kowal, P., Magnussen, C.G., & Palmer, A.J (2019). Evaluation of the association between health state utilities and obesity in sub-Saharan Africa: Evidence from WHO Study on global AGEing and adult health (SAGE) Wave 2. *Value Health*; 22(9):1042–1049

4.2 Abstract

Objectives: To estimate age and sex-specific health state utilities (HSUs) for Ghana, along with HSUs by weight status. Associations between HSUs and overweight and obesity will be examined.

Methods: Data were sourced from the World Health Organization's WHO Study of global AGEing and adult health (WHO SAGE), 2014/15. Using a "judgement-based mapping" method, responses to items from the World Health Organization Quality-of-Life (WHOQOL-100) used in the WHO SAGE were mapped to EQ-5D-5L profiles; and the Zimbabwe value set was applied to calculate HSUs. Post-stratified sampling weights were applied to estimate mean HSUs and a multivariable linear regression model was used to examine associations between HSUs and overweight/obesity.

Results*:* Responses from 3,966 adults aged 18-110 years were analyzed. The mean (95 % confidence interval) HSU was 0.856 (95% CI: 0.850, 0.863) for the population, 0.866 (95% CI: 0.857, 0.875) for males and 0.849 (95% CI: 0.841, 0.856) for females. Lower mean HSUs were observed for obese individuals and with older ages. Multivariable regression analysis showed that HSUs were negatively associated with obesity (-0.024; 95% CI: -0.037, -0.011), being female (-0.011; 95% CI: -0.020, -0.003) and older age groups in the population.

Conclusions*:* The study provides HSUs by sex, age and BMI categories for the Ghanaian population, and examines associations between HSU and high BMI. Obesity was negatively associated with health state utility in the population. These data can be used in future economic evaluations for Ghana and sub-Saharan African populations.

4.3 Introduction

Overweight and obesity, hereafter referred to as high body mass index (BMI), has become a major public health challenge with increasing prevalence reported among adults aged 18 years and above in most parts of the world, including sub-Saharan Africa, between 1980 and 2014 [6]. In particular, the prevalence of obesity amongst adults in urban West African populations has doubled over a period of 15 years since 1990 [8, 134], an indication for the need to institute sustainable prevention and management measures. BMI is widely used to determine whether someone is in a healthy weight range for a given height. It is calculated as body mass (measured in kilograms) divided by the square of body height (measured in meters). The World Health Organization (WHO) defines overweight as a BMI $\geq$25.00 and < 30.00 kg/m^2, and obesity as a BMI $\geq$30.00 kg/m^2 [145]. Whilst high BMI is often regarded culturally as a source of beauty and a sign of affluence in some developing countries [8, 37], it is associated with many chronic diseases including type 2 diabetes mellitus, hypertension, lipid disorders, osteoarthritis, gallbladder disease, strokes, some cancers, heart disease, obstructive sleep apnoea as well as reduced life expectancy [122, 126]. Internationally, several studies have reported that high BMI has further been associated with a reduction in quality-adjusted life years, and a high economic burden due to the associated medical and treatment costs [128, 129, 160].

Health state utilities (HSUs) indicate the numerical strength of preference for a health state, and are globally accepted as health-related quality of life (HRQoL) weights [161, 162]. Age and sex- specific HSUs for a population can be used to calculate quality-adjusted life-years (QALYs), a common measure of effectiveness used in cost utility analysis (CUA) [1]. CUA is a common approach used in health economic evaluations to inform and support decision making [163]. CUA is mostly used by many health economic evaluation entities, as it allows for comparisons across different health interventions and diseases, and incorporates more aspects of health and well-being [163, 164].

Several outcome measures can be used in CUA, including disability-adjusted life-years (DALYs), health-adjusted life years (HALYs), healthy years equivalent (HYE) and QALYs [1]. QALYs, one of the most commonly used outcomes, combines HSUs with survival time. The HSU scale ranges from 0 (corresponding to death) to 1 (corresponding to perfect health), with negative values representing states worse than death [1].

Preference-based measures for health outcomes are used to estimate HSUs with a pre-scored multi-attribute health status classifications system [1, 165, 166]. However, generic preference-based measures are not often used in clinical trials of new therapies and it is more common that a non-preference-based measure is adopted to measure the health status of interest. Even though generic preference-based measures have been used in health economic evaluations in Europe for a longer period [167], the use of health economic evaluations and specific instruments is relatively new in many parts of the world [64]. Hence the lack of inclusion of generic preference-based measures in clinical trials. In this case, mapping or cross-walking from non-preference-based measure to preference-based measure can be used to statistically estimate the HSUs [1, 166, 168-170]. In recent times, many mapping models have been developed to estimate HSUs. These models use a range of statistical methods, including ordinary least squares, two-part models, ordinal logit or multinomial logit regression models, cart analysis, and the Censored Least Absolute Deviation Model (CLAD) [166].

Whilst HSUs are essential for CUA, they are lacking in most low and middle-income countries including sub-Saharan Africa, largely because preference-based measures have not been included in data collections [64]. In addition, the absence of algorithms/value sets has been a further barrier [64]. In such situations, algorithms/value sets from similar populations have previously been adopted as proxies for more precise local utilities [128, 170-172].

To achieve the Universal Health Coverage and the Sustainable Development Goal three on health, Ghana has identified the need to improve the quality and efficiency in its healthcare services to provide fair and equitable access to health [63, 173]. However, the lack of parameters including those to measure effectiveness has been a major challenge hindering the course of conducting health economic evaluations in the population [44]. Hence the need to develop these parameters. This study aims to address one aspect of this, by providing HSU estimates for both the general population of Ghana and for BMI categories. HSU data for the general population can be used across a broad range of health economic evaluations in Ghana and similar countries that lack such data. This can be particularly useful when evaluating new interventions for which short-term trial data is available. As many health economic evaluations adopt medium- to long-term time horizons, estimates of general population HSUs can be used for the period following the trial. For example, in a cost-effectiveness analysis of intensive versus standard blood-pressure control [174], long-term HSUs were based on general population HSUs from the Medical Expenditure Panel Survey. Also, in the cost-effectiveness analysis of screening for osteoporosis in Chinese women, the age-specific HSUs for the female general population were retrieved from the National Health Services Survey 2008-a population-wide survey for the comparator [175]. As such, the HSUs reported in this study will be critical to future health economic evaluations in the Ghanaian population. Thus, the estimated HSUs in this study are intended for use in a range of health economic models including that which will simulate progression through the BMI health states to assess the impact of changing prevalence on clinical and economic outcomes.

HSUs may differ based on factors such as age, sex and BMI status [128, 132, 176]. Generating these HSUs could differentiate the quality-of-life of men and women across different ages and BMI categories, and hence improve the accuracy of the cost-effectiveness results. Thus, this study aims to derive the first age and sex-specific HSUs and HSUs stratified by weight status (i.e. healthy weight, overweight, obese) for Ghanaian adults, and examine the extent to which HSUs are associated with overweight and obesity.

4.4 Methods

Study Population

Data for persons aged ≥18 years from Wave 2 of the World Health Organization's Study on global AGEing and adult health (WHO SAGE) in Ghana were used [69, 177]. Briefly, SAGE collected individual-level data from nationally representative households of adults using a stratified, multistage cluster design. The primary sampling units (PSUs) were stratified by region and location of residence (urban/rural) with samples selected from 250 enumeration areas. This study utilized responses from the individual questionnaire in the individual dataset. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee

(Ghana). Further information on WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

Of the 4,735 survey respondents, 229 had missing data for height, 227 for weight and 207 for one or more EQ-5D-5L dimensions. Also, biologically implausible values (height <100cm or >250 cm and weight <30.0 kg or >250.0 kg) were excluded using listwise deletion [72, 73]. A total of 229 (4.8%) respondents who had missing data and 25 (0.005%) with biologically implausible values were excluded from the analyses. As the focus of this study was on those with high BMI, those who were underweight (weighted proportion=7%) were excluded from the analyses. In total, 16% of observations were excluded from the analyses. Consequently, 3,966 (84%) participants who had complete responses were included in the final estimation sample for this study.

Variables

Outcome Variable: Health State Utilities (HSUs)

Ideally, the collection of primary data using a preference-based measure is used to calculate HSUs. However, preference-based measures have not been used in large population surveys in Ghana: the WHO SAGE employed the WHOQOL-100, a non-preference-based measure. The items on the WHOQOL-100 have been used in more than 100 studies worldwide to measure quality of life [178]. However, WHOQOL-100 is a non-preference-based instrument and HSUs cannot be directly calculated. To calculate HSUs, a two-step approach was used. First, using a judgement-based method [162, 169, 179], items from the WHOQOL-100 questionnaire in the WHO SAGE individual questionnaire were mapped onto the EQ-5D-5L, a preference-based measure. Second, according to the responses in the WHOQOL-100, a HSU was assigned for each individual using the EQ-5D-5L scoring algorithm.

A valid judgement-based mapping could be achieved in one of two ways [169]: first, the dimensions of the preference-based measure must be included in the source measure, e.g., survey, and items must correspond to those of the preference-based measure. The mapping could be conducted using the dimensions or items. Another approach is to choose specific health states described in the source measure and assign them onto a generic health state descriptive system or the preference-based measure. Due to the subjectivity associated with this method [169], and structural challenges especially, when response levels are condensed, empirical mapping methods [1] are preferred. However, the 'judgement-based' method of mapping is a useful alternative to generate HSUs where a non-preference-based measure is the only measure included in a study, as in the case of WHO SAGE. Despite the usefulness of the 'judgement-based mapping' in such conditions, this method should not supersede the empirical methods of mapping when data are available from both preference and non-preference-based measure for the same population, and this weakness should be considered when interpreting results in this study.

The EQ-5D-5L instrument is a simple and widely used generic preference-based measure used to estimate HSUs. The EQ-5D-5L comprises five domains: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, with five response options [167] (1 for no problems, 2 for slight problem, 3 for moderate problems, 4 for severe problems and 5 for extreme problems/unable to perform activity). The WHOQOL-100 instrument is an international, cross-cultural comparable tool that covers 24 facets hierarchically organized within six domains including physical, psychological, level of independence, social relationships, environment and spirituality, with an additional facet representing overall quality of life and health. For each item under the domains, five response options are available (1 for none or no problem, 2 for mild, 3 for moderate, 4 for severe and 5 for extreme) [178]. Under the domains, there are items that address mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Thus, the EQ-5D-5L and WHOQOL-100 have domains and response items that closely correspond to each other.

The EQ-5L-5L responses were mapped with 1 through 5 corresponding to 1 through 5 on the WHOQOL-100 item responses (Table 4.1) and then assigned values/utility weights derived from the EQ-5D-5L value set. Judgement-based mapping of the WHOQOL-100 items to EQ-5D-5L was advantageous because each WHOQOL-100 item had five level responses that corresponded directly to the responses on the EQ-5D-5L. Furthermore, use of the EQ-5D-5L instead of the EQ-5D-3L had the advantage of reducing the ceiling effect and improved the discriminatory effect [180, 181]. In addition, aside from mapping closely corresponding questions from both instruments, directly mapping five-level WHOQOL-100 to five-level EQ-5D-5L rather than condensing the WHOQOL-100 five level responses to match the EQ-5D-3L three level responses helps to overcome any structural and response rating challenges [162, 179]. The Zimbabwe EQ-5Q-5L value set and the calculator from the EuroQol Group's crosswalk project were used [181] as Ghana currently does not have its own dataset. At the time of developing this study, only Zimbabwe had developed the value set in the whole of sub-Saharan Africa [64], hence the adoption of their value set.

Table 4. 1 Mapping from WHOQOL-100 items in WHO SAGE Health State Descriptions to EQ-5D-5L

WHOQOL-100 questions in WHO SAGE		Overall, in the last 30 days, how much difficulty did you have…?	EQ5D-5L	Which statement best describes your health state today?
Q2002. …how much difficulty did you have with moving around?			Mobility	
	1	None	1	I have no problems in walking about
	2	Mild	2	I have slight problems in walking about
	3	Moderate	3	I have moderate problems in walking about
	4	Severe	4	I have severe problems in walking about
	5	Extreme/Cannot do	5	I am unable to walk about
Q2004. …how much difficulty did you have with self-care, such as bathing/ washing or dressing yourself?			Self-Care	
	1	None	1	I have no problems washing or dressing myself
	2	Mild	2	I have slight problems washing or dressing myself
	3	Moderate	3	I have moderate problems washing or dressing myself
	4	Severe	4	I have severe problems washing or dressing myself
	5	Extreme/Cannot do	5	I am unable to wash or dress myself
Q2039. …how much difficulty did you have in your day to day work			Usual Activities (e.g., work, study, housework, family or leisure activities)	
	1	None	1	I have no problems doing my usual activities
	2	Mild	2	I have slight problems doing my usual activities
	3	Moderate	3	I have moderate problems doing my usual activities
	4	Severe	4	I have severe problems doing my usual activities
	5	Extreme/Cannot do	5	I am unable to do my usual activities
Q2007. …how much bodily aches or pains did you have?			Pain/Discomfort	
	1	None	1	I have no pain or discomfort
	2	Mild	2	I have slight pain or discomfort
	3	Moderate	3	I have moderate pain or discomfort
	4	Severe	4	I have severe pain or discomfort
	5	Extreme/Cannot do	5	I have extreme pain or discomfort
Q2019. …how much of a problem did you have with worry or anxiety?			Anxiety/ Depression	
	1	None	1	I am not anxious or depressed
	2	Mild	2	I am slightly anxious or depressed
	3	Moderate	3	I am moderately anxious or depressed
	4	Severe	4	I am severely anxious or depressed
	5	Extreme/Cannot do	5	I am extremely anxious or depressed

Explanatory and other variables

The main explanatory variables were overweight and obesity with healthy weight as the base category. In the WHO SAGE, anthropometric measurements of body weight and height of respondents were taken using standard protocols [177]. BMI were categorised according to WHO classifications as follows: healthy BMI: BMI=18.50 to $\leq$ 25.00 kg/m^2; overweight: BMI=25.00 to $\leq$ 30.00kg/m^2; and obesity: BMI $\geq$ 30.00kg/m^2 [145].

Covariates were included based on previous literature [128, 182] and these included age, sex, educational level, marital status, locality (rural/urban), household wealth status, smoking status and having been diagnosed with a chronic disease.

Statistical Analysis

Accounting for the post-stratified person's weight, age-, sex- and BMI-specific mean HSUs were generated using the Zimbabwe EQ-5D-5L value set. Sampling weights provided in the WHO SAGE data were used [69]. Univariable and multivariable survey linear regression models were used to examine the association between HSUs and high BMI using healthy weight as the reference category [100]. A two-tailed *p*-value <0.05 was considered as statistically significant. All statistical analyses were conducted using STATA version 15.0 (Stata Corp., College Station, Texas, USA).

Ethics approval and consent to participate

The WHO SAGE study was approved by the WHO's Ethical Review Board and the University of Ghana Medical School Ethics and Protocol Review Committee in Ghana [69]. Therefore, the authors were not required to obtain a separate ethics approval for this study. Data were used from the GhanaINDDataW2. This data were collected using the SAGE Individual Questionnaire. All files are available from the WHO database.

4.5 Results

The sample used in the analyses comprise 3,966 adults aged 18-110 years (84% of the total sample). Sampling weights were applied throughout the analyses. HSUs could not be calculated for 207 respondents who had missing data for one or more EQ-5D-5L dimensions. Of the 207 respondents, 31% were female, 10% obese, 38% overweight and 65% were aged below 50years. In the final sample of 3,966 adults, the mean (standard deviation) age was 40.2 (14.9) years, and BMI was 25.1 (5.1) kg/m^2. Most respondents resided in urban areas (52%), were female (55%), had healthy BMI (59.5%), with low education (60%) and were from households with the highest level of wealth (28.4%) (Table 4.2). Table 4.3 shows the proportion who reported problems for each level of the five EQ-5D-5L domains for the BMI categories. Around one-fifth of the sample respectively reported they experienced slight pain/discomfort (21.9%) and slight anxiety/depression (17.7%). Few respondents reported any problems in the self-care domain. In all, 44% of males and 56% of females reported no problems across all EQ-5D-5L health domains.

Table 4.2. Summary statistics of study participants in WHO-SAGE Wave 2 (2014/15)

Number of participants		3966
BMI (kg/m^2)		25.1 (5.1)
BMI Categories	healthy BMI	59.5
	Overweight	26.6
	Obese	13.9
Age, y		40.2 (14.9)
Sex	Males	44.8
	Females	55.2
Age (years)	18-49	77.8
	50-64	15.0
	65+	7.2
Education status	Low	60.1
	High	39.9
Marital status	Married/cohabiting	59.5
	Divorced/separated	15.5
	Single	25.0
Place of residence	Rural	47.9
	Urban	52.1
Household wealth quintile	Lowest	10.6
	Low	17.0
	Moderate	19.0
	High	25.0
	Highest	28.4
Smoking	Never smoked	94.7
	Quitted smoking	2.0
	Currently smokes	3.3
Diagnosed with chronic disease	No	91.9
	Yes	8.1

All values are weighted. BMI denotes body mass index calculated as weight in kilograms divided by squared height in meters; total physical activity (minutes per week). Data are mean (standard deviation) for continuous variables and percentages for categorical variables. In the last column, the number of participants is presented as a number, BMI and age are presented as means (standard deviation) and all others are presented as percentages.

Table 4.3. EQ-5D-5L dimensions (%) stratified by BMI categories in the Ghanaian adult population (2014/15)

EQ-5D-5L Profiles		**healthy Weight**	**Overweight**	**Obese**	**Total**
	n	2468	960	538	3966
Mobility					
	No Problem	80.5	85.0	78.4	81.4
	Slight Problem	14.0	10.7	14.0	13.1
	Moderate Problem	4.2	3.4	5.5	4.2
	Severe Problem	1.2	1.0	2.1	1.3
	Unable to do	0.2	0.0	0.2	0.1
Self-Care					
	No Problem	88.3	93.8	93.8	90.2
	Slight Problem	9.5	5.2	5.2	8.0
	Moderate Problem	1.9	0.7	0.7	1.5
	Severe Problem	0.1	0.1	0.1	0.2
	Unable to do	0.1	0.1	0.1	0.1
Usual Activity					
	No Problem	79.0	83.7	81.5	80.6
	Slight Problem	14.5	9.8	9.4	12.5
	Moderate Problem	4.9	4.5	6.8	5.1
	Severe Problem	0.7	0.5	0.7	0.6
	Unable to do	1.0	1.4	1.7	1.2
Pain/Discomfort					
	No Problem	67.8	71.1	59.0	67.4
	Slight Problem	22.7	19.5	22.9	21.9
	Moderate Problem	7.7	6.9	14.4	8.4
	Severe Problem	1.4	2.2	3.6	1.9
	Unable to do	0.3	0.3	0.2	0.3
Anxiety/Depression					
	No Problem	72.5	78.6	77.1	74.8
	Slight Problem	19.8	14.3	15.5	17.7
	Moderate Problem	6.7	6.4	4.6	6.3
	Severe Problem	0.9	0.7	4.6	1.1
	Unable to do	0.2	0.0	0.2	0.1

All are weighted estimates

Age- and BMI-specific mean HSUs stratified by sex and for the population are presented in Table 4.4. The mean HSU (95% confidence interval) for the population was 0.856 (95% CI: 0.850, 0.863), 0.866 (95% CI: 0.858, 0.874) for males and 0.849 (95% CI: 0.841, 0.856) for females. In general, while HSUs were slightly higher for persons who were overweight compared to healthy weight and higher as household wealth increased, HSUs were lower for females, obese participants and decreased with age. In univariable analysis, factors that were significantly associated with HSU were obesity, sex, age, marital status, household wealth and being diagnosed with a chronic disease (Table 4.5). These factors were then used in the multivariable regressions. Whilst the inclusion of these variables attenuated the coefficients for the obesity categories, they remained statistically significant. Other factors also remained significantly associated with HSU in the multivariable analysis. Being obese was associated with significantly lower HSU (β= -0.024; 95% CI: -0.037, -0.011) while overweight was associated with higher HSU, however, this was not statistically significant. HSUs for females were 0.011 (95% CI: 0.003, 0.020) lower than for males; and higher in those with moderate, high or higher household wealth compared to those within the lowest income quintiles.

Table 4.4. Age- and Sex-specific health state utilities (HSUs) using EQ-5D-5L in the adult population of Ghana

Age Groups (years)	Males HSU (SD) (95% CI)				Females HSU (SD) (95% CI)				Total Mean HSU (SD) (95% CI)			
	healthy weight	Overweight	Obese	Total	healthy weight	Overweight	Obese	Total	healthy weight	Overweight	Obese	Total
Total	0.866 (0.089)	0.867 (0.081)	0.849 (0.099)	0.866 (0.088)	0.852 (0.092)	0.857 (0.081)	0.831 (0.096)	0.849 (0.090)	0.860 (0.091)	0.861 (0.081)	0.834 (0.097)	0.856 (0.090)
	(0.857, 0.875)	(0.853, 0.881)	(0.815, 0.941)	(0.858, 0.874)	(0.841, 0.861)	(0.849, 0.866)	(0.815, 0.847)	(0.841, 0.856)	(0.852, 0.867)	(0.853, 0.869)	(0.818, 0.849)	(0.850, 0.863)
18-29	0.895 (0.064)	0.904 (0.022)	0.900 (*)	0.896 (0.059)	0.881 (0.072)	0.890 (0.040)	0.892 (0.031)	0.885 (0.096)	0.889 (0.068)	0.894 (0.036)	0.893 (0.029)	0.890 (0.060)
	(0.884, 0.906)	(0.895, 0.913)	(*)	(0.887, 0.906)	(0.864, 0.898)	(0.879, 0.901)	(0.881, 0.903)	(0.875, 0.896)	(0.878, 0.899)	(0.886, 0.902)	(0.883, 0.903)	(0.883, 0.898)
30-39	0.891 (0.062)	0.879 (0.068)	0.861 (0.061)	0.886 (0.064)	0.870 (0.067)	0.875 (0.048)	0.844 (0.094)	0.866 (0.070)	0.879 (0.066)	0.877 (0.055)	0.847 (0.090)	0873 (0.068)
	(0.875, 0.907)	(0.841, 0.918)	(0.786, 0.935)	(0.872, 0.901)	(0.854, 0.887)	(0.862, 0.889)	(0.804, 0.884)	(0.853, 0.879)	(0.867, 0.891)	(0.862, 0.892)	(0.811, 0.882)	(0.863, 0.884)
40-49	0.857 (0.090)	0.876 (0.065)	0.875 (*)	0.863 (0.082)	0.855 (0.083)	0.856 (0.078)	0.833 (0.072)	0.848 (0.078)	0.856 (0.087)	0.865 (0.073)	0.838 (0.070)	0.856 (0.080)
	(0.839, 0.875)	(0.853, 0.899)	(*)	(0.849, 0.878)	(0.835, 0.876)	(0.837, 0.876)	(0.809, 0.856)	(0.835, 0.862)	(0.842, 0.871)	(0.849, 0.881)	(0.815, 0.861)	(0.845, 0.867)
50-59	0.837 (0.097)	0.840 (0.094)	0.797 (0.162)	0.834 (0.102)	0.807 (0.101)	0.805 (0.103)	0.795 (0.105)	0.804 (0.103)	0.824 (0.099)	0.821 (0.100)	0.796 (0.118)	0.818 (0.104)
	(0.821, 0.852)	(0.813, 0.866)	(0.722, 0.871)	(0.819, 0.850)	(0.792, 0.823)	(0.786, 0.825)	(0.772, 0.818)	(0.792, 0.815)	(0.812, 0.836)	(0.804, 0.839)	(0.772, 0.819)	(0.807, 0.829)
60-69	0.822 (0.101)	0.815 (0.102)	0.832 (0.130)	0.821 (0.102)	0.793 (0.107)	0.802 (0.096)	0.754 (0.132)	0.786 (0.112)	0.809 (0.1104)	0.809 (0.099)	0.764 (0.134)	0.803 (0.109)
	(0.809, 0.836)	(0.783, 0.847)	(0.764, 0.899)	(0.807, 0.834)	(0.775, 0.810)	(0.782, 0.823)	(0.708, 0.800)	(0.769, 0.803)	(0.797, 0.821)	(0.790, 0.828)	(0.721, 0.808)	(0.790, 0.816)
70+	0.763 (0.134)	0.729 (0.176)	0.715 (*)	0.766 (0.142)	0.737 (0.132)	0.733 (0.149)	0.710 (0.187)	0.733 (0.144)	0.750 (0.133)	0.732 (0.158)	0.711 (0.218)	0.743 (0.143)
	(0.743, 0.782)	(0.669, 0.789)	(*)	(0.736, 0.775)	(0.719, 0.756)	(0.701, 0.765)	(0.654, 0.766)	(0.716, 0.750)	(0.735, 0.764)	(0.702, 0.761)	(0.662, 0.760)	(0.729, 756)

All are weighted estimates
(*), data in this age group were not enough to estimate standard deviation and confidence intervals. The sub-sample for obese males in age group 18-29 years (n=1), 40-49 years (n=7) and 70+ years (n=13).

Table 4.5. Multivariable regression estimates (β) and 95% confidence intervals (CI) of association between HSU and categories of BMI and other covariates in Ghanaian adults, 2014/15

		Univariable		Multivariable	
		β (95% CI)	*p* value	β (95% CI)	*p* value
BMI Categories	healthy BMI	Reference		Reference	
	Overweight	0.002 (-0.008, 0.011)	0.720	0.003 (-0.006, 0.012)	0.479
	Obese	-0.026 (-0.042, -0.010)	0.002	-0.024 (-0.037, -0.011)	<0.001
Sex	Males	Reference		Reference	
	Females	-0.017 (-0.026, -0.008)	<0.001	-0.011 (-0.020, -0.003)	0.009
Age (years)	18-49	Reference		Reference	
	50-64	-0.056 (-0.066, -0.046)	<0.001	-0.047 (-0.057, -0.036)	<0.001
	65+	-0.113 (-0.124, -0.100)	<0.001	-0.101 (-0.114, -0.087)	<0.001
Education status	Low	Reference		Reference	
	High	0.026 (0.017, 0.035)	<0.001	0.007 (0.001, 0.016)	0.099
Marital status	Married/cohabiting	Reference		Reference	
	Divorced/separated	-0.019 (-0.032, -0.006)	0.004	0.006 (-0.004, 0.016)	0.261
	Single	0.043 (0.034, 0.053)	<0.001	0.026 (0.016, 0.036)	<0.001
Place of residence	Rural	Reference		Reference	
	Urban	0.011 (-0.002, 0.023)	0.092	-0.001 (-0.014, 0.012)	0.878
Household wealth quintile	Lowest	Reference		Reference	
	Low	0.015 (-0.004, 0.034)	0.131	0.015 (-0.004, 0.033)	0.119
	Moderate	0.021 (0.002, 0.040)	0.026	0.020 (-0.003, 0.038)	0.025
	High	0.033 (0.014, 0.053)	0.001	0.028 (0.009, 0.048)	0.004
	Highest	0.039 (0.019, 0.059)	<0.001	0.035 (0.015, 0.057)	0.001
Smoking	Never smoked	Reference		Reference	
	Quitted smoking	-0.008 (-0.036, 0.019)	0.543	0.010 (-0.016, 0.035)	0.462
	Currently smokes	-0.014 (-0.049, 0.020)	0.416	-0.010 (-0.046, 0.026)	0.580
Diagnosed with chronic disease	No	Reference		Reference	
	Yes	-0.043 (-0.062, -0.023)	<0.001	-0.015 (-0.032, 0.001)	0.068
CONS		-	-	0.847 (0.828, 0.867)	

4.6 Discussion and conclusion

For the Ghanaian population, few studies have focused on finding the effect of BMI on HRQoL, and to-date, no studies have generated age and sex-specific HSUs and HSUs stratified by weight status or studied the extent to which HSUs are associated with high BMI [8, 11, 183]. However, in most low and middle income countries, particularly in sub-Saharan Africa, increasing prevalence of obesity has been reported, which in turn, is a major risk factor for NCDs [35, 184, 185]. The lack of HSUs for the population underscores the difficulties in conducting economic evaluations to support the effective prioritization of health programmes or health technology assessments within the Ghanaian as well as other sub-Sahara African populations. This study bridges this gap by generating age and sex-specific HSUs and HSUs by weight status; and examining the associations between HSUs and high BMI in a sub-Sahara African setting. Most importantly, the weighted age- and sex-specific HSUs can be used to calculate QALYs, which may be used for economic evaluations for the Ghanaian context. Additionally, HSUs generated by weight status can be used to support cost-effectiveness evaluations of measures, policies or interventions to address overweight/obesity in this setting.

In this study, around two-fifths of respondents reported slight problems with pain/discomfort or anxiety/depression, and the least problems were reported for self-care. The results showed that HSUs were significantly lower in persons who were obese compared to healthy weight, females compared to males, and in older ages compared to younger age groups. In addition, HSUs were significantly higher for respondents who were single compared to married and higher as household wealth increased. While the association was not significant, the results showed that HSUs were positively associated with overweight in the population. HSUs were also not significantly associated with respondents' education, place of residence, smoking or having a chronic disease.

In most countries where HSUs have been calculated, mean individual HSUs were slightly lower than those reported in this study [128, 132, 176]. A strong negative association was found between HSU and obesity; controlling for other factors made only a small difference. The findings of lower HSUs for obese respondents and for older respondents are consistent with previous studies [128, 160, 176, 182, 186, 187]. However, contrary to findings in previous studies, this study findings showed that both the unadjusted and adjusted HSUs for overweight were higher compared to healthy BMI, although this was not significant [128, 132, 176].

The negative associations found between HSU and obesity but not overweight may be an effect of general awareness of the health consequences of obesity [188]. In most settings in low and middle income countries like Ghana, the recognition of high BMI as a public health problem is a more recent phenomenon [8], however the burden associated with this may have existed over a longer period. Just like in most developing countries, to some people in Ghana, high BMI may be considered as beautiful and as a sign of affluence [8, 37], despite the associations with many chronic diseases and reduced life expectancy. Whilst recent improvements in public health activities have likely increased awareness around the health problems associated with overweight and obesity, addressing these societal norms will be a critical aspect of future public health initiatives.

The key strength of this study is the attempt to generate age and sex-specific HSUs, as well as HSUs by weight status, and to determine the associations between HSU and high BMI for the Ghanaian population. The set of age and sex-specific HSUs generated in this study can be used to calculate QALYs for CUA in the general Ghanaian population, and in similar sub-Saharan countries. Specifically, the BMI-specific HSUs can be used to calculate QALYs for economic evaluations that are required to guide decision-making around policy, preventative and management measures for overweight/obesity in sub-Saharan Africa. Instead of condensing the WHOQOL-100 responses and mapping onto the EQ-5D-3L responses, “judgement-based” mapping were used to directly map the WHOQOL-100 five-level responses to the EQ-5D-5L, an instrument which reduces ceiling and floor effects [180, 181]. Additionally, objectively measured weights and heights were used rather than self-reported. Although the most current population-based data were used to calculate HSUs - rarely available in sub-Saharan Africa -this study has several limitations. First, a non-preference-based instrument (WHOQOL-100) was used to indirectly estimate HSUs. Employing mapping models is the second-best method to obtain utility values. In the WHO SAGE, as only a non-preference-based instrument was implemented during data collection, the “judgement-based” method was used to map items and responses to the EQ-5D-5L; this may reduce the precision of the HSUs obtained. In general, the underlying objective for using the EQ-5D-5L and the WHOQOL-100 instruments differ. Thus, using one instrument in place of the other may over- or underestimate the objective of measurements and may affect the estimation of the effects of HSUs or quality of life. The extent of over- or underestimation can be objectively determined when both instruments have been implemented in the same population at the same time. Until this is done, one may not be able to estimate the extent to which the effect may differ. Despite this limitation, this study implemented the second-best method to obtain utility values and 95% confidence intervals. There is, therefore, confidence that the estimates are reliable for the Ghanaian population. Moreover, the results in this study only serve as interim results HSUs that will be useful in cost-utility analyses in the Ghanaian population. To provide more reliable HSUs, I recommend that future studies use direct HSU elicitation methods or preference-based measures to generate a better population HSUs in Ghana.

The second limitation is the use of the Zimbabwe value set as the surrogate. The Zimbabwe EQ-5D-5L value set was derived from the existing EQ-5D-3L which was based on data collected from 2,488 high-density urban dwellers in 2000 [181, 189]. Due to the differences in economic and political environment between Ghana and Zimbabwe [190] both of which may affect health outcomes in the populations, the preference weights might vary. Health states valued differently in the Ghanaian population will result in biased HSUs in this study. However, this value set was used as the characteristics of this population are much closer to that of the Ghanaian population in comparison to other existing value sets. Finally, the WHO SAGE data is cross-sectional, therefore I could not estimate the effect of changes in high BMI and subsequent HSUs. Although the data are representative of the older adult Ghanaian population, participants with missing anthropometric or EQ-5D-5L dimensions data were omitted, and this may have introduced selection bias. However, missing data accounted for less than 5% of the total sample [191] and the use of sampling weights in the analyses reduced the potential for selection bias.

Despite these limitations, the most robust statistical methods available were used to generate HSUs for the population. QALYs, an important outcome measure recommended by national bodies such as National Institute for Health and Care Excellence (NICE), can be estimated by combining HSU and survival/life expectancy. In turn, these QALYs can be used in CUA. Until a population-based study is conducted to determine HSUs for the Ghanaian population, these estimates can provide baseline HSUs for use in future CUA for Ghana.

In conclusion, this study provides age and sex-specific HSUs, and HSUs by weight status, and investigates associations between HSU and high BMI. HSUs were found to be negatively associated with obesity, to be lower among females, and lower amongst those of older age. The age and sex-specific HSU can be used to calculate QALYs which may be used for a range of health economic evaluations for the population. The study also provides HSUs by weight status, which will be important in studies to evaluate the cost-effectiveness of preventative and management actions for overweight and obesity.

4.7 Postscript

The aim of this chapter was to estimate age and sex-specific health state utilities (HSUs) for Ghana, HSUs stratified by weight status and the associations between HSUs and overweight and obesity. As primary data collected using a preference-based measure were lacking in the Ghanaian population, the WHOQOL-100, a non-preference-based measure, was indirectly used through "judgement-based" mapping method. As an internationally validated instrument, the WHOQOL-100 is a cross-cultural comparable tool that has mostly been used to measure quality of life. One key advantage of this instrument is its ability to assess quality of life over 30 days as opposed to the EQ-5D that measures the same in one day. Hence the WHOQOL-100 provides an overview of the quality of life that allows the individual to think of his/her over the past 30 days compared to the shorter window of one day. However, WHOQOL-100 remains a non-preference based tool in measuring HSUs, and this should be considered when interpreting our results in this study.

Findings showed lower mean HSUs for females, obese individuals and among older ages. It was also observed that HSUs were negatively associated with obesity, female sex and older age groups in the population. With the country's quest to a develop more safe and efficient healthcare system that eschews wastage, the age and sex-specific HSUs will be very useful in many health economic evaluations. Most importantly, the BMI-specific HSUs will be very useful parameters in developing locally sustainable and cost-effective weight reduction strategies.

The HSUs can be used to estimate QALYs, a key health outcome in economic evaluations and the values can be used as proxies for other sub-Saharan African populations with similar backgrounds. In health economic evaluations, even though QALY is a useful measure of effectiveness, studies will normally evaluate effectiveness against specific costs and use such information to prioritize cost-effective interventions. QALYs can be a stand-alone outcome measure, however, when measured against costs, this can provide vital information on the cost-effectiveness of interventions. Therefore, in Chapter 5, nationally representative survey data were combined with administrative data to estimate the direct healthcare costs associated with overweight and obesity. With the estimation of HSUs in Chapter 4 and costs in Chapter 5, this thesis becomes an important data source for future health economic evaluations for Ghana.

5 The associations between health services utilization as well as direct healthcare costs and overweight and obesity among older adults

5.1 Preface

This chapter presents work on the health services utilization and healthcare costs associated with overweight and obesity. So far, there is almost no evidence of the estimated costs associated with overweight or obesity [11] in the Ghanaian population as found in other populations [192-194]. Most obesity-related costs or health service utilization data applied to the Ghanaian population were taken from mostly developed country data [11]. However, costs in particular, are a key parameter necessary for conducting economic evaluations through modelling. Since results from modelling are used to inform health care decisions and resource allocation in specific populations, it is important that the parameters used are developed from the same or very similar population [68]. This is because circumstances like economic or political conditions, and how populations value their health, differ.

Using parameters such as body mass index (BMI)-specific costs from different countries in economic evaluations and using the results to inform local health care decisions and resource allocation may lead to choosing unaffordable, inaccessible and unsustainable interventions. Thus, data were used from a nationally representative sample of an older adult population to estimate BMI-specific utilization and costs which reflects the precise or close to the precise situation in Ghana.

This chapter is published in Health Policy and Planning (Appendix 4).

Lartey, S.T., de Graff, B., Magnussen, C.G., Boateng, G.O., Aikins M., Minicuci, N., Kowal, P., Lei, S., & Palmer, A. Health service utilization and direct healthcare costs associated with obesity in older adult population in Ghana. *Health Policy and Planning*. 2019: czz147: 1–11.

5.2 Abstract

Background and objective: Obesity is a major risk factor for many chronic diseases and disabilities, with severe implications on morbidity and mortality among older adults. With an increasing prevalence of obesity among older adults in Ghana, it has become necessary to develop cost-effective strategies for its management and prevention. However, developing such strategies is challenging as BMI-specific utilization and costs required for cost-effectiveness analysis are not available in this population. Therefore, this study examine the associations between health services utilization as well as direct healthcare costs and overweight (body mass index, BMI ≥25.00 and < 30.00 kg/m^2) and obesity (BMI ≥30.00 kg/m^2) among older adults in Ghana.

Methods: Data were used from a nationally representative, multistage sample of 3350 people aged 50+ years from WHO SAGE (2014/15). Health service utilization was measured by the number of health facility visits over a 12-month period. Direct costs (2017 US dollars) included out-of-pocket payments and the National Health Insurance Scheme (NHIS) claims. Associations between utilization and BMI were examined using multivariable zero-inflated negative binomial regressions; and between costs and BMI using multivariable two-part regressions.

Results: Twenty-three percent were overweight and 13% were obese. Compared with healthy weight participants, overweight and obesity were associated with 75% and 159% more inpatient admissions, respectively. Obesity was also associated with 53% additional outpatient visits. One in 5 of the overweight and obese population had at least one chronic disease, and having chronic disease was associated with increased outpatient utilization. The average per person total costs for overweight was $78 and obesity was $132 compared with $35 for healthy weight. The NHIS bore approximately 60% of the average total costs per person expended in 2014/15. Overweight and obese groups had significantly higher total direct healthcare costs burden of $121 million compared with $64 million for healthy weight in the entire older adult Ghanaian population. Compared with healthy weight, the total costs per person associated with overweight increased by 73% and more than doubled for obesity.

Conclusion: Even though the total prevalence of overweight and obesity was about half of that of healthy weight, the sum of their cost burden was almost doubled. Implementing weight reduction measures could reduce health service utilization and costs in this population.

5.3 Introduction

Whilst obesity is among the leading risk factors for non-communicable diseases (NCDs) globally, the prevalence of obesity has substantially increased since 1980 [6, 9]. Obesity (body mass index, BMI ≥30 kg/m^2) has immediate negative health consequences [28], and a complex aetiology that ultimately results in increased morbidity, disability, mortality, and reduced quality of life [122, 194]. In many developing countries, mortality of older adults (50+ years) is commonly due to NCDs rather than infectious or parasitic diseases [33]. In other countries, it has been established that overweight and obesity and obesity-related conditions in the older population siphon considerable resources from the health system due to the associated increased health services utilization and healthcare costs [193-199]. Even though overweight and obesity prevalence are increasing [8, 10], there is no way to estimate whether the current prevalent rates among the older population have similar effects on health service utilization and costs in Ghana. Also, there are few studies that have examined such effects globally [200, 201]. Additionally, this has been a major concern for policy makers, stakeholders and financiers of healthcare who can only speculate an increase in health resource utilization and cost, without any published estimates.

Healthcare in Ghana is financed mainly by the government, development partners and households [202]. To improve equity in healthcare delivery and sustainable health financing, the Government of Ghana in 2003 introduced the National Health Insurance Scheme (NHIS) [203] and commenced implementation in 2005. Administered by the government's National Health Insurance Authority (NHIA), the scheme is financed through the national health insurance levy and deductions by Social Security and National Insurance Trust (SSNIT); and funds are largely expended through claims [202]. Since the introduction of the NHIS, increase health service utilization and costs to the government has been reported [202, 203]. The "total number of inpatient and outpatient visits to health facilities rose from just under 0.5 per capita in 2005 to almost 3.0 per capita in 2014" [202].

Yet there is no evidence of how overweight and obesity have influenced the process.

As Ghana is among the few countries in Africa experiencing an ageing population [50] in addition to increasing life expectancy [33]. Therefore, a concurrently increasing obesity prevalence [8, 10, 11] which may increase the risk of chronic diseases [123] will likely impose major financial costs [75, 204], especially to the government's NHIS. Due to a lack of adequate health care cost data reported in many developing countries, it is difficult to estimate the cost burden overweight ($25 \geq$BMI <30 kg/m^2) and obesity impose on households and the health systems. However, such research is essential for forecasting, planning, and development of cost-effective and sustainable obesity interventions. Estimating utilization and costs can be used in health economic modelling studies, including those that will simulate progression impact of changing prevalence obesity on economic outcomes.

Since results from modelling are to inform health care decisions and resource allocation in specific populations, it is important that the parameters such as costs, utilization and health state utilities used are developed basically from the same or very similar population [68]. Thus, as health systems and treatment patterns may differ across countries, the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) recommends the use of locally available input parameters in modelling [60, 205]. Therefore, using parameters such as BMI-specific utilization and costs from different countries in economic evaluation and using its results to inform local health care decisions and resource allocation might lead to choosing unaffordable, inaccessible and unsustainable interventions. As evidence of association between utilization, costs and high BMI are porous in Ghana, this study aimed to examine the associations between health service utilization, healthcare costs, and excess weight in the older adult population of Ghana in 2014/15.

5.4 Methods

Study Sample

Data from a sub-sample of 3,350 respondents aged ≥50 years with complete responses from the World Health Organization's Study on global AGEing and adult health (WHO SAGE) Wave 2 were used. SAGE used a stratified multistage cluster design to collect data that yielded national and subnational estimates with acceptable precision using region and locality type (rural/urban) as the primary sampling unit [69, 206]. Of the 4,735 survey respondents, a final sample for analysis was determined after missing weight (227) and height (229) measurements and biologically implausible weight and height measurements (25) were excluded. Biologically implausible values were determined to be height <100cm or >250cm, weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm, and were excluded [72, 73]. Overall, 246 (5.2%) missing anthropometric measurements and 25 (0.5%) biologically implausible values were excluded. Out of this, only 160 (4.8% of 3,350) were excluded from those 50 years and above. Since the focus of the study was those aged 50 years and above, person below age 50 years (1,114) were excluded from this study. Thus, the final sample for analysis was 3350. Data were used from the GhanaINDDataW2 that had responses to the individual questionnaire in this study. Further information on the WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

Outcome Variables

This study focused on four outcome variables. This in study, examined the annualized health service utilization and total direct healthcare costs including costs that were stratified by out-of-pocket and NHIS costs.

Health service utilization: The SAGE questionnaires included information on self-reported health service utilization in the 12 months prior to data collection. This included the number of visits to a specific type of health facility (this includes pharmacy, health centre, clinic, polyclinic, district hospital, regional hospital, teaching/tertiary hospital), for outpatient visits and inpatient admissions over the period. Based on the assumption that those who did not provide response to visiting a health facility did not make any visits, their missing values were considered to be zero in the analysis. Three thousand and ten (90% of the 3,350) and 980 (29% of the 3,350) respondents did not report any inpatient admissions and outpatient visits, respectively.

Out-of-pocket (OOP) costs: Respondents who have had inpatient and/or outpatient visits were asked to indicate the OOP costs they incurred during the most recent visit. This included fees for healthcare provider, medication, laboratory tests, transportation, and other incidental costs related to the hospital visit. These costs were summed and multiplied by the total number of visits a respondent made to a health facility in the past 12 months. Using the health-related mean consumer price index (CPI) for years 2015 and 2017, these costs were converted into real costs in 2017 in Ghana cedi [207, 208].

NHIS Costs: Where an insured respondent had an inpatient admission, or an outpatient visit and indicated in the out-of-pocket costs sections that this was ‘free’, it was acknowledged that the NHIS as a public health insurance system covered the costs of such services (healthcare provider and medication fees). People who visited a health facility and incurred transport, laboratory tests or other incidental costs but not health provider or medication fees, were assumed to have incurred both OOP and NHIS costs. The NHIS reimburses healthcare providers mostly for health services and medication costs per person per visit using their diagnosis, the level of the facility visited dosage of medication consumed. These services and medication costs were based on the Ghana Diagnosis Related Groupings (G-DRG), 2015 and fee-for-service payment methods, respectively [202].

The NHIS costs were calculated in four steps: 1) diseases that were reported as the main reason for outpatient visit or inpatient admission in a health facility in the WHO SAGE were mapped to diseases in the G-DRG, stratifying by level of health facility. Minimum costs were assigned based on the service and type of health facility visited (Table 5.1) to obtain medication costs, claims data on mean medication costs were accessed from five districts stratifying these by outpatient or inpatient services for the 2017 fiscal year (Table 5.2) [209]. The differences in the mean medication costs can potentially be attributed to the kinds of diseases reported within a district. As access to individual level data was not given for this study. The study only used aggregated claims data for inpatient and outpatient services. Thus, differences in district costs may not be fully explained without access to individual level data. These NHIS claims data were the most current and validated data that used the 2015 G-DRG. Claims data from two districts (Gonja East and Shai-Osudoku) were excluded because service costs were not separated from medication costs. It is important to note that the costs of medications do not vary by district, rather the costs depend on the dosage prescribed for specific diagnosis [202]; and 3) the NHIS costs were calculated as the sum of service (from the G-DRG) and medication costs (mean of medication costs from the districts) per visit based on the purpose of visit, the department (inpatient or outpatient) and level of health facility visited. 4) finally, the NHIS costs obtained per visit per person was then multiplied by the total number visits the respondent made to a health facility in the past 12 months for which health provider and medication fees were free.

Total healthcare costs: These were estimated as the sum of the OOP and NHIS costs per person in the 12 months prior to the study. All costs were converted into US dollars ($) equivalent using the 2017 mean exchange rate ($1≈ GHS 4.3562) [210].

Table 5. 1. Disease mapping from G-DRG to purpose (diagnosis) of hospital visit in WHO SAGE

DRG Code	Disease on DRG	Disease in SAGE
MEDI28A	Malaria	Communicable disease (e.g. Malaria)
MEDI05A	Malnutrition	Nutritional deficiencies
MEDI23A	Diarrhoea	Acute conditions (e.g. diarrhoea)
MEDI02A	Simple Diabetes	Diabetes
MEDI32A	Hypertension	Hypertension
MEDI07A	Heart Disease	Heart Problems
MEDI14A	Cerebro-Vascular Accident/Stroke	Stroke
OBG34A	Spontaneous vaginal delivery	Maternal
ORTHO1A	Injury	Injury
ASUR30A	General Surgery	Surgery
ZOOM02A	Detention for Observation and Treatment - Adult	Unspecified inpatient disease
OPD06A	General [1]OPD - Adult	Unspecified OPD disease

[1]OPD means outpatient department. Diseases identified in the WHO SAGE data as the main purpose for health facility attendance. Minimum service prices were obtained from the G-DRG, 2015 tariffs that is the current version and was used for reimbursement in 2017.

Table 5. 2. Mean medication costs from NHIA District offices (based on 2017 figures)

	Secondary/Hospital Level		Other primary health Levels
Districts	Outpatient	Inpatient	Outpatient
Atiwa	30.2	64.9	14.8
Kwahu South	34.7	101.1	10.9
Affram Plains	14.4	58.2	10.9
Fanteakwa	29.6	88.4	10.9
*Osu Klottey	40.5	110.0	0.0
Mean Total costs (GHS)	29.9	84.5	9.5
Mean Total costs (USD)	6.9	19.4	2.2

Note: Mean medication costs received from East Gonja and Shai Osudoku Districts were not used because the costs of service and medication were not separated. *Mainly, Ridge hospital

Explanatory variable:

Overweight and obesity: Overweight and obesity were the main explanatory variables. In the WHO SAGE data, anthropometric measurements of body weight and height of respondents were taken by trained assessors using standardized protocols [177]. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2) [5]. BMI was classified into four categories: underweight, BMI<18.50kg/m^2; healthy weight, 18.50≥BMI<25.00/m^2; overweight, 25.00≥BMI <30.00kg/m^2; and obesity, BMI ≥30.00 kg/m^2 [5, 89].

Covariates

Covariates considered as confounders included age, sex, marital status, educational level, location, employment status, household wealth, having health insurance and being diagnosed with at least one chronic disease or none. Covariates were specified based on Andersen behavioural model for studying factors that facilitate or impede health service utilization [211] and factors that affect costs[208, 212]. In particular, the Andersen model shows that the individual accesses and utilizes health services depending on three groups of characteristics described below: 1) predisposing factors, also known as the socio-cultural characteristics of the person including age, gender, marital status, educational level, occupation. 2) enabling factors focus on the operational or logistical requirements needed to seek care such as individual or family income, having health insurance, availability of health personnel and facilities. 3) need factors that are the immediate cause for which a person seeks care including diseases or disabilities.

In this study, sex was categorized as male/female while age was a continuous variable. Educational level was grouped into low education where the highest level of education was less than secondary or high school, and high education where a person completed secondary/ high school and above. Marital status was coded as (1) single, (2) married/cohabiting and (3) divorced/separated/widow/widower. Location of residence was coded as rural or urban residence; and employment status was categorised as employed or not employed. Furthermore, household wealth index served as a proxy for household economic status [95, 140]. This was constructed using principal component analysis from a total of 22 assets/characteristics/items [140, 143]. These included having radio, television, refrigerator, computer, mobile or fixed telephone, livestock, land, jewellery, bicycle, motorcycle, car; access to utilities such as electricity, having improved sanitation facility, having improved source of drinking water, cooking fuel and housing characteristics, such as the type of floor or wall materials.

The Cronbach's alpha for the 22 assets/characteristics/items that measured household wealth was 80.8%, indicating that assets/characteristic/ items included measured wealth appropriately. The derived index was converted into wealth quintiles coded as quintile one representing the lowest household status; with quintile two as low; quintile three representing moderate; quintile four representing high, and quintile five representing highest household wealth status. Insurance status was defined uninsured or insured. A respondent was insured if he had an unexpired insurance card. From previous studies, having obesity-related medical conditions included diabetes (ICD-9-CM code 250 for type 2 or unspecified type); hypertension (ICD-9-CM code 401-405); unspecified angina pectoris (ICD-9-CM 413.9); arthritis (ICD-9-CM code 716.9 for unspecified arthritis); stroke or cerebral artery occlusion (ICD-9-CM 434.91); and depression (ICD-9-CM code 311) [213]. Thus, having chronic disease was defined as yes if a respondent had at least one of these diseases.

Statistical Analysis

As population health service utilization typically has many zero values, survey zero-inflated negative binomial regression models were employed in univariable and multivariable analyses to examine the association between healthcare usage and BMI categories. Characteristic of population healthcare cost data, cost was a continuous outcome variable and right skewed with excess zeroes [212, 214]. Therefore, a survey two-part regression model was used in univariable and multivariable analyses to explore associations between costs and the BMI categories [215]. The two-part model involved two steps: the first step estimated the probability of having a health cost; then the second step estimated the total costs conditional on having positive costs. The analysis in this study employed a two-part model that utilized a logit model in the first part and a generalized linear model with gamma distribution and a log link function in the second part [214, 216].

The exponentiated coefficients (incidence rate ratios, IRR of health service usage, and predicted mean and incremental costs) were reported. The WHO post-stratified person weights were applied to all estimations. A two-tailed p value<0.05 was considered as statistically significant.

As costs incurred during the last visit were used to calculate annual costs, a sensitivity analysis around costs was conducted by varying the average per person costs by ±20% [68]. All analyses were performed using STATA v.15 (Stata Corp., College Station, Texas, USA).

5.5 Results

Of the 3,350 respondents aged 50+ years used in this analysis, approximately 53% were female, of mean (standard deviation) age 62 (9.9) years, 48% lived in urban areas and 72% were insured (Table 5.3). Ten percent were underweight, 54% had healthy weight, 23% were overweight and 13% were obese. Twenty-three percent of the 3,350 respondents came from the highest income households and 17% were diagnosed with at least one chronic disease. Twenty-three percent (p value=0.001) forming about one in five of the total number of respondents who were overweight or obese (1,209) had at least one chronic disease.

Health Service Utilization

Of the 3,350 respondents, 1,703 (51%) made at least one visit in the 12 months prior to data collection. At least one inpatient admission was reported by 182 (5%) of which 10% were underweight, 24% were overweight and 12% were obese. About half of the sample (49%, n=1,631) reported at least one outpatient visit; of this group, 11% were underweight, 22% were overweight and 13% were obese (Table 5.3). Among the overweight group who visited any health facility, the unadjusted mean number of inpatient admissions was 2.1 (95% CI: 1.8, 2.2) and outpatient visits was 2.8 (95% CI: 2.4, 3.2) (Table 5.4). In the obese group, the unadjusted mean number of inpatient stays was 2.5 (95% CI: 2.4, 2.6) and outpatient visits was 3.7 (95% CI: 3.4, 4.2) (Table 5.4). The univariable and multivariable associations between annual health service utilization and BMI categories showed that both overweight and obesity were associated with significantly higher health services (Table 5.5). However, the magnitude reduced in the multivariable analysis where persons who were obese had 53% (IRR=1.53; 95%; CI: 1.19, 1.98) more outpatient visits and 159% (IRR=2.59; 95% CI: 1.20, 5.51) more inpatient admissions compared with those of healthy weight.

Being overweight was also associated with 75% (IRR=1.75; 95% CI: 1.21, 2.53) more inpatient admissions compared with those of healthy weight. Underweight was not significantly associated with any health service utilization domain. Another important factor that was associate with high outpatient utilization was having at least one chronic disease (IRR=1.38; 95% CI: 1.07, 1.78). Other factors associated with more outpatient visits included being female, high education and high household wealth. Being unemployed and having high or higher household wealth were associated with more inpatient admissions.

Table 5.3. Characteristics of older adult (50+ years) respondents, WHO SAGE Wave 2 (2014/15)

Characteristics		Weighted Prevalence (%)
Sample, n (%)		3350 (100)
Sex	Males	47.1
	Females	52.9
BMI		
	Underweight	10.1
	healthy	53.8
	Overweight	22.9
	Obesity	13.2
Educational Level	Low	70.3
	High	29.7
Marital Status	Single	2.7
	Married/Cohabiting	63.5
	Divorced/ separated /Widow	33.8
Location	Rural	51.7
	Urban	48.3
Employment status	Employed	69.5
	Unemployed	30.5
Household Wealth Status	Lowest	13.0
	Low	19.7
	Moderate	22.0
	High	22.0
	Highest	23.4
Health Insurance	Uninsured	28.3
	Insured	71.7
Has a chronic disease	No	83.3
	Yes	16.7

All estimates are weighted

Table 5.4. Health service usage, by weight status among older adult (50+ years) respondents in Ghana, WHO SAGE Wave 2 (2014/15)

Weight status		Utilization (mean number of visits per year)			
		Outpatient visits		Inpatient Services	
		No.	Mean (95%CI)	No.	Mean (95%CI)
Full Sample	Underweight	429	0.8 (0.7, 1.0)	429	0.1 (0, 0.2)
	healthy	1854	1.0 (0.8, 1.2)	1854	0.1 (0, 0.2)
	Overweight	683	1.5 (1.3, 1.7)	683	0.1 (0, 0.3)
	Obese	384	2.2 (1.9, 2.4)	384	0.1 (0, 0.5)
Only those who visited health facility	Underweight	179	2.0 (1.7, 2.5)	19	1.9 (0.9, 2.3)
	healthy	874	2.0 (1.8, 2.2)	98	1.3 (1.0, 1.5)
	Overweight	360	2.8 (2.4, 3.2)	44	2.1 (1.8, 2.2)
	Obese	218	3.7 (3.4, 4.2)	21	2.5 (2.4, 2.6)

All estimates are weighted
CI mean confidence interval

Table 5.5. Factors associated with health service utilization among older adult population in Ghana, 2014/15

Characteristics		†Annual Outpatient Utilization				†Annual Inpatient Utilization			
		Univariable		Multivariable		Univariable		Multivariable	
		[1]IRR	95% CI	IRR	95%CI	IRR	95% CI	IRR	95% CI
Weight status (Ref: healthy)	Underweight	0.90	0.68, 1.18	0.83	0.66, 1.06	1.58	0.52, 4.76	1.66	0.71, 3.87
	Overweight	1.44**	1.14, 1.83	1.15	0.92, 1.42	2.20***	1.46, 3.32	1.75**	1.21, 2.53
	Obesity	2.17***	1.74, 2.70	1.53**	1.19, 1.98	2.70**	1.48, 4.93	2.59*	1.20, 5.51
Sex (Ref: Male)	Female	1.77***	1.50, 2.09	1.60***	1.33, 1.92	1.20	0.77, 1.87	1.08	0.72, 1.62
Age, years	Age	1.02***	1.01, 1.03	1.02**	1.01, 1.03	1.01	0.98, 1.03	1.01	0.99, 1.02
Educational level (Ref: Low)	High	1.26*	1.04, 1.53	1.35**	1.09, 1.68	1.56*	1.06, 2.29	1.20	0.84, 1.87
Marital status (Ref: Single)	Married/ Co-habiting	1.97*	1.10, 3.53	2.20*	1.19, 4.05	0.96	0.11, 3.40	1.17	0.20, 4.92
	Divorced/ separated/Widow	3.24***	1.82, 5.77	2.66**	1.47, 4.82	1.18	0.12, 4.36	1.06	0.18, 4.38
Location (Ref: Rural)	Urban	1.22	0.98, 1.51	0.82	0.66, 1.02	2.09**	1.30, 3.34	1.23	0.75, 2.02
Employment status (Ref: Employed)	Unemployed	1.70***	1.41, 2.06	1.40**	1.15, 1.69	1.91**	1.22, 2.99	1.53*	1.11, 2.44
Household wealth status (Ref: Lowest)	Low	1.97***	1.35, 2.87	1.81***	1.31, 2.50	1.87	0.74, 4.74	1.39	0.52, 3.70
	Moderate	2.26***	1.61, 3.20	2.07***	1.49, 2.87	3.52**	1.50, 5.25	2.34	0.90, 6.10
	High	2.44***	1.82, 3.31	2.14***	1.52, 3.01	5.40**	2.05, 6.18	2.82*	1.02, 6.89
	Highest	3.29***	2.39, 4.52	2.68***	1.86, 3.85	5.83***	2.36, 7.41	3.62*	1.25, 7.20
Health insured (Ref: Uninsured)	Insured	1.44**	1.15, 1.80	1.19	0.96, 1.48	1.95	0.96, 3.94	1.79*	1.09, 2.96
Having chronic disease (Ref: No)	Yes	1.84***	1.43, 2.37	1.38*	1.07, 1.78	1.79**	1.28, 2.50	1.17	0.81, 1.70
[2]Intercept		0.87***	0.76, 1.00	0.58***	0.10, 0.89	0.63***	0.51, 0.79	0.15	0.01, 1.61

†Annual mean utilization estimated as the sum of outpatient visits and inpatient stays 12months prior to data collection.
[2]Intercept for univariate pertains to only BMI categories.
[1]IRR = incident rate ratio
CI = confidence interval
**P* <0.05, ***P* <0.01, ****P* <0.001

Healthcare Costs

Tables 5.6 shows the annualized costs of direct healthcare. In this population, the unadjusted annualized average costs per person incurred through either OOP or NHIS were higher among persons who were overweight or obese versus those with healthy weight. Government bore approximately 60% of the total direct healthcare costs per person in 2014/15 (Fig 5.1). Results of the sensitivity analyses around the per person costs are presented in Table 5.9. Based on the estimated prevalence (Table 5.3) and the entire 50+ years population in year 2015 [49], the prevalence-based unadjusted mean total direct healthcare costs for healthy weight were estimated to be $ 64,817,248, overweight were $ 61,442,129 while those of obesity was $60,276,468 (Table 5.7). Overweight and obese groups had significantly higher total direct healthcare costs burden compared with that for healthy weight in the entire older adult Ghanaian population.

Table 5.8 shows the univariable and multivariable analyses of the association between annual healthcare costs and BMI categories. Overweight and obesity were significantly associated with higher costs versus healthy weight in all cost domains. In the multivariable analyses, the mean annualized direct healthcare costs for the healthy weight reference group was $51.79 (95% CI: 46.35, 57.22) per person for total costs including $21.16 (95% CI: 17.51, 25.84) for OOP and $30.24 (95% CI: 27.73, 32.75) for NHIS costs. However, being overweight was associated with $37.86 (95% CI: 26.71, 49.02) additional total costs per person, $17.68 (95% CI: 9.67, 25.68) additional OOP costs and $20.13 (95% CI: 15.08, 25.18) increase in NHIS costs. Being obese was associated with total incremental costs of $63.96 (95% CI: 48.71, 79.20), $28.16

(95% CI: 18.83, 37.48) as OOP and $34.64 (95% CI: 26.92, 42.36) as NHIS costs. Total costs increased with age, high education and high household wealth.

Table 5.6**.** Annualised direct healthcare cost per person by stratified by weight status among older adult (50+ years) respondents in Ghana, WHO SAGE Wave 2 (2014/15). All costs are quoted in US dollars ($). Mean exchange rate equivalence of $1 ≈ GHS 4.3562 was used from year 2017.

Sample used	Weight status	*OOP cost per person [Mean (95%CI)]			†NHIS cost per person [Mean (95%CI)]			Total Costs per person (OOP +NHIS) [Mean (95%CI)]
		Outpatient visits	Inpatient services	Total OOP	Outpatient visits	Inpatient services	Total NHIS	Total Costs
Full Sample	Underweight	8.6 (6.3, 10.8)	9.3 (1.7, 19.1)	17.9 (10.0, 28.0)	15.6 (13.8, 19.0)	5.1 (2.7, 7.7)	22.1 (18.7, 25.5)	41.1 (30.4, 51.9)
	healthy	13.9 (6.4, 20.3)	4.3 (1.8, 6.8)	14.5 (10.3, 18.6)	13.5 (12.2, 14.8)	4.5 (3.4, 5.6)	20.3 (18.8, 21.7)	34.8 (29.9, 39.5)
	Overweight	19.4 (13.0, 25.7)	10.9 (1.5, 20.2)	30.2 (18.9, 41.5)	27.0 (23.6, 30.4)	20.3 (12.6, 27.1)	47.3 (41.7, 53.0)	77.5 (55.6, 95.8)
	Obese	33.3 (25.1, 41.5)	14.9 (6.0, 36.2)	48.2 (25.6, 70.8)	50.9 (44.6, 57.2)	18.9 (9.6, 28.1)	83.6 (60.7, 96.40)	131.9 (107.7, 162.1)
Only those who visited health facility	Underweight	17.4 (15.2, 25.5)	223.1 (52.5, 417.6)	233.5 (63.5, 429.8)	40.2 (38.3, 42.8)	121.6 (94.7, 141.5)	146.1 (116.7, 170.5)	379.6 (213.3, 567.2)
	healthy	18.1 (15.0, 21.2)	95.0 (48.7, 139.4)	116.4 (48.5, 196.6)	31.0 (29.7, 32.3)	99.0 (93.4, 110.3)	120.9 (111.6, 130.1)	234.0 (168.9, 317.9)
	Overweight	42.8 (30.5, 43.1)	220.8 (60.2, 390.0)	245.9 (82.3, 418.6)	59.7 (57.7, 61.0)	225.6 (229.6, 277.6)	292.3 (263.4, 317.0)	538.2 (373.4, 707.9)
	Obese	65.3 (53.8, 75.8)	326.8(124.5, 657.0)	381.7 (98.3, 722.0)	99.8 (95.3, 106.4)	413.6 (386.5, 534.6)	486.9 (457.7, 616.1)	868.6 (510.1, 1224.2)

CI = confidence interval
Note: Government bore for each person approximately 60% share of the total direct healthcare costs in the older adult population in 2014/15.
*OOP denotes out-of-pocket; †NHIS denote National Health Insurance Scheme.
Values are supposed to take two decimal places however, using such structure distorts the table.

Figure 5.1. Percentage cost share per person between out-of-pocket (OOP) and the National Health Insurance scheme (NHIS) costs, among older adult population in Ghana WHO SAGE 2014/15.

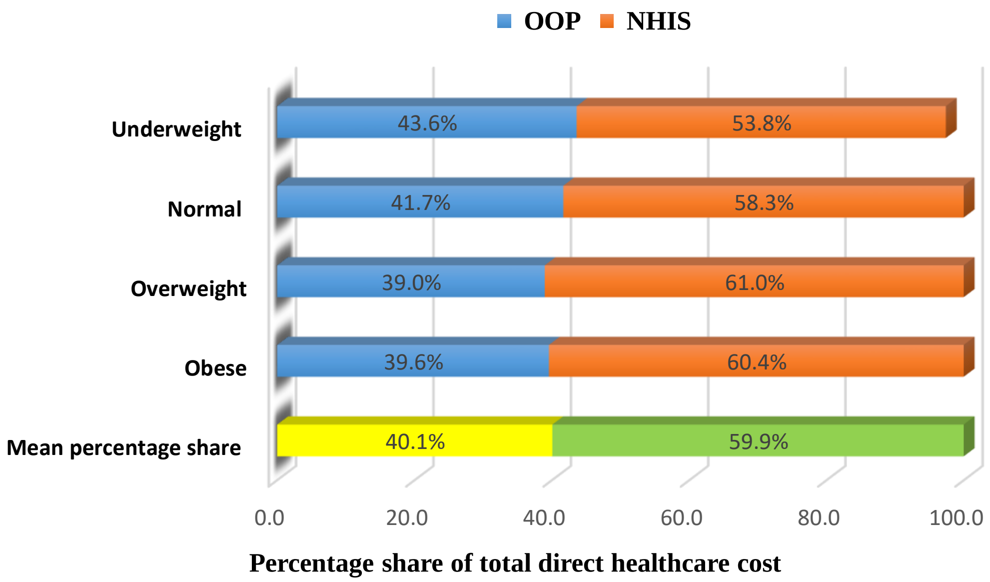


Figure 5.1. Percentage cost share per person between out-of-pocket (OOP) and the National Health Insurance scheme (NHIS) costs, among older adult population in Ghana WHO SAGE 2014/15. For each person, Government bore approximately 60% share of the total direct healthcare costs in the older adult population in 2014/15. Mean percentage cost share for OOP shown in yellow and that of NHIS shown in green.

Table 5.7**.** Prevalence-based NHIS and total direct healthcare costs (2014/15), by BMI categories among older adult population (50+ years) in Ghana. Population source: Ghana Statistical Service.

	Weight status			
	Underweight	Healthy	Overweight	Obesity
Prevalence, %	10.1	53.8	22.9	13.2
2015 Total adult Population (aged 50+y) = 3,462,016.00, n	349,664	1,862,565	792,801	456,986
[1]Prevalence-based NHIS costs (95% CI), $	7,727,565.91 (6,538,709.62, 8,916,422.21)	37,810,061.54 (35,016,214.63, 40,417,651.99)	37,499,518.71 (33,059,829.39, 42,018,488.19)	38,204,038.96 (27,739,057.00, 44,053,461.20)
[1]Prevalence-based total costs (95% CI), $	$14,371,175 (10,629,774, 18147542)	$64,817,248 (55,690,682, 73,571,302)	$61,442,129 (44,079,773, 75,950,399)	$60,276,468 (49,217,404, 74,077,449)

[1] Prevalence-based costs estimated from total costs by weight status categories for full sample
CI = confidence interval

Table 5.8. Factors associated with direct healthcare costs (annualised cost per person) among older adult population in Ghana, 2014/15

	Annualised total costs [Predicted incremental costs, $]				OOP Costs [Predicted incremental costs, $]				NHIS Costs [Predicted incremental costs, $]			
	Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate	
	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI
Weight status (Ref: healthy)												
Underweight	20	-4.66, 37.47	20.35	-7.19, 19.88	10.81	-5.00, 22.60	9.48	-6.38, 11.35	12.6	-1.30, 6.49	10.51	-1.51, 8.53
Overweight	39.57***	24.96, 54.18	37.86***	26.71, 49.02	18.00**	6.47, 29.53	17.68***	9.67, 25.68	21.57***	15.90, 27.24	20.13***	15.08, 25.18
Obesity	87.68***	59.55, 115.81	63.96***	48.71, 79.20	35.98***	13.16, 58.79	28.16***	18.83, 37.48	51.71***	40.04, 63.37	34.64***	26.92, 42.36
Sex (Ref: Male)												
Female	17.04**	7.16, 26.93	14.03	-1.52, 22.32	1.5	-7.61, 8.6	1.06	-5.57, 10.77	16.53***	12.59, 20.48	7.75***	3.60, 11.89
Age, years	3.4	-.09, 8.95	1.81**	0.91, 3.30	1.32	-0.15, 3.79	1.45**	1.30, 7.55	1.18	-2.02, 3.84	1.34**	0.13, 2.55
Educational level (Ref: Low)												
High	31.61***	16.05, 47.17	17.19**	7.23, 27.16	23.63***	10.71, 36.54	12.21***	5.76, 18.67	7.98**	2.68, 13.28	5.64	-0.99, 8.26
Marital status (Ref: Single)												
Married/Co-habiting	20	-9.31, 49.56	34.11*	0.27, 67.96	7.19	-10.20, 24.68	9.29	-6.03, 24.61	12.93*	0.35, 25.51	23.70**	5.91, 41.49
Divorced/ Separated/Widow	36.47*	6.92, 66.02	42.47*	9.80, 75.14	11.19	-6.00, 28.37	11.62	-2.55, 25.79	25.28***	12.06, 38.50	28.48**	10.53, 46.42
Location (Ref: Rural)												
Urban	16.11*	3.92, 28.31	10.97	-2.57, 24.37	5.70	-3.57, 15.00	6.16	-2.20, 17.11	10.41***	5.26, 15.56	7.91	-2.73, 12.92
Employment status (Ref: Unemployed)												
Employed	21.43**	6.68, 36.18	9.1	-0.59, 8.78	13.95	1.81, 26.08	5.94*	1.50, 11.37	7.48**	2.08, 12.89	3.17	-2.38, 6.71
Household wealth status (Ref: Lowest)												
Low	11.47**	4.37, 18.58	15.11*	1.63, 28.58	3.5	-0.05, 7.04	4.22	-3.55, 11.99	7.97**	3.46, 12.49	8.57*	1.95, 16.20
Moderate	23.07***	13.12, 33.01	28.72**	11.96, 45.47	9.31	2.82, 15.81	14.31*	3.06, 25.56	13.75***	8.67, 18.83	12.34**	4.70, 19.99
High	41.54***	30.38, 52.71	38.24***	22.73, 53.75	16.87	9.34, 24.41	18.86***	8.81, 28.91	24.67***	18.52, 30.82	18.30***	10.45, 26.16
Highest	65.97***	46.00, 85.94	45.73***	29.53, 61.93	34.24	18.27, 50.21	24.57***	13.74, 35.40	31.72***	23.93, 39.52	19.28***	10.84, 27.73
Health insured (Ref: Uninsured)												
Insured	13.19*	1.70, 28.07	7.34	-2.63, 17.31	-2.09	-8.97, 10.79	3.53	-10.00, 5.91	15.27***	10.91, 19.63	12.52***	8.23, 16.81
Having chronic disease (Ref: No)												
Yes	27.15*	5.73, 48.58	18.01	-1.09, 25.07	10.85*	2.11, 28.81	7.45	-8.08, 18.13	16.30***	7.80, 24.80	10.84	-3.78, 16.81
Intercept	51.54***	45.75, 57.32	51.79***	46.35, 57.22	21.47***	17.04, 25.91	21.16***	17.51, 25.84	30.06***	27.55, 32.58	30.24***	27.73, 32.75

CI = confidence interval, **P*<0.05, ***P*<0.01, ****P*<0.001

Table 5.9. Sensitivity analysis of annualised direct healthcare costs per person stratified by weight status among older adult (50+ years) respondents in Ghana, WHO SAGE Wave 2 (2014/15).

Sample used	Weight status	OOP costs	NHIS costs	*Total Costs	OOP costs	NHIS costs	Total Costs	OOP costs	NHIS costs	Total Costs
		Mean (95% CI)			Mean (95% CI) varied by -20%			Mean (95% CI) varied by +20%		
Whole Full Sample	Underweight	17.9 (10.0, 28.0)	22.1 (18.7, 25.5)	41.1 (30.4, 51.9)	14.3 (8.0, 22.4)	17.7 (15.0, 20.4)	32.9 (24.3, 41.5)	21.5 (12, 33.6)	26.5 (22.4, 30.6)	49.3 (36.5, 62.3)
	healthy	14.5 (10.3, 18.6)	20.3 (18.8, 21.7)	34.8 (29.9, 39.5)	11.6 (8.2, 14.9)	16.2 (15.0, 17.4)	27.8 (23.9, 31.6)	17.4 (12.4, 22.4)	24.4 (22.7, 26.0)	41.8 (35.9, 47.4)
	Overweight	30.2 (18.9, 41.5)	47.3 (41.7, 53.0)	77.5 (55.6, 95.8)	24.2 (15.1, 33.2)	37.8 (33.6, 42.4)	62.0 (44.5, 76.6)	36.2 (22.7, 49.8)	56.8 (50.0, 63.6)	93.0 (66.7, 115.0)
	Obese	48.2 (25.6, 70.8)	83.6 (60.7, 96.40)	131.9 (107.7, 162.1)	38.6 (20.5, 56.6)	66.9 (48.6, 77.1)	105.5 (86.2, 129.7)	57.8 (30.7, 85.0)	10.3 (72.8, 115.7)	158.3 (129.2, 194.5)
Only those who visited health facility	Underweight	233.5 (63.5, 429.8)	146.1 (116.7, 170.5)	379.6 (213.3, 567.2)	186.8 (50.8, 343.8)	116.9 (93.4, 136.4)	303.7 (170.6, 453.8)	280.2 (76.2, 515.8)	175.3 (140.0, 204.6)	455.5 (256.0, 680.6)
	healthy	116.4 (48.5, 196.6)	120.9 (111.6, 130.1)	234.0 (168.9, 317.9)	93.1 (38.8, 157.3)	96.7 (89.3, 104.1)	187.2 (135.1, 254.3)	139.7 (58.2, 235.9)	145.1 (133.9, 156.1)	280.8 (202.7, 381.5)
	Overweight	245.9 (82.3, 418.6)	292.3 (263.4, 317.0)	538.2 (373.4, 707.9)	196.7 (65.8, 334.9)	292.3 (263.4, 317.0)	430.6 (298.7, 566.3)	295.1 (98.8, 502.3)	350.8 (316.1, 380.4)	645.8 (448.1, 849.5)
	Obese	381.7 (98.3, 722.0)	486.9 (457.7, 616.1)	868.6 (510.1, 1224.2)	305.4 (78.6, 577.6)	389.5 (366.2, 492.9)	694.9 (408.1, 979.4)	458.0 (118.0, 866.4)	584.3 (549.2, 739.3)	1042.3 (612.1, 1469.0)

*Total costs per person was estimated as the sum of the average OOP and NHIS costs per person;
All costs are quoted in US dollars ($). Mean exchange rate equivalence of $1 ≈ GHS 4.3562 was used from year 2017.

5.6 Discussion

This study aimed to examine the association between annual health service utilization as well as annual direct healthcare costs and four BMI categories in the older adult population of Ghana. Findings in this study showed that people who were overweight or obese had increased annual health service utilization and costs compared with those of healthy weight, despite making up only 36% of the population. Being obese was associated with about 53% more outpatient visits and 159% more inpatient admissions compared to those with healthy weight. Being diagnosed with at least one chronic disease was also associated with 38% additional outpatient visits. Similarly, overweight was associated with 73% more inpatient admissions compared with those of healthy weight, but there was no significant association for outpatient visits. Despite that the prevalence of overweight and obesity was only about half of the healthy weight, total healthcare costs burden was almost doubled. The total per person direct healthcare costs associated with overweight increased by 73% and for obesity, these costs were more than double in all cost domains compared to persons with healthy weight.

Our findings are consistent with previous international studies which have shown that health service utilization among the overweight and obese among older adults are higher compared with healthy weight [193, 195-197, 208]. For example, a comparison of healthcare utilization by weight status in the US found those with obesity to be more likely to have more inpatient admissions and orthopaedic procedures compared with those of healthy weight [196]. Similarly, in Ireland, Doherty et al found overweight and obesity to be associated with significantly higher outpatient visits and inpatient admissions [193] which translated to higher healthcare costs in those who were overweight or obese compared with those of healthy weight. Increased healthcare utilization associated with overweight or obese in this study could be attributed to a possible increased burden in prevalence of NCDs [146]. This could be the case as findings in this study also showed that one out of five in the overweight or obese population had at least one chronic disease; and having a chronic disease was associated with increased utilization.

The findings that 20% (one out of five) of overweight or obese respondents had at least one chronic disease, and that having a chronic disease was associated with increased hospital utilization may imply a substantial but avoidable burden on the health system. This result is consistent with previously published research, which has shown obesity increases the risk of developing chronic diseases[9, 123] and the presence of chronic disease is associated with increased health service utilization, especially among older populations [9, 195, 212, 217].

As obesity mediates the occurrence and exacerbation of chronic diseases, an increasing prevalence of overweight and obesity in the older adult population [10] would likely increase health service utilization. Like most low and middle income countries, Ghana is facing a rapidly increasing burden of NCDs, however the country's health systems are under-resourced and unprepared [11, 35, 218]. The Ministry of Health's NCDs management strategy aimed to reduce overweight and obesity prevalence by 2% for people aged 15-49 years [17], with no plans for those aged 50 years and above. It can be argued that this strategy that neglects the 20% of the adult population of Ghana aged 50+ years - in whom the prevalence of overweight and obesity are rapidly increasing - is mistaken and requires urgent attention. This study highlights the increasing burden and associated costs of overweight and obesity amongst these older age groups. These findings can be used by clinicians to increase surveillance on NCD markers and by decision-makers to develop evidence-based strategies for overweight and obesity in Ghana.

Another significant result was the finding of a positive association between overweight and obesity and a higher additional annualized healthcare cost. This finding agrees with previous international studies which also found that people who were overweight/obese relative to those with healthy weight were associated significantly higher healthcare costs [23, 26, 192, 195, 196, 198, 219]. Overweight and obesity have been associated with increased health care costs that ranged from 19- 95% that were in some instances more than doubled those of persons whose weights were healthy [195, 208, 214, 220]. Results in this study showed that relative to healthy weight, overweight was associated with 73% additional total cost, and obesity was associated with more than a doubling of the total cost. This finding is also consistent with reports that such costs are driven by increased inpatient and outpatient utilization [194, 195, 221]. Finally, the finding that the government covered 60% of the total direct healthcare costs per person in 2014/15, suggests that high prevalence of overweight and obesity in the population potentially poses a substantial burden on the health budget.

This study has some limitations. First, mean costs were used to estimate from five districts of Ghana to estimate the NHIS costs for medications. Although the WHO SAGE data is representative of the older adult population [70] and medication prices do not change by district, medication costs from five districts may not be fully representative of the whole of Ghana. However, only these five districts provided complete claims data. Additionally, unlike service-related costs that were estimated based on diagnoses, type of services and the level at which service was accessed, mean medication costs were assumed to be the same for all purposes but only differentiated based on outpatient or inpatient services. This may result in overestimating the medication costs if majority who visited the facilities required medications with lower costs or underestimate the medication costs if majority of people used medications that had higher costs. However, medication costs based on diagnosis for each person were not available at the time of data collection.

Second, service utilization and OOP costs in the WHO SAGE were self-reported hence may be subject to recall bias. Any over- or under-reporting of the utilization and specific costs will likely introduce some degree of measurement error; although in WHO SAGE, these data were reasonably well-reported [69] and this recall period may not have major effect [222, 223]. Annual costs were estimated from costs incurred during the last health facility visit which was available from the WHO SAGE. However, due to factors such as the reason of visit and level of facility last visited, costs may be over- or underestimated. To provide additional scenarios around the costs, sensitivity analyses on annual costs were conducted by varying the unit (OOP, NHIS and total) costs by ±20%. Findings from the sensitivity analyses show that costs burden may differ based on the dispersion around the average costs. However, the significantly high costs burden due overweight and obesity compared to healthy weight would remain the same. Additionally, since this is population-based and not hospital data, this study may not have accounted for some specific healthcare costs directly associated with obesity from sections, such as physiotherapy and dietician services. Therefore, I propose that future health services utilization and healthcare costs evaluations use hospital data that would most likely capture all costs. Regarding costs, this study could not account for indirect costs including those associated with absenteeism or presenteeism as these were not captured in the WHO SAGE. Even though the data is representative of the population aged 50 years and above, the analysis omits observations with missing data and BIVs. Hence, there is a chance for selection bias to be introduced that might have affected external validity. However, missing data formed less than 5% of the total sample, which is likely to have minimal effect on the analysis [224]. Lastly, as this is a cross-sectional study the results are indicative of associations rather than causal relationships.

To the best of the author's knowledge, evidence of association between health service utilization as well as costs and BMI have been predominantly conducted in developed economies [192, 193, 195, 197, 208, 220] but are scarce especially, in sub-Saharan Africa. A major strength of this study is the effort made to extend such analyses to a sub-Sahara African setting where prevalence of overweight and obesity are reported to be on the increase.

5.7 Conclusion

This study provides evidence of the utilization and cost burden of overweight and obesity in Ghana. The results demonstrate that overweight and obesity were associated with increased health service utilization and direct healthcare costs. One in five respondents in the overweight or obese population had at least one chronic disease, and having chronic disease was associated with increased outpatient utilization. Additionally, this study showed that even though the combined prevalence of overweight and obesity was 36%, the total cost burden was almost double that of healthy weight. This cost burden to the government was high since it may have to bear more than half the healthcare costs per person. The results provide a compelling evidence to include those 50+ years in the Ministry of Health NCDs strategy and thus suggest the need for cost-effective and sustainable preventative and weight management programs to mitigate the associated increased health service utilization and high cost burden of overweight and obesity.

5.8 Postscript

Results from Chapter 5 highlight higher numbers of inpatient admissions associated with overweight and obesity compared with healthy weight; that obesity is associated with additional outpatient visits; that overweight is associated with increased total costs per person and the costs associated with obesity are more than double that for healthy weight. One in five of the overweight and obese population had at least one chronic disease, and this was associated with increased outpatient utilization. Additionally, the government's NHIS was found to bear approximately 60% while the individual bore 40% of the average total costs per person expended in 2014/15. Overweight and obese groups had significantly higher total direct healthcare cost burden compared with the healthy weight group in the entire older adult Ghanaian population.

The work presented shows the implications of overweight and obesity in the older adult population who were neglected in the Ministry of Health's strategy. The results suggest that implementing weight reduction measures is necessary and could reduce health service utilization and costs in this population. However, weight reduction interventions can be cost- and resource-intensive, and hence the need for economic evaluations to prioritize and use sustainable "value-for-money" interventions. The direct healthcare costs estimated in this chapter were used in Chapter 7 as input parameters for health economic modelling.

6 Annual transition probabilities between three body mass index (BMI) categories: healthy weight, overweight and obesity among older adults aged ⩾50 years in Ghana to be used in future modelling studies

6.1 Preface

This Chapter presents the transition probabilities between three health states: healthy weight, overweight and obesity in older adults. The study generated an essential parameter required for health economic modelling which was absent for the Ghanaian older adult population. Besides its importance in health economic evaluation, the estimated sojourn times [2] between the three health states are useful in informing both financial and health system preparedness. The continual increase in the prevalence of obesity and hence non-communicable diseases (NCDs) requires households and nations to have the financial and health system capacity for management. The knowledge of the sojourn times of stages of diseases/risk factors helps physicians determine the survival rates and treatment to give. It also facilitates the estimation of the costs to the individual and/ or health system [29] and supports adequate financial preparedness. This chapter also presents factors that influence movement between BMI states and the sojourn times. Estimates presented in this study will be used in future studies to extend the model presented in Chapter 7.

[2] Sojourn time in this thesis means average period of a single stay in a given state.

This chapter is published in Social Science and Medicine (Appendix 5).

Lartey, S.T., Si L., Otahal, P., de Graaff, B., Boateng, G.O**.,** Biritwum, R.B., Minicuci, N., Kowal, P., Magnussen, C.G., & Palmer, A.J. Probabilities of Changing between healthy Weight, Overweight, and Obesity in Older Adults: the WHO SAGE Older Adults Longitudinal Study. *Social Science and Medicine*. 2020; 247(112821): 1-9.

6.2 Abstract

Introduction: Overweight/obesity is becoming increasingly prevalent in sub-Saharan Africa including Ghana. However, transition probabilities, an essential component to develop cost-effective measures for weight management are lacking in this population. We estimated annual transition probabilities between three body mass index (BMI) categories: healthy weight (BMI ≥18.5 and < 25.0kg/m^2), overweight (BMI ≥25.0 and < 30.0kg/m^2), and obesity (BMI ≥30.0kg/m^2), among older adults aged ≥50 years in Ghana.

Methods: Data were used from a nationally representative, multistage sample of 1496 (44.3% females) older adults in both Waves 1 (2007/8) and 2 (2014/15) of the Ghana World Health Organization's Study on global AGEing and adult health (WHO SAGE). A multistage Markov model was used to estimate annual transition probabilities. I further examined the impact of specific socio-economic factors on the transition probabilities.

Results: At baseline, 22.8% were overweight and 11.1% were obese. The annual transition probability was 4.0% (95% CI: 3.4%, 4.8%) from healthy weight to overweight, 11.1% (95% CI: 9.5%, 13.0%) from overweight to healthy weight and 4.9% (95% CI: 3.8%, 6.2%) from overweight to obesity. For obese individuals, the probability of remaining obese, transitioning to overweight and completely reverting to healthy weight was 90.2% (95% CI: 87.7%, 92.3%), 9.2% (95% CI: 7.2%, 11.6%) and 0.6% (95% CI: 0.4%, 0.8%) respectively. Being female, aged 50-65 years, urban residence, having high education and high wealth were associated with increased probability of transitioning into the overweight or obese categories.

Conclusion: Findings from this study highlight the difficulty in transitioning away from obesity especially, among females. The estimated transition probabilities will be essential in health economic simulation models to determine sustainable weight management interventions.

6.3 Introduction

Globally, the prevalence of obesity is progressively increasing and has almost doubled in those aged ⩾18 years between 1980 and 2014 [6]. This trend is also seen in sub-Saharan Africa including Ghana, where females and urban dwellers have relatively high overweight/obesity prevalence [8, 70, 143]. Nationally representative studies in Ghana suggest that the prevalence of overweight/obesity increases with age [15, 70]. High and increasing prevalence of overweight/obesity has implications for physical [9, 122, 225] and mental health [24, 25], quality of life [128, 132] and hence the potential to increase cost burden on the health system and the general economy [65, 129, 131, 184]. These implications of obesity may be exacerbated among older adults (50+ years) [9].

Given the high prevalence of overweight/obesity and the difficulty in returning to normal/healthy weight once classified as overweight or obese [226], coupled with the impact overweight/obesity has on the health of older adults, economic evaluation and implementation of weight reduction strategies have become increasingly important in affected populations. Health economists in conducting economic evaluations are interested in both health resource management and health outcome consequences of health care interventions. Due to scarcity of resources, there is a need for appropriate justification where an institution invests in any preventative or treatment strategy. Pharmaceutical industry uses economic evaluations for decision making prior to large investment in various trials phases to decide the chances that a new drug would be cost effective [227]. Health economic evaluation is used to determine whether a health technology is cost-effective. There are three ways of conducting a health economic evaluation, i.e. clinical trial-based, economic modelling-based and a combination of both [1]. Health economic evaluation modelling (mostly Markov model) is mostly useful for chronic diseases and it is used to synthesize key parameters used for decision making. In this, the risk factor/disease is divided into distinct states and transition probabilities assigned for the movement between states [227]. Attaching the transition probabilities in economic evaluation improves the precision of an appropriate estimation of long-term costs and health effects. Additionally, reliable estimation of transition probabilities is required for the correct implementation of such models, and the models are mostly used to determine cost-effective interventions for the risk factor or disease [228]. On their own, transition probabilities and sojourn times would provide very essential information on both short and in particular long term risk(s), health and cost implications of each distinct health state.

Increasing prevalence of obesity in Ghana [10, 11] calls for an urgent information on the distinct state risks, health and costs implications. Such information is essential for health education; public health/ clinicians' prescription of interventions; and government and health systems preparedness as obesity is a major risk factor for NCDs. Additionally, the trends in prevalence demands for the development of evidence based cost-effectiveness analysis of preventive strategies for weight reduction. This will ensure "value-for-money" in the choices of alternative strategies. However, cost-effectiveness analysis of interventions in obesity is lacking in Ghana due to limited and in most cases the lack of required data such as transition probabilities in obesity health economics models. As a consequence, prediction of the course of weight gain or reduction in patients who suffer from obesity-related diseases such as diabetes is challenging.

Key challenges to estimating transition probabilities are the lack of the needed data and previously unclear methods for estimation [205, 226, 229]. The World Health Organization's Study on global AGEing and adult health (WHO SAGE) data collected in Ghana provides the most current and appropriately structured data which makes estimating transition probabilities possible. Additionally, in recent years, there are a wide range of multistate modelling methods to estimate transition probabilities and some of these methods can also be used to examine the effects of covariates on the obtained probabilities [229-232]. Thus, this study aimed to estimate the annual transition probabilities between healthy weight, overweight, and obesity among the older adult population in Ghana; and investigated factors associated with these transition probabilities. To the best of the authors' knowledge, this is the first study that estimates the BMI-specific annual transition probabilities for the Ghanaian population.

Transitions in Disease Stages

Obesity is associated with a burden of health risks as well as negative economic consequences for individuals, communities, and nations [9, 85, 131]. For instance, people with obesity are at a higher risk of several chronic diseases, poor quality of life, and overall mortality [122, 132]. It is also accompanied by a higher cost in health management which is a burden to households and puts pressure on publicly financed healthcare systems [195, 196, 233]. These effects have worsened over the years due to the shifting age structure of the global population and changing trends in urbanization and lifestyle in developing countries, which have culminated in the prevalence of adult obesity nearly doubling from 1980 to 2014 [9]. The continual increase in obesity prevalence require that households and nations have the capacity to plan for financial management of these health problems if life expectancy continue to increase.

Medically, it is known that individuals transition between disease stages for most diseases or risk factors experienced [229, 234]. Diseases such as cancer do progress in stages from 0–4 for many types of cancer, with the higher number generally indicative of the greater extent to which the cancer has spread [235]. Similarly, there are three stages of human immunodeficiency virus (HIV) infection. Stage 1, signifying an initial acute infection; stage 2, the asymptomatic stage; and stage 3, the symptomatic stage, where the person’s immune system is severely damaged [236]. These stages of diseases and progression between stages helps physicians determine the survival rate of patients, the kind of treatment to give, predict the effectiveness of treatments, and how to manage the disease. Such classifications also facilitate the estimation of the cost to be incurred by either the individual and/ or a healthcare system depending on whether the person is insured or not insured [29]. Although several simulation studies have been used to determine how a person progresses from one disease stage to the other, most of these have been explained from a medical standpoint.

From a social science perspective, there are fewer studies that focus on estimating the probability of transitioning from one disease stage to another [237]. In the area of predisposing health risks such as obesity, the lack of knowledge of transition probability makes it difficult for health economists in conducting health economic evaluations upon which policy makers can decide which health intervention to be funded. If effective and cost-effective health interventions failed to be found, obesity-associated NCDs might cause long term comorbidities and mortality [123] over time given the increasing trend of obesity in Ghana [10]. In low and middle-income countries, the increasing obesity prevalence is likely to lead to increasing burden of NCDs [35, 75, 123] and dwindling health gains as obesity will reduce life expectancy [67]. If clinicians, public health practitioners and the patient are aware of the chances of transitioning from a lower BMI to a higher BMI and sojourn times, reaching a particular BMI state would serve as a signal for appropriate sustained action. Additionally, availability of transition probability for economic evaluation would help identify specific cost-effective strategy to prevent or manage high BMI.

Diseases or risk factors such as obesity with dire health and economic consequences [30, 67, 123, 129, 233] can be prevented if health economists can find cost-effective interventions. The awareness of transitions, key populations affected, and cost-effective measures could lead to a more informed health education and risk prevention implementation [238], and improve general and targeted surveillance of obesity and obesity-related diseases in the population. Further to this, the estimates will be used to support the development of sustainable and cost-effective measures if data on transition probabilities and average sojourn times are available. This is because transition probabilities are among essential parameters used to develop models which are normally used to predict long-term effects and for cost-effectiveness analysis of alternative strategies [1, 62]. Additionally, as it signals the health and costs implications in specific health states, knowledge of sojourn times it will support health systems and financial preparedness and planning for both the affected individual and the health sector. This is because transition probabilities also shows the proportion of the population at risk who move over a particular period of time into adjourning health states [227, 239]. Thus, the estimates can inform health financing policies designed to ameliorate health disparities [226].

So far, in sub-Saharan Africa, such evidence as to how adults move between various BMI health states, factors that influence such movement and how long an individual will spend in a particular health state are unknown. Consequently, this study seeks to use a Markov theory to estimate the probability of progressing between the different stages of weight gain – healthy weight, overweight, to obesity. The theory, which is explained further in the methods section assumes that the future state of a particular event only depends on the current state and not the previous states [229]. Briefly, figure 6.1 suggests that individuals who have healthy weight may remain in the same BMI category or can transition to overweight; the same can transition into obesity only after entering the overweight category. Similarly, those who are overweight can transition in time to healthy weight or to obese.

Figure 6.1. Allowable transitions between BMI states used to estimate annual transition possibilities

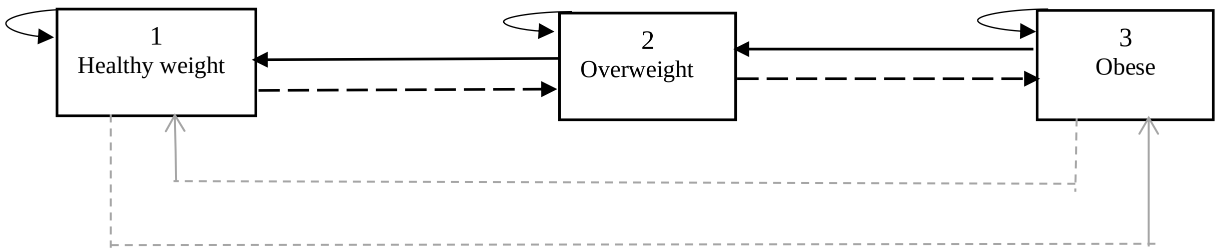


Figure 6.1. Allowable transitions between BMI states used to estimate annual transition possibilities. The arrows illustrate the possible transitions between states. State transition can be a transition into the immediate next state, previous or into itself. A bidirectional transition is allowed. A two-step movement is allowed; however, the subject may pass through the immediate adjacent state first. Respondent can be in only one state at a time. Movement from healthy weight to obese state and vice versa are shown in grey colours to show that these movements are possible; however, the individual will have to first pass through the overweight state.

Previous studies have emphasised the difficulty in transitioning away from high BMI [226, 240] while others have shown the sojourn time which is essential in revealing the implications of obesity [241]. Even though the characteristics of obesity may not differ in populations, manifestations such as who are the affected, proportion affected and duration of the impact may differ due to local factors [37, 72, 190, 240]. On the basis that findings from previous studies may differ from those in the Ghanaian populations [226, 241, 242], for the first time using a Ghanaian data we hypothesize that in a year,

1) individuals who are obese will have a higher probability of staying obese than transitioning to overweight.
2) the sojourn time at the stage of obesity before transition will be higher than the sojourn time at overweight.
3) individuals who are overweight will have a higher probability of transitioning to obese than to healthy weight.
4) individuals who have healthy weight will have a higher probability of staying longer with healthy weight than transitioning to overweight.

6.4 Methods

Study population

Data from the World Health Organization Study on global AGEing and adult health (WHO SAGE) in Ghana were used in this study. The WHO SAGE is a longitudinal study on the health and well-being of adult populations aged $\geqslant$50 years in six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa. It also collects sample data of younger adults, aged 18–49 years for comparison. In Ghana, WHO SAGE collected individual-level data from nationally representative households of adults using stratified, multistage cluster design. The sampling technique used in both Waves 1 (2007/08) and 2 (2014/15) was based on the WHO SAGE wave 0 in which the primary sampling units were stratified by region and locality (urban/rural) [70, 71, 206]. Systematic replacement was used in Wave 2 to account for losses to the sample from Wave 1. The socio-demographic characteristics and the anthropometrics measurements were used from the individual questionnaire [70].

Classification of body mass index

Body weight and height of respondents were measured by trained assessors using standard protocols [15, 71]. Pregnant women were exempted from weight measurements in both surveys [71]. BMI was calculated as a person's weight in kilograms divided by the square of their height in meters (kg/m^2). WHO classifications was used to categorize BMI as follows: normal/healthy weight, BMI $\geqslant$18.5 and <25.0kg/m^2; overweight, BMI=25.0 and <30.0kg/m^2; and obesity as BMI $\geqslant$30.0kg/m^2 [5].

Covariates

Covariates used in this study included sex, categorized as male/female; age, recorded as 50-65 years and above 65 years; and the level of education which was categorized as low education where educational level completed was less than a secondary or high school, and high education where a person completed secondary/high school and above. Location of residence was coded as rural/urban residence; and household wealth index constructed from a total of 22 assets/characteristics/ items were converted into wealth quintiles [95, 96, 143].

Statistical Analysis

Characteristic of the cohort used were described. Annual transition probabilities from the cohort were estimated using a validated multistate continuous-time Markov model in the "msm" package in R [229]. A transition probability meets the requirement of the Markov assumption that future evolution only depends on the current state. The Markov model has been applied and validated in several previous clinical studies [205, 241, 243, 244]. In this study, I applied a three-BMI-states model using the previously defined healthy weight, overweight and obese categories (Figure. 1). In this model, the underlying progression into a specific state rather than the observed progression is emphasized since transition may have mostly occurred outside the follow-up dates and a two-step movement (i.e. movement into the next two states) is not necessarily instantaneous. Thus, a person with healthy weight at time t=0, may pass through the overweight state before ending in the obese state at time t=1.

Since the exact time of transition is not observed but evolved continuously in time and is presumed to have occurred before the next assessment, the state-to-state transitions are interval-censored [229, 241, 243]. Thus, due to unknown exact transition time and irregular follow-up times for assessment among individual observations, the standard multistate model could not be used. Rather, I employed the time-homogenous continuous-time Markov model that can accommodate such irregularities to calculate transition intensities and probabilities [229]. At time t in the model, the individual is in state S(t). Movement into the next state is guided by a set of transition intensities, (i.e. the rate at which an individual has the likelihood of moving from one state i to another state j at a given time t). The intensities form a "3 x 3" matrix Q whose rows sum to zero. The diagonals of the matrix are the rates at which individuals do not transition and remain in their state whereas the off-diagonals represent the rates at which individuals transition into other states [229, 241, 243]. The model specified that an individual transitioning to a nonadjacent state (e.g. from healthy weight to obese state) must have passed through the immediate adjacent state (i.e. overweight state) rather than a direct movement to a nonadjacent state. Therefore, the maximum likelihood estimate was zero for the nonadjacent states (i.e. a two-step movement).

Under the assumption that Q is constant over time, the transition probability $\mathrm{P(t)}$, which is the chance of transitioning from one stage to the other is calculated by taking the matrix exponential of the scaled transition intensity matrix as follows:

$$\mathbf{P}(\mathbf{t}) = \mathbf{Exp}(\mathbf{tQ})\ \mathrm{t} \geq 0$$

In this study, the annual transition probabilities were calculated. Additionally, using the unadjusted model, the mean sojourn times (i.e. the average time spent in a specific state before transitioning into another state) were calculated for each state. Due to the model flexibility, covariates including sex, age, educational level, location of residence and household wealth status were fitted in separate models to examine if these factors changed the probabilities.

To validate the estimated transition probabilities, a Markov model was developed in TreeAge Pro 2018 (TreeAge Software Inc. Williamstown, Massachusetts, USA). Four Markov states were included in the model, i.e. healthy BMI, overweight, obesity and died. Subjects moved between states on the basis estimated transition probabilities. The starting cohort was set according to the baseline of the WHO SAGE cohort, i.e. age was 50 years, prevalence of healthy weight was 66.2%, overweight was 22.8%, obesity was 11%. Age-specific mortality risk was taken from the Ghanaian life table [245]. Cohort analysis was run with a 5-year interval and prevalence of the three BMI states was compared to the observed prevalence in Wave 2 [243]. The probabilities were valid if the observed prevalence in Wave 2 were within the 95% CI of the estimated expected prevalence or if the observed prevalence in Wave 2 fell 1% lower or higher above the expected prevalence. Statistical analyses were performed using R (Foundation for Statistical Computing, Vienna, Austria) [246] and TreeAge Pro 2018 (TreeAge Software Inc., Williamstown, Massachusetts, USA).

6.5 Results

A total of 1496 respondents aged 50+ years with complete anthropometric measurements and responses to covariates in both Waves 1 (2007/08) and Wave 2 (2014/15) of the WHO SAGE in Ghana were analyzed (Table 6.1). At baseline, 56% were males, 73.3% were aged 50-65years, 22.8% were overweight and 11.1% were obese. Table 6.2 shows the frequency of transitions observed in each of the three BMI states at time 1 (2007/08) and time 2 (2014/15). Transitions occurred between all three BMI states. One hundred and ninety-one people transitioned from healthy weight to a high BMI state (overweight or obese), while 77 people transitioned from the obese state to a less severe BMI state (healthy weight or overweight). One hundred and forty-two individuals transitioned from overweight to healthy weight, 142 people remained in the overweight state, while 57 moved from the overweight to the obese state.

Table 6.1**.** Sample Characteristics

		Wave 1 (2007/08) n (%)	Wave 2 (2014/15) n (%)
N		1496	1496
[a] BMI category	Healthy weight	989 (66.1)	981 (65.6)
	Overweight	341 (22.8)	340 (22.7)
	Obese	166 (11.1)	175 (11.7)
Sex	Females	664 (44.3)	664 (44.3)
	Males	835 (55.8)	835 (55.8)
Age group	50-65	1096 (73.3)	793 (53.0)
	>65	400 (26.7)	703 (47.0)
Educational status	High	432 (28.9)	436 (29.1)
	Low	1064 (71.1)	1060 (70.9)
Location	Rural	884 (59.1)	890 (59.5)
	Urban	612 (40.9)	606 (40.5)
Wealth status	Lowest	251 (16.8)	168 (11.2)
	Low	291 (19.5)	349 (23.3)
	Moderate	327 (21.9)	295 (19.7)
	High	311 (20.8)	351 (23.5)
	Higher	316 (21.1)	333 (22.3)

[a] BMI: body mass index

Table 6.2**.** The beginning to end transition (n=1496) between the three BMI states

First Assessment		Last Assessment			
		Time 2 (Wave 2)			
		Healthy weight	Overweight	Obesity	Total
Time 1 (Wave 1)	Healthy weight	798	162	29	989
	Overweight	142	142	57	341
	Obesity	41	36	89	166
	Total	981	340	175	1496

The transition intensity matrix showing the maximum likelihood estimates (95% confidence intervals) over an average period of seven years is presented in Table 6.3. The results show that even though individuals with healthy weight were more likely to transit to the overweight state (0.045) and transition from overweight into obese state (0.056), the likelihood increased for a transition from overweight into the healthy weight (0.124) and from the obese state to overweight state (0.106). From the estimated intensities, the mean sojourn time for healthy weight was 22.2 years, 5.6 years for overweight, and 9.4 years for obese.

The estimated annual transition probabilities are shown in Table 6.4. The annual transition probability from healthy weight to overweight was 4.0% (95% CI: 3.4%, 4.8%) and from healthy weight to obesity was 0.1% (95% CI: 0.0, 0.2%). After one year, the transition probability from overweight to healthy weight was 11.1% (95% CI: 9.5%, 13.0%) and overweight to obese was 4.9% (95% CI: 3.8%, 6.2%). For obese individuals, the probability of remaining obese was 90.2% (95% CI: 87.7%, 92.3%), the probability of transitioning to overweight was 9.2% (95% CI: 7.2%, 11.6%) and the probability of reverting to healthy weight was 0.6% (95% CI: 0.4%, 0.8%).

A validity check of the model estimated prevalence showed good concordance with the observed prevalence. The Markov model calculated prevalence (95% CI) in wave 2 were 64.6% (63.5%, 65.7%) for healthy weight, 23.2% (23.0, 23.6%) for overweight and 12.2% (11.5, 12.8%) for obese. The corresponding observed wave 2 prevalence were 65.6%, 22.7% and 11.7% for healthy weight, overweight and obesity in wave 2, respectively.

Table 6.3**.** Transition intensity matrix for a multistate Markov model of the transition between healthy weight, overweight and obesity across older adults (50+ years) in Ghana (2007/08-2014/15)

	To					
From	Healthy		Overweight		Obese	
	MLE[a]	95% CI	MLE	95% CI	MLE	95% CI
Healthy	-0.045	-0.053, -0.038	0.045	0.0378, 0.053	0[b]	-
Overweight	0.124	0.104, 0.148	-0.18	-0.209, -0.155	0.056	0.043, 0.073
Obese	0[b]	-	0.106	0.082, 0.137	-0.106	-0.137, -0.082

[a] MLE indicates maximum likelihood estimation. [b] MLE was zero for the nonadjacent states (i.e. a two-step movement). Thus, the model specified that an individual transitioning to a nonadjacent state (e.g. from healthy weight to obese state) must have passed through the immediate adjacent state (i.e. overweight state) rather than a direct movement to a nonadjacent state. The diagonals of the matrix are the rates at which individuals do not transition and remain in their state whereas the off-diagonals represent the rates at which individuals transition into other states [229, 241, 243]. The mean time spent in the healthy weight state before a transition was made into another state was -1/(-0.045)=22.2 years, a mean of -1/(-0.180)=5.6 years for overweight and a mean of -1/(-0.106)=9.4 years for obese.

Being female was associated with increased probability of transitioning from healthy weight to overweight (5.7%; 95% CI: 4.5, 7.1), from overweight to obese (5.1%; 95% CI: 3.8, 6.7) and remaining obese (93.3%; 95% CI: 90.9, 95.1) over a one-year period (Table 6.4). However, the transition probability associated with males who transitioned from overweight to obesity was higher compared to females (males: 6.6%; females 5.1%). The probability of moving from obesity to overweight was lower for females (6.3%; 95% CI: 4.5, 8.6), although higher for males (23.7%; 95% CI: 14.0, 37.9). Thus, whereas females had the higher probability to remain obese (93%), for males this was lower (75%). Transition probabilities relating to age showed variable associations; for adults aged 50-65 years, the probability of transitioning from healthy weight to overweight was higher when compared to those aged over 65 years. Meanwhile, the probability of transitioning from obese to overweight was lower for those aged 50-65 years when compared with those aged over 65years. Those with a high education compared to low education, living in urban areas compared to rural areas, and higher wealth compared to lower wealth showed an increased probability of transitioning from healthy weight into the overweight or obese category in the next 12 months (Table 6.5). Statistically significant hazard ratios were estimated for sex, urban living and household wealth (Table 6.6). The ratios were mostly significant for the progressive transitions, that is, female sex, living in urban area and having higher wealth were associated with a transition from healthy weight to overweight.

Table 6.4. One-year transition probabilities (95% confidence intervals) between healthy weight, overweight and obesity across older adults (50+ years) in Ghana (2007/08-2014/15)

		To					
	From	**Healthy Weight**		**Overweight**		**Obese**	
		Probabilities	**95% CI**	**Probabilities**	**95% CI**	**Probabilities**	**95% CI**
Total	Healthy Weight	0.959	0.951, 0.965	0.040	0.034, 0.048	0.001	0.0, 0.002
	Overweight	0.111	0.095, 0.130	0.840	0.819, 0.858	0.049	0.038, 0.062
	Obese	0.006	0.004, 0.008	0.092	0.072, 0.116	0.902	0.877, 0.923

Note: One-year transition probabilities between healthy weight, overweight and obesity among older adults estimated using Wave 1 (2007/8) and Wave 2 (2014/15) of the WHO-SAGE

Table 6.5. The impact of specific socio-economic factors on one year transition probabilities

		From	To					
			Healthy Weight		**Overweight**		**Obese**	
			Probabilities	**95% CI**	**Probabilities**	**95% CI**	**Probabilities**	**95% CI**
Total		Healthy Weight	0.959	0.951, 0.965	0.040	0.034, 0.048	0.001	0.0, 0.002
		Overweight	0.111	0.095, 0.130	0.840	0.819, 0.858	0.049	0.038, 0.062
		Obese	0.006	0.004, 0.008	0.092	0.072, 0.116	0.902	0.877, 0.923
Sex	Females	Healthy Weight	0.942	0.927, 0.954	0.057	0.045, 0.071	0.002	0.001, 0.003
		Overweight	0.110	0.085, 0.141	0.839	0.803, 0.866	0.051	0.038, 0.067
		Obese	0.004	0.003, 0.006	0.063	0.045, 0.086	0.933	0.909, 0.951
	Males	Healthy Weight	0.968	0.960, 0.975	0.030	0.024, 0.038	0.001	0.0, 0.002
		Overweight	0.110	0.092, 0.142	0.820	0.764, 0.859	0.066	0.037, 0.116
		Obese	0.016	0.009, 0.029	0.237	0.140, 0.379	0.747	0.596, 0.850
Age group	50-65	Healthy Weight	0.955	0.945, 0.963	0.044	0.036, 0.054	0.001	0.0, 0.002
		Overweight	0.108	0.089, 0.131	0.845	0.820, 0.868	0.047	0.034, 0.061
		Obese	0.006	0.004, 0.008	0.089	0.068, 0.118	0.905	0.875, 0.927
	>65	Healthy Weight	0.966	0.954, 0.975	0.033	0.024, 0.045	0.001	0.0, 0.003
		Overweight	0.122	0.088, 0.166	0.822	0.769, 0.863	0.055	0.034, 0.089
		Obese	0.007	0.004, 0.013	0.101	0.059, 0.164	0.892	0.824, 0.936
Educational Status	High	Healthy Weight	0.950	0.933, 0.962	0.049	0.037, 0.065	0.002	0.001, 0.003
		Overweight	0.101	0.074, 0.135	0.837	0.793, 0.872	0.062	0.042,0.089
		Obese	0.005	0.003, 0.008	0.089	0.058, 0.131	0.906	0.862, 0.938
	Low	Healthy Weight	0.962	0.954, 0.969	0.037	0.031, 0.045	0.001	0.0, 0.002
		Overweight	0.116	0.096,0.139	0.841	0.812, 0.864	0.043	0.031, 0.058
		Obese	0.006	0.004,0.009	0.095	0.069, 0.125	0.899	0.866, 0.926
Location	Rural	Healthy Weight	0.970	0.963, 0.976	0.029	0.023, 0.036	0.001	0.0, 0.002
		Overweight	0.119	0.096, 0.146	0.836	0.800, 0.864	0.045	0.029, 0.070
		Obese	0.011	0.007, 0.017	0.160	0.110, 0.232	0.829	0.752, 0.883
	Urban	Healthy Weight	0.931	0.913, 0.946	0.067	0.052, 0.084	0.002	0.001,0.004
		Overweight	0.110	0.085, 0.141	0.834	0.798, 0.863	0.056	0.041, 0.074
		Obese	0.004	0.003, 0.007	0.068	0.049, 0.093	0.928	0.901, 0.948
Wealth Index	Lowest	Healthy Weight	0.975	0.960, 0.984	0.024	0.016, 0.038	0.001	0.0, 0.003
		Overweight	0.135	0.086, 0.212	0.821	0.712, 0.880	0.044	0.012, 0.137
		Obese	0.022	0.007, 0.059	0.268	0.088, 0.580	0.710	0.350, 0.904
	Low	Healthy Weight	0.965	0.946, 0.978	0.035	0.022, 0.053	0.001	0.0, 0.002
		Overweight	0.168	0.116, 0.238	0.794	0.715, 0.851	0.037	0.015, 0.083
		Obese	0.017	0.007, 0.034	0.165	0.080, 0.292	0.818	0.680, 0.911
	Moderate	Healthy Weight	0.947	0.925, 0.962	0.052	0.037,0.073	0.001	0.0, 0.003
		Overweight	0.133	0.092, 0.185	0.822	0.764, 0.865	0.046	0.027, 0.075
		Obese	0.007	0.004,0.014	0.095	0.052, 0.167	0.898	0.821, 0.944
	High	Healthy Weight	0.959	0.943, 0.971	0.039	0.028,0.055	0.001	0.0, 0.002
		Overweight	0.102	0.071, 0.139	0.841	0.790, 0.879	0.057	0.035, 0.088
		Obese	0.005	0.002, 0.009	0.079	0.045, 0.135	0.916	0.857, 0.952
	Higher	Healthy Weight	0.930	0.906, 0.950	0.067	0.048, 0.091	0.002	0.001,0.004
		Overweight	0.081	0.056, 0.114	0.859	0.819,0.894	0.059	0.040, 0.089
		Obese	0.004	0.002,0.006	0.079	0.054, 0.115	0.917	0.879, 0.944

Note: One-year transition probabilities between healthy weight, overweight and obesity among older adults estimated using Wave 1 (2007/8) and Wave 2 (2014/15) of the WHO-SAGE.

Table 6. 6. Hazard ratios from Multistate Markov model fitted separately for covariates for transitions between healthy weight, overweight and obesity across older adults (50+ years) in Ghana (2007/08-2014/15)

Covariate		Hazard ratios (HR) and 95% CI							
		From Healthy weight to Overweight		From Overweight to Healthy weight		From Overweight to Obese		From Obese to Overweight	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Sex	Males	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Females	1.87[a]	1.32, 2.64	0.97	0.67, 1.38	0.67	0.31, 1.43	0.23[a]	0.11, 0.48
Age group	50-65	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	>65	0.76	0.52, 1.11	1.14	0.77, 1.69	1.21	0.67, 2.20	1.16	0.63, 2.12
Educational Status	High	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Low	0.75	0.52, 1.09	1.14	0.77, 1.69	0.69	0.41, 1.18	1.07	0.62, 1.84
Location	Rural	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Urban	2.36[a]	1.66, 3.36	0.95	0.66, 1.37	1.17	0.66, 2.08	0.40[a]	0.23, 0.68
Wealth Index	Lowest	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Low	0.91	0.50, 2.87	1.69	0.97, 2.95	0.72	0.25, 2.09	2.27	0.90, 5.73
	Moderate	1.35	0.80, 2.27	1.33	0.76, 2.31	0.83	0.39, 1.75	1.22	0.52, 2.88
	High	1.54[a]	1.02, 2.65	0.95	0.46, 1.67	0.91	0.46, 1.89	1.14	0.50, 2.43
	Highest	1.72[a]	1.03, 2.87	0.80	0.47, 1.38	1.04	0.54, 2.00	0.98	0.49, 1.99

[a] Significant result at $P < 0.05$.

6.6 Discussion and Conclusion

To the best of the authors' knowledge, this is the first study that provides transition probabilities for older adults and applies a multistate Markov transition model to older adults' BMI status in sub-Saharan Africa with a specific focus on Ghana. Key findings from this study are discussed as follows: first, the annual transition probabilities showed that after one year, persons who began the year as obese persons had 90% chances of remaining obese at the end of the year while the probability of reverting to healthy weight in the same year from obese was 0.6%; and obese persons were more likely to remain in the same state for nine and half years before transitioning into any adjacent state. Second, individuals were more likely to transition from overweight to healthy weight, followed by obese to overweight, overweight to obese and then healthy weight to overweight state. However, after one year, the estimated probabilities of healthy weight individuals moving into the obese state and obese individuals becoming healthy weight were marginal. Finally, factors including being female, higher education, urban residence and higher wealth index were associated with higher probabilities of transitioning from healthy weight to higher BMI categories and remaining in high BMI category after one year.

First, the estimated probabilities show that individuals were more likely to be stable in their BMI status after one year. For example, the probability of remaining obese was 90% and such individuals who remained obese were more likely to be in this state for a much longer period before making any transition into adjacent states. This suggests the probability of transitioning from obesity to healthy weight within one year was very slim. This is further supported by the findings on the average sojourn times; the obese older adult will stay in the obese state for approximately nine and half years before transitioning into another state while the average sojourn time was approximately six years for overweight state. With obesity as a major risk factor for NCDs, a higher probability of remaining obese and longer average sojourn time for obese individuals could have implications on NCDs burden of disease and ultimately on productivity and government health expenditure. Hence, the dire need for public health planning and cost-effective interventions that prevent transitions to overweight or obese state.

Second, more older adults were likely to transition from overweight to healthy weight (11%) compared to a transition from overweight to obesity (5%). International studies have shown similar trends but with different magnitudes in their estimates [240, 242]. Thus, in the US, while 16% of adults reverted from overweight to healthy weight, 12% and 0.7% transitioned into obese class 1 ($30.0 \leqslant \text{BMI} < 35.0$ kg/m^2) and 2 ($35.0 \leqslant \text{BMI} < 40.0$ kg/m^2) respectively, from overweight [240]. Furthermore, compared to findings in the US, the finding of 4% one-year transition probability from healthy weight to overweight, 5% from overweight to obese state, 9% from obese to overweight, and 11% from overweight to healthy weight were relatively small [240]. Additionally, the transition probability from healthy weight to obese (0.1%) or obese to healthy weight (0.6%) was marginal in this study. Thus, generally while the probability of transitioning into the immediate adjacent weight state (for example from healthy weight to overweight) was higher, the probability of transitioning into a nonadjacent weight status or a two-step movement remains small (for example, from obese to healthy weight status) within one year.

This study highlights factors associated with transitions. It was observed that being female compared to male was associated with higher probabilities of transitioning from healthy weight to overweight. Additionally, the probability of an obese female reverting to overweight (6.3%) or to healthy weight (0.4%) was lower compared to the probabilities for males (obese to overweight= 23.7%; and obese to healthy=1.6%). Thus, females had the higher probability to remain obese (93%) compared to males (75%), suggesting that being male seems to protect older adults from remaining obese. Results in this study agree with findings in a previous study in which the probability of attaining weight reduction was higher in males compared to females [242]. The lower probability of transitioning from healthy weight into overweight and the higher probability of transitioning from obese to overweight in those over 65 years compared to those lower than 65 years is also consistent with previous findings [247]. Findings on how education, place of residence and wealth status were associated with the probability of transitioning to and from different BMI statuses will be useful in targeting high risk older adults for weight reduction programs, and in the development of health economic simulation models that will identify cost-effective interventions for weight management in Ghana.

As the major strength of this study, data from WHO SAGE were used to estimate the annual transition probabilities. WHO SAGE is one of the most current and a longitudinal study that collects a nationally representative data of older. Additionally, the estimates in this study were validated using a multistate Markov model. This is the first study within the sub-Sahara African context that has estimated BMI-specific annual transition probabilities. The estimated transition probabilities will be useful to estimate, extrapolate and monitor the burden of overweight/obesity which has previously been monitored only using prevalence studies. Findings in this study highlight the difficulty in transitioning away from obesity especially for females, once they become obese, they are very likely to stay obese. Additionally, findings of the average sojourn time for especially obese persons would provide a platform for policy makers to amend strategies to prevent overweight/obesity in the older adult population, retool health practitioners to actively monitor BMI and help prevent the consequence overweight/obesity in this population. Apart from age and sex, findings of associated factors which most studies did not consider [137, 240-242] will be useful in targeting preventive measures. Finally, the estimated transition probabilities can form an integral part of health economic evaluations both to develop cost-effective weight reduction measures and for any disease in which overweight and obesity play a significant role, e.g. diabetes or hypertension [240].

The study has some limitations that are worth noting. First, this study maybe limited by the period from which estimates were gathered; future changes in prevalence may alter the estimated probabilities. The estimated transition probabilities were estimated in adults aged over 50 years and residing in Ghana such that inferences may not apply to other populations due to different environmental and social factors. Second, previous studies have shown that measuring obesity using BMI does not fully capture important aspects such as central adiposity and therefore suggests other anthropometric measures [85, 86, 150]. Due to data inadequacy and availability of full information on respondents with complete information of BMI, BMI was used as the measure of obesity in this study. Also, even though the use of BMI is associated with limitations [86], it has been considered as the gold standard measuring obesity [150]. Also, given that there could be an issue of loss-to-follow-up, which could not be fully accounted for due to the lack of variable to track reasons for such loss, complete data were used for our analysis. Finally, the scope of this study did not include the evaluation of intentions of weight gain or the weight loss in this population. Therefore, this study did not account for unintentional weight loss in older populations which could be due to factors such as the presence of chronic disease or bereavement.

This is the first study to provide transition probabilities between healthy, overweight, and obese states in the sub-Sahara African context. These estimates are useful to policy makers responsible for dealing with obesity, a major risk factor for non-communicable diseases. Additionally, factors that influence transition probabilities were identified to support the appropriate targeting of interventions. The estimation of these transition probabilities provides an important input for future economic evaluations through which cost-effective weight reduction and maintenance program choices can be made and implemented in the population.

6.7 Postscript

Chapter 6 identified that the probability of remaining obese was higher particularly in the female population; that the sojourn time for an obese individual was higher compared to an overweight person; and that being female, aged 50-65 years and having high SES were associated with an increased probability of transitioning into the overweight or obese categories. While the estimated transition probabilities will be an essential health economic parameter to extend the model presented in Chapter 7, the average sojourn times in each health state could have policy implications. In policy, the knowledge of the sojourn times combined with that of prevalence or incidence of obesity can be used to estimate and forecast the potential cost burden of overweight and obesity. Beside using the awareness of the sojourn times in designing and deciding the longevity of sustainable interventions, this will also support efforts in budgeting for NCDs, financial preparedness for both policy makers and households, and resource mobilization activities in the Ghanaian population.

From the findings in Chapter 5, an average sojourn time of about ten years by an obese individual who has a chronic disease could mean an increase in health resource utilization and higher health care costs. The probabilities will be useful to estimate, extrapolate and monitor the burden of overweight and obesity in the population. Findings on the average sojourn time for especially the obese provides a platform for policy makers to amend strategies to actively monitor BMI and help prevent the consequences of overweight/obesity in this population. The factors identified that influence the transitions will be useful in targeting preventive measures.

7 Construction and validation of a health economic model and application to quantify the long-term impact of overweight and obesity on remaining life expectancy (LE), quality-adjusted life years (QALYs), and total direct healthcare costs

7.1 Preface

The Chapter presents a study that aimed to quantify the remaining life expectancy (LE), quality-adjusted life years (QALYs) and long-term total direct healthcare costs associated with overweight and obesity among the older adult population in Ghana. This Chapter culminate all the works presented from Chapter 2, 3 4, 5 and 6 using the developed parameters as inputs for modelling. The parameters included the prevalence of healthy weight, overweight and obesity, body mass index (BMI)-specific health state utilities (HSUs), costs and hazard ratios. A health economic model with two states (alive or dead) was constructed in which the alive state showed three BMI categories. All individuals began as alive and were in one of the specific BMI states. The cohort moves through annual cycles for up to 50 years. This provides estimates for the long term impacts associated with each BMI category. From the estimated outcomes, years of life lost (YLL), QALYs lost and extra costs of overweight and obesity were calculated and scaled-up to the entire base case population.

This chapter has been processed into manuscript and ready for submission.

Lartey, S.T., Lung, T., Hayes, A., Si, L., Magnussen, C.G., Boateng, G.O., de Graff, B., & Palmer, A. Impact of overweight and obesity on life expectancy, quality-adjusted life years and lifetime costs in the adult population of Ghana.

7.2 Abstract

Aims: This study aimed to quantify the long-term impact of overweight and obesity on remaining life expectancy (LE), quality-adjusted life years (QALYs), and total direct healthcare costs in Ghana.

Methods: A Markov simulation model projected health and economic outcomes associated with three categories of body mass index (BMI): healthy weight ($18.5 \leq$ BMI <25.0); overweight ($25.0 \leq$ BMI < 30.0); and obese (BMI $\geq 30.00\text{kg/m}^2$) in simulated adult cohorts over a 50-year time horizon from age fifty. Costs were estimated from government and patient perspectives and discounted 3% annually and reported in 2017 USD. Mortality rates from Ghanaian lifetables were adjusted by BMI-specific all-cause mortality hazard ratios. Inputs were estimated from the 2014/2015 Ghana WHO Study on global AGEing and adult health data. Internal and external validity were assessed.

Results: From age 50 years, average (95% confidence interval (CI)) remaining LE for females were 25.6 (95% CI: 25.4-25.8), 23.5 (95% CI: 23.3-23.7) and 21.3 (95%: 19.6-21.8) for healthy weight, overweight, and obesity, respectively. In males, remaining LE were healthy weight (23.0; 95% CI: 22.8-23.2), overweight (20.7; 95% CI: 20.5-20.9) and obesity (17.6; 95%: 17.5-17.8). The undiscounted QALYs for healthy weight, overweight, and obesity among females were 23.0 (95% CI: 22.8-23.2), 21.0 (95% CI: 20.8-21.2) and 19.0 (95%: 18.8-19.7) respectively. The discounted total costs per person for females were $619 (95% CI: 616-622), $1,298

(95% CI: 1,290-1,306) and $2,057 (95% CI: 2,043-2,071) for healthy weight, overweight and obesity. QALYs and costs were lower in males.

Conclusion: Overweight and obesity have substantial health and economic impacts on the Ghanaian population. The evidence and the model developed can be used to identify sustainable and cost-effective strategies in the management of overweight and obesity in this population.

7.3 Introduction

Obesity (body mass index, BMI≥30.00 kg/m^2) is one of the leading risk factors for non-communicable diseases and has become a major global concern [9]. Since 1980, the prevalence of obesity has doubled among adults in most parts of the world including sub-Saharan Africa [6-10]. Obesity substantially increases morbidity, disability and mortality, and poses significant economic burden to populations [6, 9, 23]. In spite of the difficulty associated with its management [28] , associated health consequences, and cost burden, obesity prevalence is burgeoning in many places [7, 8, 10]. Thus, the increasing prevalence of obesity may present a major challenge to households, clinicians, health systems and especially, health policy decision makers who must allocate resources to prevent, manage or control obesity [29] and obesity-related morbidities and disabilities [30].

Interventions to prevent or control obesity in populations can be resource-intensive. As obesity is a major risk factor for non-communicable diseases (NCDs), evaluating associated policies could pose significant challenges as NCDs impose short, medium and long-term health and economic effects [65, 66]. While clinical trials and some epidemiological studies are limited by time and therefore can provide evidence of short- to medium-term effects, economic modelling is a method that can be used to provide estimates of likely long-term effects [1, 66]. Estimating the long-term effects of overweight and obesity are necessary to identify major differences in sub-populations, inform the development and correctly target obesity preventive and control strategies, and allocation of health resources [67]. A key long-term effect that has also been useful in communicating the impact of obesity is years of life lost (YLL) [248]. In this context, YLL is estimated as the difference between the remaining life expectancy of a person with healthy weight and that of an obese person [67, 248]. Previous studies have shown that compared with healthy weight, the remaining life expectancy due to obesity is lower; and therefore, obesity is associated with a higher number of YLL [67, 124, 248].

Despite the challenges obesity presents [9, 17, 30], there is a paucity of data estimating the long-term impacts of obesity on health and economic outcomes in sub-Saharan Africa. To bridge this gap, this study aimed to develop a Markov simulation model that quantifies the long-term health and economic effects of overweight and obesity in a sub-Saharan African setting. Specifically, reported were the remaining life expectancy (LE), YLL, quality-adjusted life years (QALYs) and the direct healthcare costs associated with sex, and with healthy weight ($18.50 \leq$ BMI <25.00 kg/m^2), overweight ($25.00 \leq$ BMI < 30.00 kg/m^2) and obesity (BMI ≥ 30.00 kg/m^2) for individuals aged 50 years. Finally, the estimated YLL, QALYs and total costs were scaled-up to the entire population of individuals with overweight and obesity, compared to those with healthy weight.

7.4 Methods

Model description

A Markov model that utilized survey-estimated parameters was adapted in this study to simulate the health and costs outcomes for a hypothetical adult cohort of 10,000 subjects [65, 249], accounting for age, sex and BMI status. The model was capable of generating average remaining LE, YLL, QALYs and costs for healthy weight, overweight and obese individuals. Second-order Monte Carlo simulation in which the subjects were simultaneously drawn from multiple distributions, was performed. The cycle length was one year, and the subjects, with initial age of 50 years were simulated until death or until age 100 years. This study used an initial age of 50 years due to the availability of key input parameters for this age [10, 233, 250]. To estimate the impact of different categories of BMI on remaining LE, YLL, QALYs and costs, simulated subjects were assumed to remain in their BMI category for their lifetime. Even though in reality there might be changes in the BMI of these individuals, there is little information to estimate the annual BMI changes for this population.

There were two health states: alive and dead as an absorbing state, [251]. A subject either remained in the alive state or moved onto the next cycle or died (Fig 7.1). The probability of death was determined by the mortality rates from the Ghanaian general population adjusted according to the BMI category [65]. BMI-specific mortality was estimated as a function of age, sex and BMI category. Current age- and sex-specific prevalence of individuals in each BMI category were estimated in our previous studies [10, 143], age- and sex-specific mortality rates were taken from the 2015 Ghana life tables [252] (Table 7.1), and BMI -specific hazard ratios of all-cause mortality taken from published literature [122] (Table 7.2). An increased risk of mortality for each five-units increase of BMI allowed the variation of mortality for subjects based on the BMI category [67, 122]. This method used to determine mortality rates has been described previously [67].

Health state utilities [250] and direct healthcare costs data [233] were simulated using beta and gamma distributions, respectively [253]. The model was constructed using the TreeAge Pro Suite 2018 R1.1 (TreeAge Software, Williamstown, Massachusetts). One-way (shown in tornado diagram) and probabilistic sensitivity analyses were used to address parameter uncertainty. The model was tested on its face, internal and external validity.

Study population

Parameters including the prevalence of the BMI categories [10, 143], health state utilities (HSUs) [250] and direct healthcare costs [233] were estimated using the 2014/15 Ghana Wave 2 of the World Health Organisation’s Study on global AGEing and adult health (WHO SAGE). SAGE used a stratified multistage cluster design to collect data that yielded national and subnational estimates with acceptable precision using region and locality type (rural/urban) as the primary sampling unit [69, 206]. Household and individual questionnaires were administered to selected respondents. Of the 4,735 survey respondents, 1,114 were excluded if they had missing or biologically implausible (height <100cm or >250cm, weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm [72, 73]) weight and height measurements, or were less than 50 years of age. This left 3,350 for analysis. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). Survey weights provided by WHO SAGE were applied in all estimations to ensure that values are representative of the Ghanaian population. Further information on the WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

Base Case Population

The WHO SAGE data was the source of most of the model parameters. As such, the base case population was Ghanaian adults aged 50 years.

BMI Measurement

In the WHO SAGE, anthropometric measurements of body weight and height of respondents were taken by trained interviewers using a weighing scale and stadiometer following standard protocols [71]. BMI was calculated as a person's weight in kilograms divided by the square of their height in meters and obesity was defined using cut-offs following the WHO classification. Three BMI categories were used as follows: healthy weight, $18.5 \leq$ BMI $<25.0kg/m^2$; overweight, $25.0 \leq$ BMI < 30.0 kg/m^2; and obese as BMI$\geq$30.00 kg/m^2 [145]. Pregnant women were exempted from weight measurements and excluded from this analysis [71].

Health State Utilities (HSUs)

BMI-related HSUs were used to calculate QALYs. These were taken from a published study conducted by our group using the Ghanaian population [250] . It is the only study to-date that has estimated BMI-related utility values in this population. This study reported HSUs amongst a nationally representative sample of Ghanaian adults who were categorised into various BMI ranges. The average age-and sex-specific utilities and their distributions were calculated for each of the three BMI categories (Tables 7.1).

Costs

Costs were used from both the government and patient perspectives and were limited to direct healthcare costs (Table 7.3). These costs stratified by BMI categories were taken from our previous study. Costs included self-reported out-of-pocket costs and the government National Health Insurance Scheme (NHIS) claims, both of which were estimated for outpatient consultations and inpatient admissions. Total costs were estimated as the sum of out-of-pocket and the government's NHIS costs. All costs were then converted into US dollars ($) equivalent using the 2017 average exchange rate ($1≈ GHS 4.3562) [210]. Future costs were discounted at 3% [44].

Figure 7.1. Structure of the Markov model in which all individual begin as alive

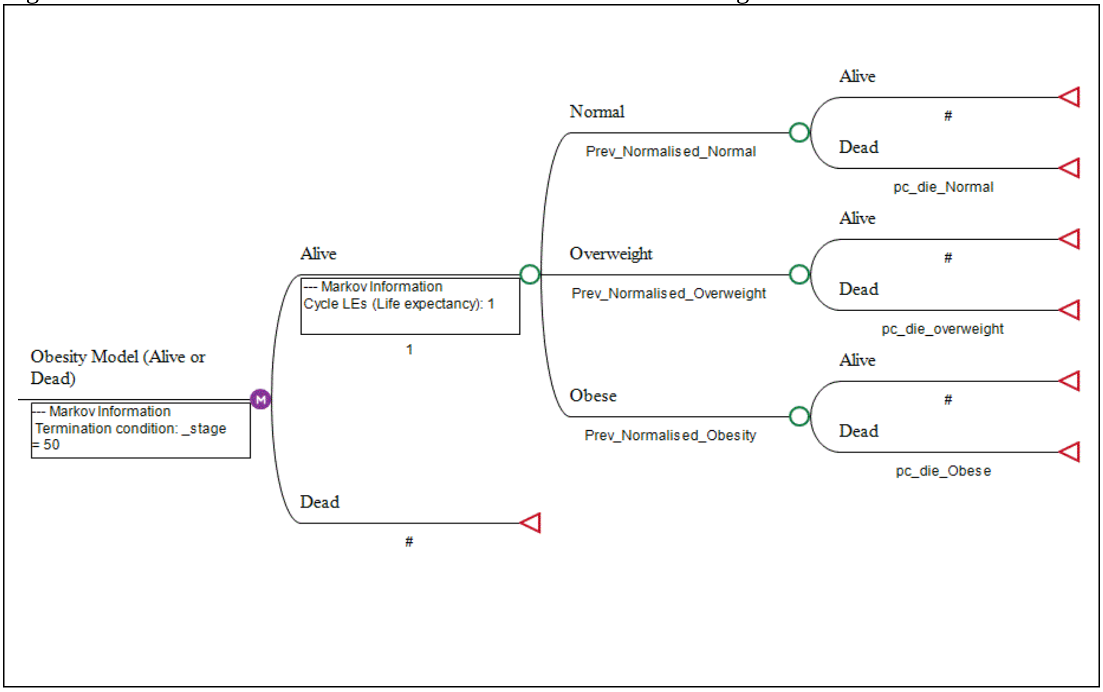


Figure 7.2. Structure of the Markov model in which all individual begin as alive. Once alive, an individual can assume one of the three BMI states, ie. healthy weight, overweight or obesity. BMI-specific mortality was estimated based hazard ratios obtained from literature [122] and the Ghananian life table [252].

Table 7.1. Key parameters in the model [Prevalence, health state utilities and mortality rates]

Parameters		Females			Males			Distributions
BMI Categories	Age groups, y	Healthy Weight	Overweight	Obese	Healthy Weight	Overweight	Obese	
Prevalence (95% CI)								
	50-59	0.468 (0.413, 0.520)	0.259 (0.235, 0.314)	0.262 (0.221, 0.305)	0.656 (0.590, 0.713)	0.271 (0.219, 0.334)	0.072 (0.044, 0.121)	
	60-69	0.520 (0.461, 0.578)	0.243 (0.204, 0.290)	0.237 (0.181, 0.300)	0.687 (0.614, 0.760)	0.275 (0.204, 0.349)	0.038 (0.021, 0.066)	
	70-79	0.587 (0.511, 0.645)	0.282 (0.233, 0.345)	0.131 (0.093, 0.192)	0.819 (0.758, 0.866)	0.139 (0.098, 0.196)	0.043 (0.024, 0.080)	
	85+	0.759 (0.659, 0.808)	0.153 (0.099, 0.299)	0.088 (0.065, 0.169)	0.774 (0.677, 0.855)	0.202 (0.122, 0.301)	0.024 (0.008, 0.072)	
Health state utilities [Average (95% CI)]	50-59	0.807 (0.792, 0.823)	0.805 (0.786, 0.825)	0.795 (0.772, 0.818)	0.837 (0.821, 0.852)	0.840 (0.813, 0.866)	0.797 (0.722, 0.871)	Beta
	60-69	0.793 (0.775, 0.810)	0.802 (0.782, 0.823)	0.754 (0.708, 0.800)	0.822 (0.809, 0.836)	0.815 (0.783, 0.847)	0.832 (0.764, 0.899)	Beta
	70+	0.737 (0.719, 0.756)	0.733 (0.701, 0.765)	0.710 (0.654, 0.766)	0.763 (0.743, 0.782)	0.729 (0.669, 0.789)	0.715 (*)	Beta
Mortality Rates (per 1000) for the general population	50-54		0.009			0.012		
	55-59		0.012			0.017		
	60-64		0.021			0.026		
	65-69		0.034			0.040		
	70-74		0.059			0.067		
	75-79		0.102			0.112		
	80-84		0.164			0.177		
	85+		0.273			0.286		

BMI means body mass index;
CI means confidence intervals;
(*) Data in this age group were not enough to estimate standard deviation and confidence intervals. The subsample for obese males in age group 18-29 years (n = 1), 40-49 years (n = 7), and $70 years (n = 13).

Table 7.2. Key parameter in the model [Hazard ratio]

*Hazard Ratios	Age groups, y	BMI ranges		Distributions
		15–25 kg/m²	25–50 kg/m²	
	35–59	0·76 (0·71–0·81)	1·37 (1·31–1·42)	Not reported
	60–69	0·77 (0·73–0·82)	1·32 (1·27–1·36)	
	70–79	0·82 (0·77–0·87)	1·27 (1·23–1·32)	
	80–89	0·89 (0·80–0·97)	1·16 (1·10–1·23)	

*Hazard ratio increased per 5kg/m^2 unit increase of BMI

Table 7.3. Key parameter in the model [Direct healthcare costs ($)]

Costs type	BMI Category			Distributions
	Healthy Weight Mean (95% CI)	Overweight Mean (95% CI)	Obese Mean (95% CI)	
OOP	14.5 (10.3, 18.6)	30.2 (18.9, 41.5)	48.2 (25.6, 70.8)	Gamma
NHIS	20.3 (18.8, 21.7)	47.3 (41.7, 53.0)	83.6 (60.7, 96.40)	Gamma

OOP, out-of-pocket cost;
NHIS, National Health Insurance Scheme;
CI, confidence intervals;

YLL, QALYs losses and extra costs

Using healthy weight as a comparator, I estimated the average YLL, QALYs loss and the extra direct healthcare total costs due to overweight and obesity. Average YLL was estimated as the difference in average remaining LE between subjects with healthy weight and those who were overweight or obese [67]. The same process was used to estimate the average QALYs lost, as well as additional costs. The estimated average effects of YLL, QALYs and extra costs were scaled up to the entire 50 year old population in each BMI category based on the 2015 projected population in Ghana [49].

Model validity

Validation of the model followed the recommendations of the International Society of Pharmacoeconomics and Outcomes Research Task-Force 7 [254]. This was conducted in three ways: face validity, internal validity and external validity. Face validity was a subjective approach and involved people with health expertise in the disease area, to ensure the model incorporates the highest level of health and epidemiological evidence. The overall structure of the model, population and outcomes were reviewed and validated by three health economists (AJP, LS, STL), biostatistician (LB, NM, GOB), a clinician (AJP) and epidemiologist (CGM). Internal validity using goodness of fit was performed to test whether the model correctly reproduced the input parameters [68, 175]. The model was used to reproduce the sex-, and age-specific mortalities and compared the sex-, and age-specific mortalities used as input parameters. A linear regression was fitted to estimate the squared linear correlation coefficient (R^2)- an index of the degree to which the data variation can be explained. As part of the internal validation process, one-way sensitivity analysis of key parameters was conducted to check whether the results changed in the direction expected when the base values were varied. By way of external validation, the model was used to predict life expectancies for males and females from age 25-85 years using a five-year age interval and compared with those in the life table. The estimated LEs were assumed to be valid if they fell within 1% of the observed LEs reported in the life tables when all the BMI categories are kept at their prevalence levels in the model.

Uncertainty and Sensitivity analyses

Health economic models are mostly characterized by some degree of uncertainty [68, 255]. Tornado diagrams, one-way and probabilistic sensitivity analyses were used to address uncertainty. One-way sensitivity analyses were performed to identify the impact of key parameters on the outcomes by varying them from the base case. The parameters are listed in tornado diagrams by their impact on the outcomes. Prevalence of healthy weight, overweight and obesity, the probability of death for all BMI categories, utility values and costs were varied by ±20% of the values used in the base-case analysis [62, 68, 253]. Finally, probabilistic sensitivity analysis using second-order Monte Carlo simulation was conducted to incorporate multiple parameter uncertainties simultaneously. This allowed for the estimation of the confidence intervals which quantifies the level of uncertainties around the calculated LEs, QALYs and costs.

7.5 Results

Validity assessment

Face validity was confirmed by our clinical, biostatistical, health economics and epidemiological experts. The internal validation using the model to compare sex- and age-specific mortalities with published sex- and age-specific mortalities (Fig 7.2) obtained an R^2 of 0.999 for females and 0.998 for males. Univariate sensitivity analysis showed that the results changed in the expected direction when each input parameter was varied by ±20%. For example, when the probability of dying among 50-year-old females with obesity was varied by ±20% of the base value, lower average LEs was 23.7 and the upper was 24.5 years, QALYs was 21.4 and 22.2 while cost was $1,131 and higher as $1,158. For external validity, the overall hypothetical cohort in the model predicted LEs from age 25 years using a five-year interval for males and females which were compared and found to be almost identical to the LEs in the Ghanaian life table (Table 7.6). The R^2 for the predictions and the published LEs were 0.998 in males and 0.999 in females.

Model predictions for the base case (age 50 years)

Results for the base-case simulations are presented in Table 7.4 for both males and females aged 50 years. The average remaining LE for healthy weight females was 25.6 (95% CI: 25.4-25.8) years and healthy weight males was 23.0 (95% CI: 22.8-23.2) years. LE of females and males who were overweight was 23.5 (95% CI: 23.3-23.7) years and 20.7 (95% CI: 20.5-20.9) years respectively and that for obese was 21.3 (95% CI: 19.6-21.8) years and 17.6 (95% CI: 17.5-17.8) years for females and males respectively. The average remaining QALYs at age 50 years for those who were overweight (female: 21.0: 95% CI: 20.8-21.2, male: 19.0: 95% CI: 18.8-19.2) and obese (female: 19.0: 95% CI: 18.8-19.7, male: 16.0: 95% CI: 15.8-16.2) were lower compared to those with healthy weight (female: 23.0: 95% CI: 22.8-23.2, male: 21.0: 95% CI: 20.8-21.2). The average total costs at the same age were higher for overweight (female: $1,298: 95% CI: 1,290-1,306, male: $1177: 95% CI: 1,169-1,186) and obesity (female: $2,057: 95% CI: 2,043-2,071, male: $1,831: 95% CI: 1,817-1,846) compared to those with healthy weight (female: $619: 95% CI: 616-622, male: $571: 95% CI: 567-575).

Table 7.4. Simulated lifetime LE, QALYs and direct healthcare costs for Ghanaian population aged 50years

Outcomes Average (95% CI)	Female All	Female Healthy Weight	Female Overweight	Female Obese	Male All	Male Healthy Weight	Male Overweight	Male Obese
LE (years)	24.07 (23.88-24.54)	25.58 (25.39-25.77)	23.50 (23.31-23.69)	21.30 (19.64-21.84)	22.12 (21.92-22.55)	22.99 (22.79-23.19)	20.67 (20.48-20.86)	17.62 (17.45-17.79)
QALYs	22.00 (21.82-22.43)	23.00 (22.84-23.16)	21.00 (20.84-21.16)	19.00 (18.84-19.66)	20.00 (19.82-20.39)	21.00 (20.82-21.18)	19.00 (18.82-19.18)	16.00 (15.84-16.16)
OOP Costs ($)	461 (458-470)	258 (256-260)	506 (503-509)	752 (747-757)	322 (320-328)	238 (236-240)	459 (456-462)	670 (664-675)
Median	493	301	542	816	346	260	496	711
SD	147	82	158	258	114	81	170	274
NHIS Costs ($)	718 (713-732)	361 (359-363)	792 (787-797)	1305 (1296-1313)	484 (481-494)	333 (331-335)	719 (713-724)	1162 (1152-1171)
Median	763	383	848	1416	517	364	776	1233
SD	230	102	247	448	174	113	267	475
Total Costs ($)	1145 (1138-1167)	619 (616-622)	1298 (1290-1306)	2057 (2043-2071)	806 (800-822)	571 (567-575)	1177 (1169-1186)	1831 (1817-1846)
Median	1227	657	1390	2232	863	624	1272	1945
SD	355	174	405	706	288	193	437	749

Costs estimated in US$ at the 2017 average rate ($1≈ GHS 4.3562);
CI means confidence interval;
LE means life expectancy;
QALYs mean quality adjusted life expectancy;
SD means standard deviation;
OOP means out-of-pocket;
NHIS means National Health Insurance Scheme.

YLL, QALYs losses and extra costs

The base-case analysis of average and population scaled-up effect of overweight and obesity on LE, QALYs and healthcare costs are presented in Table 7.5. The average effects for overweight were YLL (female: 2.1: 95% C1: 1.9-2.3, male: 2.3: 95% CI: 2.1-2.5), QALYs lost (female: 2.0: 95% CI: 1.8-2.3, male: 2.0: 95% CI: 1.8-2.2), and extra total costs (female: $679: 95% CI: 675-683, male: $607: 95% CI: 602-611). The average effect due to obesity were YLL (female: 4.3: 95% CI: 4.1-4.5, male: 5.4: 95% CI: 5.2-5.6), and QALYs lost (female: 4.0: 95% CI: 3.8-4.7, male: 5.0: 95% CI: 4.8-5.2), and extra total costs (female: $1,438: 95% CI: 1427-1449, male: $1,260: 95% CI: 1250-1271). When the average effect was scaled-up to the total overweight population, notable losses were observed for YLL (females: 66,129: 95% CI: 59,771-72,170 and males: 58,107: 95% CI: 53,348-62,865 years), QALYs (females: 63,585: 95% CI: 58,499-72,170 and males: 50,092: 95% CI: 45,584-54,600 years) and extra total costs (females: $21.5: 95% CI: 21.4-21.7 million and males: $15.2: 95% CI: 15.0-15.3 million). For the obese population, substantial losses were estimated. The YLLs were 112,992 (95% CI: 108,240-117,744) and 30,630 (95% CI: 29,718) years in females and males, respectively. The QALYs lost were 105,600 (95% CI: 101,376-123,024) and 28,520 (95% CI: 27,607-29,433) years in females and males, respectively. Total extra total costs were estimated at $38.0 (95% CI: 37.6-38.2) million and $7.1 (7.1-7.4) million in females and males, respectively. Of note, the health and economic burdens were substantially higher among females compared with males. Overweight and obesity combined contributed to 267,869 (95% CI: 251,077-284,437) YLL, 247,779 (95% CI: 233,066-279,227) lost QALYs and an extra cost of $81.9 (81.3-82.5) million in the Ghanaian population aged 50years.

Sensitivity analysis

Tornado diagrams, one-way sensitivity and probabilistic sensitivity analyses were performed to address the uncertainties in the model. Uncertainties around the LEs, QALYs and costs were addressed through probabilistic sensitivity analysis by sampling from distributions around the parameters, generating mean and 95% confidence intervals (CI) the outcomes. The sensitivity analyses among the 50-year-olds showed the parameters that had notable impact on the outcomes (Fig 7.3-5). The Tornado diagrams demonstrated in descending order that for LE, the parameters with the greatest impact were the probabilities of dying for healthy weight, overweight and for obese. For QALYs, the parameters with the greatest impact were HSUs for healthy weight, overweight and obese. For costs, total costs for obesity, total costs for overweight and NHIS costs for obesity had the greatest impact.

Table 7.5. Base case (Age 50 years) analysis of average and total population scaled-up effect of overweight and obesity on YLL, QALYs and total healthcare costs when compared to healthy weight individuals

	Female, *N=103,897				**Male, *N=96,518**				**Total Population, *N=200,415**
	Overweight population †n=31,793		Obese population †n =26,400		Overweight population †n=25,046		Obese population †n = 5,704		Overweight and obese population †n = 88,943
Outcomes Average	Average Loss (95% CI)	Loss scaled-up to population (95% CI)	Average Loss (95% CI)	Loss scaled-up to population (95% CI)	Average Loss (95% CI)	Loss scaled-up to population (95% CI)	Average Loss (95% CI)	Loss scaled-up to population (95% CI)	Population Total Loss (95% CI)
YLL	2.08 (1.89-2.27)	66,129.44 (59,770.84-72,170.11)	4.28 (4.10-4.46)	112,992.00 (108,240.00-117,744.00)	2.32 (2.13-2.51)	58,106.72 (53,347.98-62,865.46)	5.37 (5.21-5.55)	30,630.48 (29,717.84-31,657.20)	267,858.64 (251,076.66-284,436.77)
QALYs	2.00 (1.84-2.27)	63,586.00 (58,499.12-72,170.11)	4.00 (3.84-4.66)	105,600.00 (101,376.00-123,024.00)	2.00 (1.82-2.18)	50,092.00 (45,583.72-54,600.28)	5.00 (4.84-5.16)	28,520.00 (27,607.36-29,432.64)	247,779.00 (233,066.20-279,227.03)
OOP Costs ($)	248 (247-249)	7,884,664 (7,852,871-7,916,457)	494 (491-497)	13,041,600 (12,962,400-13,120,800)	221 (220-222)	5,535,166 (5,510,120-5,560,212)	432 (428-435)	2,464,128 (2,441,312-2,481,240)	28,925,558 (28,766,703-29.078,709)
NHIS Costs ($)	431 (428-434)	13,702,560 (13,607,404-13,798,162)	944 (937-950)	24,921,600 (24,736,800-25,080,000)	386 (382-389)	9,667,756 (9,567,572-9,742,894)	829 (821-836)	4,728,616 (4,682,984-4,768,544)	53,020,532 (52,594,760-53,389,600)
Total Costs ($)	679 (675-683)	21,587,447 (21,460,275-21,714,619)	1438 (1427-1449)	37,963,200 (37,672,800-38,253,600)	607 (602-611)	15,202,922 (15,077,692-15,303,106)	1260 (1250-1271)	7,187,040 (7,130,000-7,249,784)	81,940,609 (81,340,767-82,521,109)

*N denotes the 2015 population of 50 years;
†n denotes the sex-specific 50 years old obese population;
†n was calculated based on the sex-and age-specific prevalence of obesity in the 2014/15 WHO SAGE sample;
YLL means years of life loss;
QALYs mean quality adjusted life years.

7.6 Discussion

The objective of this study was to quantify the long-term impact of overweight and obesity on LE, QALYs, and total direct healthcare costs in Ghana. findings in this study show that being overweight and obese is associated with significantly lower LEs and QALYs, and higher healthcare costs across all ages, with these effects being higher in females and in younger age groups. The model predicts the average YLL in 50-year-old females due to overweight was 2.1 and obesity was 4.3 years. In males, it was 2.3 years for overweight and 5.4 years due to obesity. The average QALYs lost were for overweight (females: 2.0 and males: 4.0 QALYs) and obesity (females: 4.0 and males: 5.0 years). The extra total costs were for overweight (females: $679 and males: $607) and obesity (female: $1,438 and males: $1,260). Overall, over a 50-year period, the aggregate losses due to overweight and obesity in the entire Ghanaian population aged 50years were 267,859 YLL, 247,799 QALYs lost and an extra cost of $82million, of which 64% will be borne by the government's NHIS.

Similar previous studies have shown that overweight and obesity are associated with YLL, loss of QALYs and increased costs despite use of different time frames [65, 194, 255, 256]. For example, when the impact of obesity on QALYs and costs was examined in the US over a ten-year period [256], researchers found that being obese led to an average of 1.2 QALYs lost per person and increased total medical costs of $42,800 per person compared to having healthy weight. Similar studies in the Belgian populations [255] modelled over a 20-year period showed that a unit decrease in BMI resulted in improved QALYs and reduced costs. For example, Verhaeghe *et al* [255] found that in females, a one-unit reduction in BMI among the obese resulted in €1,039 cost saving and in overweight, €785 was saved. They found that the cost impact was higher among females compared with males. Extrapolating this to the Belgian population resulted in an economic benefit of €15.9million over the 20-year period. The huge costs reported in these studies was because costs were estimated based on various obesity-related diseases and disabilities, and the availability of national cost data. Some costs included in previous papers - but not in this study - include direct costs such as cost of exercise interventions in cardiovascular disease prevention, and indirect costs such as productivity losses [255].

In this study, overweight and obesity had dramatic adverse health and financial effects on individuals as well as on the entire base case population. Even though the average YLL was higher in males compared with females, the scaled-up effect in the female population were higher mainly due to the higher prevalence of overweight and obesity in that population. Thus, in general, overweight and obesity have enormous impacts on the health and economic outcomes in the various studied populations [67, 248, 255, 256], and Ghana is no exception. In Ghana, the prevalence of overweight and obesity are steadily increasing, particularly in the female population [10]. With looming crises of non-communicable diseases (NCDs) and an under-resourced health system with constant budget cuts [218], a huge impact of overweight and obesity on health and economic outcomes in the population necessitates urgent cost-effective interventions.

To the best of the authors' knowledge, so far no study in Ghana and sub-Sahara Africa have estimated the long-term effects of overweight and obesity on health and economic outcomes despite the increasing prevalence of obesity in most adult populations in this region [6, 8, 143]. It is anticipated that most low- and middle-income countries will likely face one of the biggest global health crises due to increasing rates of NCDs, yet healthcare is inequitable and inaccessible, and health facilities are under-resourced along with a limited proportion of the health budget available to manage NCDs [75, 184, 218]. Besides the association with NCDs and higher all-cause mortality [122], obesity has been associated with reduced quality of life and life expectancy [67, 127], and high economic costs [30, 129, 255]. Thus, for populations facing an increasing prevalence of overweight and obesity, the provision of concrete evidence of the long-term effects based on validated clinical and epidemiological data, and the subsequent development of cost-effective interventions is vital. The use of obesity preventative and/or control measures adapted from other, mostly developed countries' populations may not be sufficient for decision making in most low-and middle-income countries where the local conditions may be very different. Thus, this validated model has been developed at a very important time when decision makers are confronted with challenges of identifying cost-effective measures to manage obesity as well as prioritization of resources to achieve major local and global health goals [63].

This study has some limitations. First, the BMI-specific hazard ratios used to calculate the BMI category-specific probability of dying in this model were taken from a large global population sample [122], and were not specific to Ghana. Second, in order to estimate the long-term outcomes, the model assumes that a subject would remain in the same BMI category over the period. Thus, the model overly depended on the current BMI prevalence rather than varying prevalence over time. As costs were estimated from self-reported health services utilization, it might be subject to recall bias which may lead to overestimation or underestimation of the costs. Finally, costs used were limited to outpatient consultations and inpatient admissions [233] due to the lack of other cost data, such as physiotherapy and dietician services and indirect costs (e.g. cost associated with presenteeism and absenteeism from work) in the Ghanaian population. Thus, apart from the costs not reflecting the full direct healthcare costs in the population, this study did not include indirect costs of overweight and obesity. However, studies have shown that obesity is increasingly associated with factors that reduce work productivity such as absenteeism and presenteeism, as well as short-term disabilities [256, 257]. The limitation of the current model was mostly due to inadequate or a lack of the necessary data. The model will be updated when more suitable data becomes available.

Despite the above limitations in these studies, most input parameters were estimated from the Ghanaian population for which the model has been developed, in-line with best practice recommendations [1, 60]. Additionally, the internal and external validations, and the sensitivity analyses performed showed that the clinical and epidemiological data used in this model produced results which were close to the reality in this population. The choice of modelling technique through to reporting also followed best practice [249, 254] . Furthermore, the results from this modelling study bridges an important gap in the evidence in this area in the Ghanaian and in most sub-Saharan African populations. Additionally, the model has been developed at a strategic time when most LMICs need to urgently develop sustainable and cost-effective weight reduction strategies to curb the burgeoning overweight and obesity prevalence.

7.7 Conclusion

I estimated the long-term impact of overweight and obesity on LE, YLL, QALYs and direct healthcare costs in Ghana, a sub-Sahara African population. The results show that individuals with overweight or obesity incur substantial health and economic burdens in Ghana. This model can serve as a basis for future cost-effectiveness studies for weight management strategies for this population.

Table 7.6. External validation using life expectancies predicted from the model and life expectancies from the 2015 Ghana lifetables (SI)

	Females		Males	
Age (years)	2015 Lifetable Life Expectancies	Model Predicted Life Expectancies Average (95% CI)	2015 Lifetable Life Expectancy	Model Predicted Life Expectancies Average (95% CI)
25-29	44.9	42.2 (41.9-43.0)	43.3	40.6 (40.4-41.4)
30-34	40.6	39.5 (39.2-40.2)	38.9	37.6 (37.4-38.4)
35-39	36.4	36.1 (35.8-36.8)	34.5	34.0 (33.7-34.6)
40-44	32.3	32.2 (32.0-32.8)	30.3	29.9 (29.7-30.5)
45-49	28.2	28.2 (27.9-28.7)	26.3	26.0 (25.8-26.5)
50-54	24.2	24.1 (23.9-24.5)	22.5	22.1 (21.9-22.6)
55-59	20.1	20.0 (19.8-20.4)	18.7	18.4 (18.2-18.7)
60-64	16.2	15.9 (15.8-16.3)	15.1	14.8 (14.6-15.1)
65-69	12.7	12.4 (12.3-12.6)	11.9	11.5 (11.3-11.7)
70-74	9.5	9.1 (9.0-9.3)	9.0	8.6 (8.5-8.8)
75-79	7.0	6.6 (6.5-6.7)	6.6	6.2 (6.1-6.3)
80-84	5.0	4.6 (4.5-4.7)	4.8	4.3 (4.2-4.4)
85-89	3.7	3.2 (3.1-3.2)	3.5	3.1 (3.0-3.2)
R^2	0.998		0.999	

CI means confidence intervals;
R^2 means the squared linear correlation coefficient.

Figure 7.3. Model internal validation using goodness-of-fit test

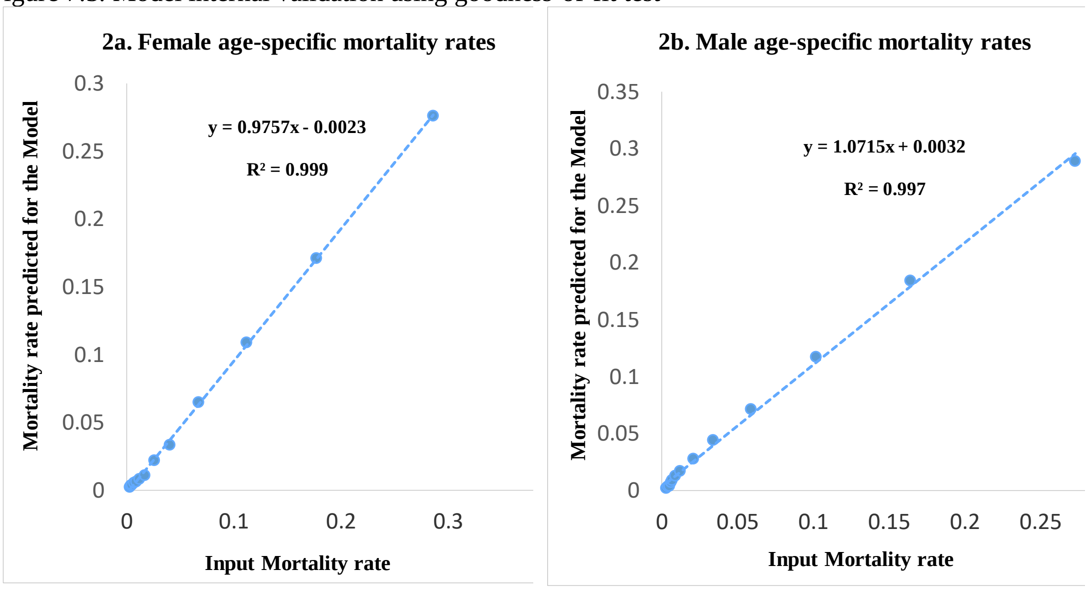


Figure 7.4. Tornado diagram of key parameters that impacted on LEs in Females

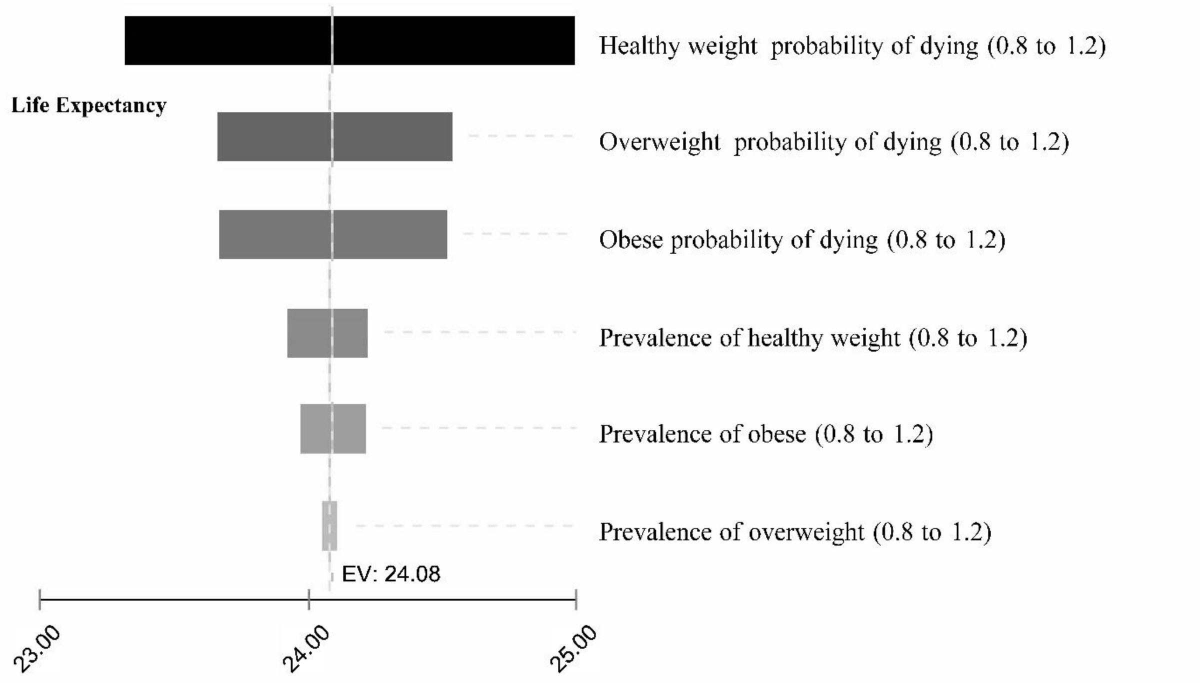


Figure 7.5. Tornado diagram of key parameters that impacted on QALYs in Females

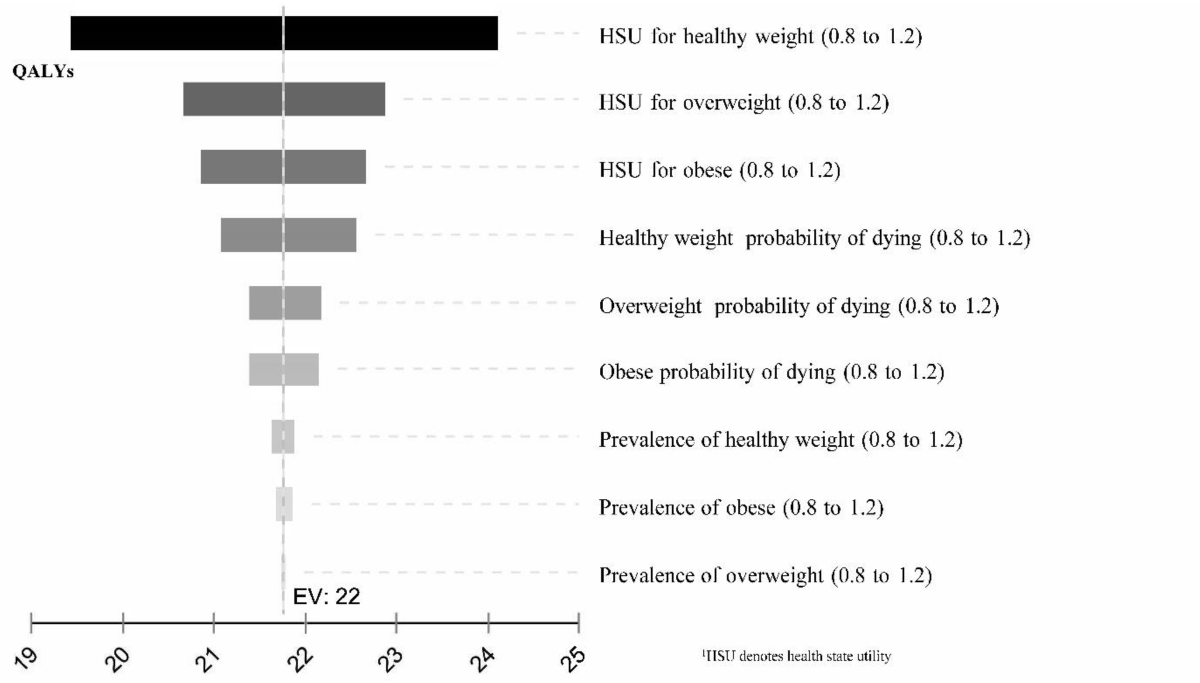
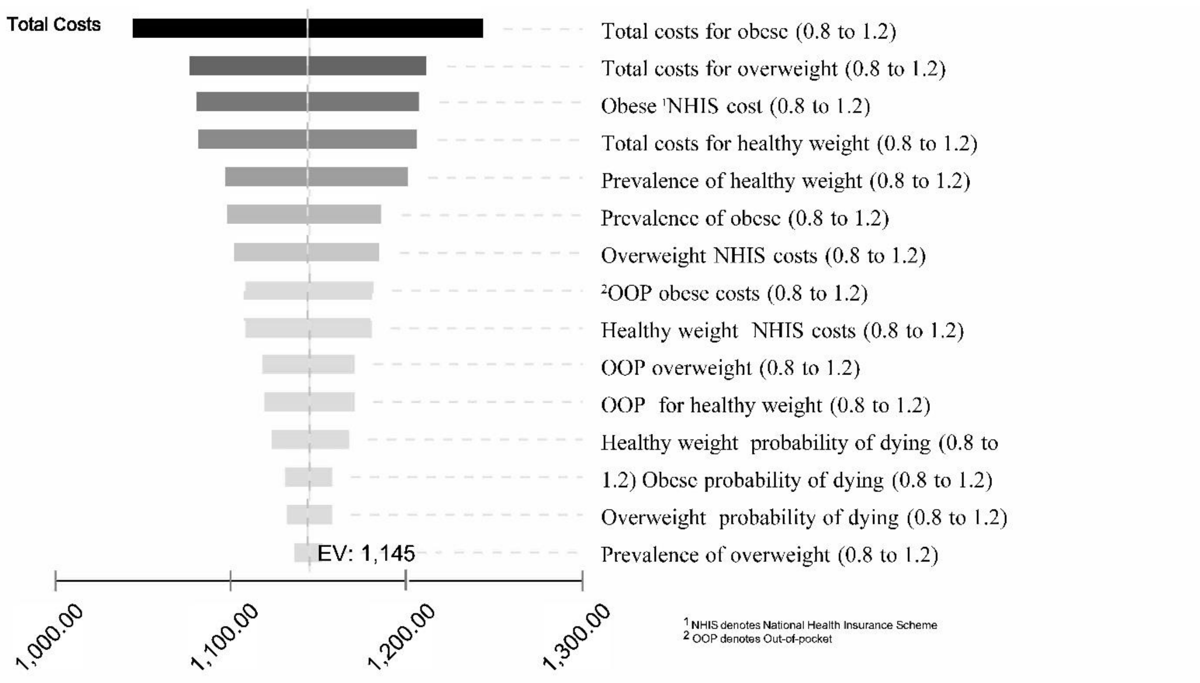


Figure 7.6. Tornado diagram of key parameters that impacted on Total Costs in Females



7.8 Postscript

Findings presented in this Chapter serve as very important evidence that bridges a major gap in studying obesity in the Ghanaian and in most sub-Saharan African populations. The model has been strategically developed at a time when most low income countries need to urgently identify sustainable and cost-effective interventions to manage overweight and obesity. Simulating the BMI categories over time demonstrated that overweight and obesity have substantial clinical and economic impact on the population.

Due to high prevalence of overweight and obesity among the female cohort, YLL, QALYs lost and extra costs incurred due to high BMI were higher than for males. From the studies presented in Chapter 2, 3, 4, 5 and 6, the impact of overweight and obesity have been relatively intense in the female population. This suggests the need to appropriately target weight reduction programs in this population. Appropriate targeting might minimize the impact of overweight and obesity on the health and the healthcare budget in the population. The developed model will be useful for decision-makers to identify cost-effective weight management strategies.

8 Summary and future directions

8.1 Preface

This chapter presents a synopsis of the prevalence, health and economic impacts of obesity in the adult population of Ghana. In this thesis, descriptive analyses, regression models and Markov modelling methods were used to estimate the current prevalence and trends in obesity; examine the current and life time factors of obesity; examine the associations between direct healthcare costs and utilization and body mass index (BMI), determine the transition probabilities between different BMI categories; and finally, quantify the long-term remaining life expectancy (LE), quality-adjusted life years (QALYs) and healthcare costs of overweight and obesity using the parameters obtained in studies one to four. This chapter provides a summary, discussion and suggestions for future directions.

8.2 Summary of the thesis

Chapter 1 provided the introduction to obesity, health economics and economic evaluations. The prevalence of obesity has reached epidemic proportions in most regions of the world, including sub-Saharan Africa [6, 8]. At the same time, obesity is associated with many chronic diseases reduced LE, overall mortality and high economic burden [8, 18, 20, 21, 122]. As a major risk factor for NCDs it is recommended that the prevalence of obesity is monitored, and the necessary sustainable strategies developed based on the circumstance of the local setting. Health economic tools used in the process of estimating value-for-money for different preventative strategies require some parameters. These parameters were absent for the Ghanaian population. In this PhD, scientific and systematic methods were used to generate the required parameters for health economic evaluation for Ghana.

Additionally, using some of the parameters, a health economic model was constructed and validated for obesity in the population. Thus, this chapter provides an introduction and background of my PhD thesis and outlines how the objectives of this PhD thesis were set to estimate the parameters and subsequently construct and validate an obesity health economic model.

In Chapter 2, the current prevalence of obesity in the Ghanaian adult population using the most current data were estimated. Additionally, both current and lifetime factors that could be associated with obesity were examined. Since increasing prevalence of obesity as well as preventative strategies could differ based on several factors, it was crucial to understand these factors in order to tailor efficient and cost-effective preventive programmes and policies [37, 76]. As one of the best measures of central adiposity, waist circumference was used to also measure obesity and verified the associations with the SES markers. The current waist circumference optimal cut-offs for the sub-Saharan Africa population were used to determine central adiposity [86]. Thus, waist circumference (WC) cut-off of WC $\geq$ 81.2cm for men, WC $\geq$80.0cm for women and population WC $\geq$81.1cm were categorized as central adiposity otherwise, healthy. Thus, this chapter elaborates how the most current prevalence rate of obesity was estimated for the Ghanaian population. It also examines the association between obesity and major SES markers including intergenerational education mobility which is a life course factor. Based on the findings, it was concluded that the prevalence of obesity exceeded the prevalence of underweight in the population. Additionally, stable high and upwardly mobile education patterns were found to be associated with higher odds of obesity and central adiposity in women while the stable high pattern was associated with higher odds of overweight in men.

Chapter 3 discussed the current trends in obesity prevalence in the older adult population from 2007/08 to 2014/15. As the data available were more representative of the population 50 years and above, this study focused on this age group. The findings on trends in overweight and obesity prevalence are key pieces of information for all health service provider, clinicians, funder of healthcare and the government. This is important information for planning and resource allocation as the Ministry of Health is currently focused on reducing the prevalence and obesity only in those age 15-49 years. Even though at the population level prevalence of overweight increased by 25% and obesity by 47% from 2007/08 to 2014/15, the changes varied by sex. Thus, while the prevalence of overweight increased in both sexes, obesity prevalence was 16% lower in males and 55% higher in females comparing 2007/08 to 2014/15. Additionally, female sex, urban residence, high household wealth and low levels of physical activity were associated with higher odds of overweight/obesity and high central adiposity in the older adult population.

Chapter 4 introduced the health economic section of this PhD thesis. It presents the study which estimated age- and sex-specific HSUs, HSU stratified by BMI status and the relationship between HSU and obesity. As preference-based measures necessary for direct estimation of HSUs have not been used in large population surveys in Ghana, the WHOQOL-100, a non- preference-based measure was employed. The mean (95 % confidence interval) HSU was 0.866 (95% CI: 0.857, 0.875) for males and 0.849 (95% CI: 0.841, 0.856) for females. Inverse associations were found between HSUs and obesity (-0.024; 95% CI: -0.037, -0.011), being female (-0.011; 95% CI: -0.020, -0.003) and older age groups in the population. The HSUs developed are the first of their kind for Ghana and one of the key input parameters necessary to conduct cost-effectiveness analyses in this population.

The aim of Chapter 5 was to determine the associations between health services utilization as well as direct healthcare costs and overweight and obesity among older adults in Ghana. In this study, the usage of health facilities was measured by the number of outpatient consultations and inpatient admissions and direct healthcare costs incurred by the individuals and the government's NHIS in 2014/15. The results showed that one in five of the overweight and obese population had at least one chronic disease, and this was associated with increased outpatient utilization and direct healthcare costs. Even though the total prevalence of overweight and obesity was about half that of healthy weight, the overweight and obese population had a significantly higher total direct healthcare costs burden of $121 million compared with $64 million for healthy weight in the entire older adult Ghanaian population.

In Chapter 6, transition probabilities that can be used in future modelling studies were estimated. As overweight/obesity is becoming increasingly prevalent in Ghana, it is important to know the probabilities of movement between the various BMI categories. Transition probabilities form an essential component in health economic simulation models. These models could be used to determine sustainable and cost-effective weight management interventions. Transition probabilities could also inform clinicians and decision makers of sojourn times for each BMI category. The annual transition probabilities were estimated using a multistage Markov model and the results showed that the annual transition probability was 4.0% (95% CI: 3.4%, 4.8%) from healthy weight to overweight, 11.1% (95% CI: 9.5%, 13.0%) from overweight to healthy weight and 4.9% (95% CI: 3.8%, 6.2%) from overweight to obesity. For obese individuals, the probability of remaining obese was 90.2% (95% CI: 87.7%, 92.3%), an indicator of the difficulty in transitioning away from obesity. The estimated transition probabilities will be essential in health economic simulation models to determine sustainable weight management interventions.

Chapter 7 presents one of several key endpoints of this study in which the developed parameters from studies one (Chapter 2) to four (Chapter 5) were used to develop a Markov model that quantifies the long-term impact of obesity on health and economic outcomes in the older adult population. Health outcomes included remaining life expectancy, YLL and QALYs while the main economic outcome was direct healthcare costs. The input parameters of the model included the prevalence, HSUs and direct healthcare cost estimates from own previous studies. The findings were that at age 50 years, the average (95% confidence interval (CI)) remaining LE for females were 25.6 (95% CI: 25.4-25.8), 23.5 (95% CI: 23.3-23.7) and 21.3 (95%: 19.6-21.8) for healthy weight, overweight, and obesity respectively; and YLL was 2.1 for overweight and 4.3 for obese. In males, remaining LE were healthy weight (23.0; 95% CI: 22.8-23.2), overweight (20.7; 95% CI: 20.5-20.9) and obesity (17.6; 95%: 17.5-17.8); average YLL were for overweight, 2.3 and obese, 5.4. While QALYs were lower, costs increased with high BMI status. It was concluded that overweight and obesity have substantial health and economic impacts on the Ghanaian population.

8.3 Summary of key findings

The key findings from this thesis are summarised below:

1. The prevalence of obesity exceeded the prevalence of underweight, and high socioeconomic status and low physical activities were associated with higher odds of obesity and central adiposity in the population.
2. Obesity was associated with lower HSUs in women, higher health service utilization and direct health care costs in the older adult population.
3. Compared to persons with healthy weight, individuals who were overweight had a higher probability of transitioning into the obesity category. Persons who were overweight remained in this state for an average of six years and those who were obese remained obese for an average of nine years before transitioning into the adjacent BMI category.
4. Being overweight was associated with an average per person years of life lost of 2 years while obesity was associated with 4 and 5 years of life lost in females and males, respectively.

8.4 Summary of policy implications, strengths and limitations

The clinical and public health implications of the four key research findings presented in this thesis are discussed below:

1. The prevalence of obesity exceeded the prevalence of underweight, and high socioeconomic status and low physical activities were associated with higher odds of obesity and central adiposity in in the population. In Chapters 2 and 3, overweight and obesity prevalence increased while underweight declined between 2007/08 and 2014/15. As NCDs are on the rise in the Ghanaian population, obesity as a major risk factor may be contributing to the surge. Therefore, the management and subsequent prevention of overweight and obesity may be key policy areas to guide reduction of the burden of NCDs in Ghana. As economic growth continues to increase and hence households' socioeconomic status increase, strategies to

target these households are necessary. It is also necessary that both government and institutions collaborate to create an environment that facilitates physical activities to reverse the increasing trends in overweight and obesity prevalence.

2. Obesity was associated with low HSUs in women, high health services utilization and direct health care costs in the older adult population. These key findings were drawn from Chapters 4 and 5. Theoretically, HSUs are associated with the quality of life of a population or group. Having poor quality of life has implications on many aspects of life including morbidity, mortality and productivity, . High health service utilization and direct health care costs among the obese represents a higher burden for both households and government. Indeed, if the government wanted to make savings in the health sector, then it could work proactively and deliberately with policy makers in the sector to reduce preventable risk factors such as overweight and obesity. Studies in this thesis did not focus on private sector engagement in health care. However, factors that have the potential to affect productivity and increase cost burdens provides an opportunity for private sector partnerships and collaborations. Whilst such partnerships may require effective regulations, consideration of these along with the associated costs and effectiveness in reducing overweight and obesity is beyond the scope of this thesis.

3. Compared to persons with healthy weight, individuals who were overweight had a higher probability of transitioning into the obesity category. Persons who were overweight remained in this state for an average of six years and those who were obese remained obese for an average of nine years before transitioning into the adjacent BMI category. On the basis of the assumption that an obese person has at least one chronic disease for which the cost is subsidised by the health and medical system , staying in the obese category for nine years means increasing health resource utilization and cost to both government and the household. It also has

potential implications on productivity. Thus, there is the urgent need for key stakeholders to engage and work together to provide the necessary environment to reduce and prevent overweight and obesity.

4. Being overweight was associated with an average per person years of life lost of 2 years while obesity was associated with 4 and 5 years of life lost in females and males, respectively. This was one of the major findings in Chapter 7 which further predicted that obese individuals experienced the greatest decrease in life years. As the prevalence of obesity is increasing, we should expect the potential impact to be greater in the future. Thus, the evidence in this thesis points to the fact that Ghana needs to urgently develop efficient, sustainable and cost-effective obesity interventions. This action must be deliberate and involve all stakeholders.

Results from the studies presented in this thesis had several limitations. First, Study 1, it was indicated that the use of education to measure mobility for two different generations should be interpreted with caution since the applicability of education and education completion rates may differ in different generations. However, educational level is accurately recalled [77, 79], it was more stable over time compared to other SES markers such as occupation; and the education gradient in health is considered robust when there are preventive and treatment methods for the health risk/outcome such as obesity [77-79]. Throughout all the studies it was noted that although the data used is representative of the population aged 50 years and over, there are missing data which could lead to selection bias. The percentage of missing data was mostly below 5%, which is unlikely to affect the estimates [191]. Additionally, the analytical samples used were large, and the use of the post-stratified persons’ weight mostly mitigated any bias due to missing data.

In Study 5, a major limitation was the fact that health service utilization and OOP costs in the WHO SAGE were self-reported, hence may be subject to recall bias. Any over- or under-reporting of the utilization and specific costs was likely to introduce some degree of measurement error. However, it was also indicated that in WHO SAGE, these data were reasonably well-reported [69] and the recall period may not have a major effect [222, 223]. Additionally, annual costs were estimated from costs incurred during the last health facility visit which was available from the WHO SAGE. However, due to factors such as seasonality and level of facility last visited, costs may be over- or underestimated. In the study, I provide additional scenarios around the costs, and sensitivity analyses on annual costs conducted by varying the unit (OOP, NHIS and total) costs by ±20%. Findings from the sensitivity analyses showed that the absolute cost burden may differ depending on the variation around the average costs for each health state, but the relatively high cost burden due to overweight and obesity compared to healthy weight would remain. Also, only limited direct healthcare costs were used since this is population-based and not hospital data. The study did not account for indirect costs including those associated with absenteeism or presenteeism as these were not captured in the WHO SAGE.

This PhD's studies have major strengths and contributions that are worth mentioning. First, the sex differences in obesity prevalence that were identified may point to differential impacts of past initiatives to reduce overweight and obesity, identify potential high-risk groups for appropriate targeting, and the need to increase surveillance. Second, through this PhD thesis I have developed essential parameters needed for health economic evaluations which previously did not exist in Ghana or in most parts of the sub-Sahara African region. The parameters and the developed model form a very important basis for future cost-effectiveness analysis and health economic evaluations in the population. Finally, the fact that almost all input parameters used to develop the Markov model were estimated for the same population for which the model was developed is a major strength.

In conclusion, this series of related analyses provide considerable insight into the impact of adult overweight and obesity on health and economic outcomes in the Ghanaian population. Overweight and obesity were associated with lower remaining life expectancy and QALYs and substantially higher years of life lost and healthcare costs compared with healthy weight. Additionally, the studies identify that overweight and obesity mostly affected females. Recommendations for future directions are provided in the following section.

8.5 Future directions

Findings from the population-based and modelling studies presented in this thesis have provided new and additional information on the situation of obesity in older adults. In particular, key data for obesity-related health economic evaluation which were lacking in the Ghanaian population have been generated in this thesis. This offers the country an opportunity to conduct relevant economic evaluations. Once local interventions are available in this population, cost-effectiveness analysis can be conducted using results from studies in this thesis. Findings from studies in this thesis also offer new suggestions for targeting public health efforts and interventions aimed at preventing and controlling the prevalence of overweight and obesity. First, the findings highlight an increased prevalence of overweight and obesity in the population. Second, it shows that factors associated with higher odds of overweight and obesity differ in Ghana. It further shows that overweight and obesity substantially reduced remaining life expectancy and QALYs and increased years of life lost and healthcare costs in older adults. Lastly, the findings emphasize that once obese, there are higher chances of remaining obese with a sojourn time of close to 10 years.

The public health and economic impact of obesity is high and will further increase as the prevalence of this condition is rapidly increasing worldwide. Thus, in LMICs like Ghana where the health systems are not very robust regarding NCDs [218], the burden of an increasing obesity prevalence is huge. Therefore, public health programmes should emphasize reducing this burden through preventative means such as implementing cost-effective and sustainable weight management interventions. Many strategies have been proposed or developed to support and reduce overweight and obesity. Some countries would normally adopt and implement strategies developed in different countries. However, such an approach may be problematic since local conditions upon which parameters are developed and used may be different. Therefore, the strategies may be unsustainable, unaffordable and are bound to fail leading to waste of scare resources which could have been preserved. For example, in-line with studies from many developing countries, findings in this study showed that individuals with high socioeconomic status were more likely to be overweight or obese [8, 10, 37, 143]. The case is the exact opposite in many developed countries [79, 81, 83], where those with low socioeconomic status were more likely to be overweight or obese. Thus, adopting preventative measures from such countries whose health and social values are entirely different may be unsuccessful.

Regarding associations between high BMI and health outcomes, results related to HSUs or quality of life in this thesis have shown that while obesity was negatively associated with quality of life, overweight was positively associated with it. Even though the finding regarding overweight was not statistically significant, its positive association with HSUs serves as a vital indicator that measures the impact of the emphasis of public health education. While having high BMI could have roots in an intrinsic cultural norm in the Ghanaian culture, recent improvements in public health activities have increased awareness of poor health outcomes associated with obesity. Thus, the increased awareness of obesity-related health problems may have influenced the outlook of obesity and health outcomes. However, it has not been the same with overweight. This should be a source of concern for policy makers, as compared to having healthy weight, individuals who are overweight have higher chances of transitioning into the obese category. Thus, increasing awareness and public health research must emphasize not only the effects of obesity but the combined effect of both overweight and obesity.

As overweight and obesity prevention can be resource-intensive, it would be efficient and effective if evidence to be used to conduct CEA of alternative strategies were developed mostly in the population of concern. The results of the current studies suggested that factors affecting overweight and obesity could be local. In that sense, the Markov model presented in the current study can serve as the basis for further health economic evaluations of specific overweight and obesity management strategies in this population. As obesity is a major risk factor for NCDs, a higher probability of remaining obese and the longer average sojourn time for obese individuals could have implications on NCDs burden of disease and ultimately on productivity and government health expenditure. Hence, the dire need for public health planning and cost-effective interventions that prevent transitions to overweight or obese states.

In the past the Ministry of Health in Ghana focused on reducing the prevalence of overweight and obesity in those aged 15-49 years [17], neglecting those 50 years and above. Findings from this PhD study suggest this decision would affect the older adult population and consequently on the health system and government. As shown in Chapter 5, health service usage and healthcare costs of the overweight and obesity are higher, and the government bears at least 60% of these costs with the remaining borne by the individual. If the health system neglects addressing the increasing prevalence of obesity in older adults, they would impose more burden on government and households. Eventually, this would affect productivity in the population. Thus, the Ministry of health must as a matter of urgency review the approach to obesity prevention, include those over aged 50 years in the NCD strategic plan, and determine and implement cost-effective measures to prevent and reverse overweight and obesity across the age spectrum.

8.6 Collection of country-specific data

Health economic evaluations makes use of country-specific input data such as utilities and costs in order to reflect the real-world setting. In turn, this improves the evaluation and can reduce uncertainties around the choice of interventions for a specified population. The paucity of such data impedes the conduct of health economic evaluations, particularly in sub-Saharan Africa. In this thesis, the lack of data collected using direct HSU elicitation methods or preference-based measures led to the use of a non-preference based instrument to indirectly estimate HSUs. Additionally, there was also the lack of a country-specific EQ-5D-5L value set, leading to adoption of the Zimbabwean-population value set for use in the Ghanaian population. Using the direct elicitation method will yield more consistent results compared to using the indirect method. Furthermore, factors such as preferences, values and socioeconomic circumstances may differ between Zimbabwe and Ghana. Therefore, adopting one country's value set for the other can lead to a biased estimation. In this study, these hurdles were mitigated using validated and rigorous methods. Inadvertently, studies included in this thesis focused only on direct healthcare costs, and certain important clinical and indirect costs were not included due to the lack of data. Thus, it is recommended that Ghana includes in its administrative data collections and surveys preference-based instruments, takes steps to develop its own value set and collect relevant cost data. In this way, the current model can be updated for use in the Ghanaian population.

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Appendices

Appendix 1. Publication of Chapter 2

PLOS ONE

RESEARCH ARTICLE

The role of intergenerational educational mobility and household wealth in adult obesity: Evidence from Wave 2 of the World Health Organization's Study on global AGEing and adult health

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Abstract

Background

Obesity has emerged as a major risk factor for non-communicable diseases in low and middle-income countries but may not follow typical socioeconomic status (SES)-related gradients seen in higher income countries. This study examines the associations between current and lifetime markers of SES and BMI categories (underweight, normal weight, overweight, obese) and central adiposity in Ghanaian adults.

Methods

Data from 4,464 adults (2,610 women) who participated in the World Health Organization's Study on global AGEing and adult health (SAGE) Wave 2 were examined. Multilevel multinomial and binomial logistic regression models were used to examine associations. SES markers included parental education, individual education, intergenerational educational mobility and household wealth. Intergenerational educational mobility was classified: stable-low (low parental and low individual education), stable-high (high parental and high individual education), upwardly (low parental and high individual education), or downwardly mobile (high parental and low individual education).

Results

The prevalence of obesity (12.9%) exceeded the prevalence of underweight (7.2%) in the population. High parental and individual education were significantly associated with higher odds of obesity and central adiposity in women. Compared to the stable low pattern, stable high (obesity: OR = 3.15; 95% CI: 1.96, 5.05; central adiposity: OR = 1.75; 95% CI: 1.03, 2.98) and upwardly (obesity: OR = 1.71; 95% CI: 11.13, 2.60; central adiposity: OR = 1.60; 95% CI: 1.08, 2.37) mobile education patterns were associated with higher odds of obesity and central adiposity in women, while stable high pattern was associated with higher odds of overweight (OR = 1.88; 95% CI: 1.11, 3.19) in men. Additionally, high compared to the lowest household wealth was associated with high odds of obesity and central adiposity in both sexes.

Conclusion

Stable high and upwardly mobile education patterns are associated with higher odds of obesity and central adiposity in women while the stable high pattern was associated with higher odds of overweight in men.

health (WHO-SAGE). Details on data can be found at http://www.who.int/healthinfo/sage/cohorts/en/. The authors used the GhanaINDDataW2 and GhanaHHDataW2. The codes for the measured weight, height and waist circumference used to calculate body mass index (BMI) and central adiposity, the outcome variables as used in the data are q2506 for weight, q2507 for height and q2508 for waist circumference. The authors confirm that they had no special access privileges to the data. Interested researchers will have to submit a licensed data request to WHO. Upon approval, the researchers will be granted access licensed dataset.

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Introduction

Overweight and obesity have reached epidemic proportions in most regions of the world, including sub-Saharan Africa [1, 2]. With increasing prevalence of overweight and obesity in low and middle-income countries (LMICs), the World Health Organization (WHO) has indicated that a double burden of communicable and non-communicable diseases in the near future in LMICs is imminent [3]. Since increasing prevalence of overweight and obesity could differ based on several factors including sex, biosocial, sociocultural, economics, biological, and environmental factors, it is crucial to understand the factors that contribute to their occurrence in LMICs in order to tailor efficient and cost-effective preventive programmes and policies in their prevention [4, 5].

Socioeconomic status (SES), is a consistent predictor of population morbidity and mortality [6, 7]. Some SES markers include education, intergenerational education mobility and income/wealth [6, 8, 9]. Education has been cited as one of the most important markers of SES that affect individuals' health [6–9]. However, the effect of intergenerational educational mobility on individuals' health is scarcely examined in many LMICs settings. Intergenerational educational mobility is largely defined as the change in the level of education between parent (s) and their children and describes individuals' experiences in relation to an achieved position compared to their parents [8, 10]. Previous studies have shown that different childhood or initial socioeconomic circumstances might influence current and future health outcomes and inequalities [7, 8, 10, 11]. Studies conducted mostly in high-income countries that used education to define lifetime SES found individuals with high levels of education compared with their parents had better health outcomes than those who had lower education compared with their parents [8, 10, 11]. Wealth has been found to be inversely associated with obesity in developed countries [5, 12], but has shown to be positively associated with obesity in developing countries [2, 5, 13].

Few studies have explored the mechanism by which intergenerational education mobility influences health risks in low and middle-income countries, and Ghana is no exception [14, 15]. However, these studies have used BMI as a continuous variable, which limits the ability to differentiate between categories of BMI. Hence, the associations for overweight or obesity have not been distinctively made. Furthermore, categorizing BMI into obese and non-obese where underweight and overweight are grouped as non-obese could be problematic as the two categories may produce different health effects [16, 17]. Waist circumference is found to be an important marker of central adiposity and could be used independently to predict cardiometabolic diseases in different populations [18, 19]. Thus, previous studies usage of only BMI to determine obesity may limit the appropriate capturing of central adiposity. Lastly, previous studies have used sub-populations that often do not represent the population of interest and limits the generalizability of the findings. To fill the gap in these previous studies, this study uses Wave 2 data of the World Health Organization's Study on global AGEing and adult health (WHO-SAGE) to examine the association between markers of current and lifetime SES and different BMI categories in a representative sample of adult men and women in Ghana. We also conduct sub-analyses using current sub-Saharan Africa (SSA) population waist circumference optimal cut-offs for which individuals are at increased risk of cardiometabolic diseases [18].

Methods

Study population

Data from SAGE Ghana Wave 2 (2014–2015) was used. This is a longitudinal dataset on the health and well-being of adult populations aged ≥50 years for six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa [20]. For comparison, the study also collects sample data from younger adults aged 18–49 years. In Ghana, SAGE collected individual-level data from a nationally representative sample of households including older adults using a stratified, multistage cluster design. The primary sampling units were stratified by region and location of residence of a household (urban/rural) and the samples were selected from 250 enumeration areas. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). Further information on WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

The individual questionnaire responses used in the study covered the following domains: socio-demographic characteristics, work history and benefits; health state descriptions; anthropometrics, performance tests and biomarkers; risk factors and preventive health behaviour; chronic conditions and health services coverage; health care utilisation; social cohesion; subjective well-being and quality of life; impact of caregiver; and the interviewer's assessment. Of the 4,735 survey respondents, 229 had missing data for height, 227 for weight and 228 for waist circumference. Also, biologically implausible values (BIV) (height <100cm or >200 cm and weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm) were excluded using the listwise deletion [21, 22]. In total, 246 (5.2%) and 25 (0.5%) observations were excluded due to missing anthropometric measurements and BIVs of height. Consequently, data from 4,464 participants who had complete responses formed the analytical sample for the study.

Outcome variables

In the WHO SAGE data, anthropometric measurements of body weight, height, and waist circumference of respondents were taken by trained assessors using standard protocols [23, 24]. Pregnant women were exempted from weight and waist circumference measurements [23]. Respondents' height was converted from centimeters to meters, and BMI was calculated as a person's weight in kilograms divided by the square of their height in meters (kg/m^2). BMI was classified into four categories and weighted prevalence estimated: underweight, BMI <18.50kg/m^2; normal/healthy BMI, BMI ≥18.50–24.99 kg/m^2; overweight, 25.00–29.99kg/m^2;

and obesity as BMI $\geq$30.00 kg/m^2 [25, 26]. We determined central adiposity using the current waist circumference optimal cut-offs for which individuals would be at increased risk for cardiometabolic diseases within the sub-Saharan Africa (SSA) population [18]. Thus, waist circumference (WC) cut-off of WC $\geq$ 81.2cm for men, WC $\geq$80.0cm for women and population WC $\geq$81.1cm were categorized as central adiposity otherwise, normal.

Explanatory variables

SES variables. The selection of SES measures follows previous literature [6, 8, 10, 27]. These were parental and individual education, intergenerational educational mobility, and household wealth status. SAGE collected information on the respondent (individual) and parental highest level of education. The structure of the Ghanaian Educational System before and after independence in 1957 has been subjected to several structural and funding changes with significant debates around the number of years students should spend in the Senior Secondary/High School (SSS/SHS) [28]. In addition to reducing the number of years spent in pre-tertiary education, improving the quality of education and creating universal access to education, another principal aim of the SSS/SHS educational structural reforms was to enhance economic growth by ensuring that SSS/SHS school leavers would develop skills to secure jobs in the labour market when they exited the school system before tertiary education [28, 29]. Thus, the SSS/SHS would act as a better and preferable education level for entry into the labour market. Many structural reforms have occurred between 1961 and 1995. In 1995, the Free Compulsory Universal Basic Education (FCUBE) was introduced to improve the quality of education with basic education consisting of nine years. Universal Basic Education is made up of six (6) years of primary school education and three (3) years of Junior Secondary School (JSS) [28]. Between 2002 and 2008, this was changed to 11 years of free basic education to include two years of kindergarten education, and then four years of senior secondary school education. Since 2017, Ghana has embarked on free education from kindergarten to SHS [30]. While male participation in education has consistently been high, that of females has gradually increased, although with some major barriers [31].

On the basis that SSS/SHS would act as the minimum level of education required for entry into the labour market [29], and also due to fewer data observations for college or tertiary education, we divided the highest education completed into two groups. Thus, both parental and individual educational levels were grouped into low education where the highest level of education was less than a secondary or high school, and high education where a person completed secondary/ high school and above.

We used education to define the lifetime SES variable: intergenerational educational mobility was selected as studies have shown that education is reliable and vital in determining long-term social class when studying health risk factors [6–8]. Intergenerational educational mobility was assigned and coded as follows: 1) stable low if both parents and individual education were low; 2) stable high if both parents and individual education were high; 3) upwardly mobile if parents had low education and individual education was high; and, 4) downwardly mobile if parents had high education and individual education was low (Fig 1).

Household wealth index was constructed using principal component analysis from a total of 22 assets/ characteristics/ items converting these into wealth quintiles [32, 33]. The items included household ownership of durable assets (example; radio, television, and refrigerator), dwelling characteristics (example; type of floor and wall material) and access to utilities (example; electricity, improved water and having improved sanitation facility). Quintile one was the lowest quintile; two represented low; three for moderate; four was high, and five was the

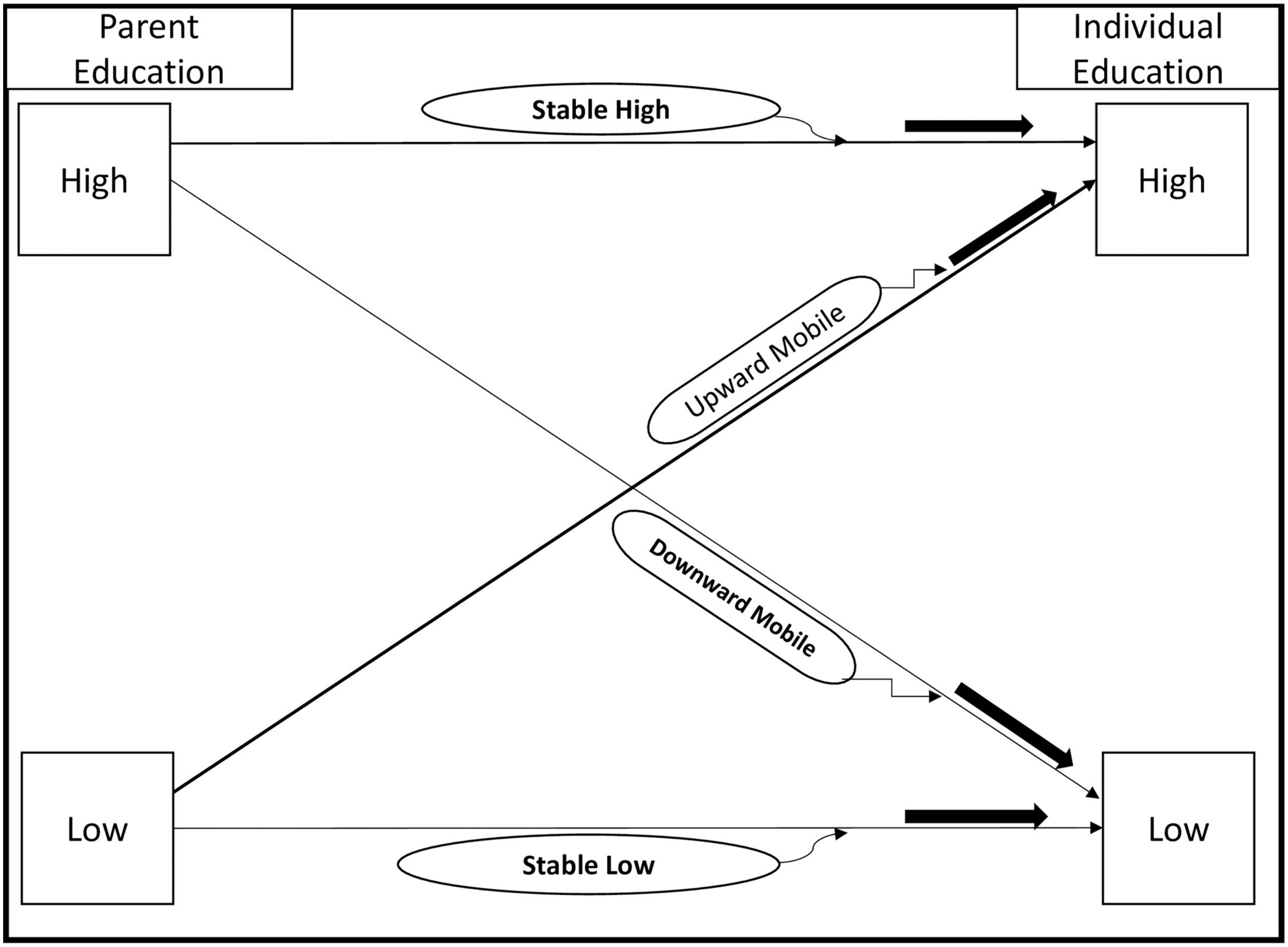

Fig 1. Schematic representation of intergenerational education mobility tracking possibilities from parental education to respondents' education in the WHO-SAGE study.

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highest quintile representing highest household wealth status. This served as a proxy for household economic status [32–34].

Covariates. Covariates included age, place of residence, marital status, alcohol intake, smoking status, daily fruit and vegetable intake, and weekly physical activity levels. In this study, age was specified in 10-year intervals except for ages 18–29 due to fewer observations based on the stated sampling strategy where the younger adult population was selected for comparison purposes, not to be nationally representative of these younger age groups. Rural/ urban residence was defined by localities, where population size less than 5,000 was classified as rural and any larger localities classified as urban. Marital status was coded as (1) for single, (2) for married/ cohabiting and (3) for divorced/ separated/ widow/ widower. Respondents' smoking status was coded as (1) for "current smoker", (2) "former smoker" and (3) for "never smoked before"; and alcohol consumption status was also coded as (1) for "current alcohol drinker", (2) "former alcohol drinker" and (3) for "never drunk alcohol before".

Daily fruit and vegetable servings were categorized according to the NCD Global Monitoring Framework specifications and recommended by the joint WHO/FAO Panel on Diet, Nutrition and Chronic Disease Prevention [35]. Following these recommendations, a serving of fruit or vegetables was equivalent to 80 grams. Respondents were determined to have met the standard recommendation if they ate five or more servings of fruits and vegetables per day (equivalent to 400 grams). The level of physical activity was determined by the total metabolic equivalents of task (MET) minutes per week using the Global Physical Activity Questionnaire (GPAQ) built into the SAGE interview instrument [36]. Meeting the recommended total physical activity was defined as engaging in activities including work, during transport and leisure time for at least 150 minutes of moderate-intensity activity per week or 75 minutes of vigorous-intensity activity per week. The Cronbach's alpha for the 15 items covering work, travel to and from places, and recreational activities that measured physical activity was 85.4% in this sample.

Statistical analysis

The prevalence estimates for each BMI category and central adiposity were computed as percentages using the total sample size separately for men, women and the total population as the denominator. In the estimation process, we used post-stratified person weights to account for the differential probabilities of selection, nonresponse, and non-coverage/under-coverage. Using these weights, we were able to estimate prevalence that reflects the true distribution of the BMI categories and central adiposity in the population aged 50 years and older [37]. Due to the categorical nature of the outcome variables in this study, we used Pearson chi-squared test or Fisher's exact test where appropriate, to examine the associations between all BMI categories, the two categories of waist circumference and the mediators.

Taking the post-stratified person weights into account, we fitted multilevel multinomial and binomial logistic models using the Generalized Latent Linear and Mixed Model (GLLAMM) to determine the association between all the SES factors with the four-level outcome variable of BMI category (underweight, normal weight, overweight, and obese) [38]. Normal/healthy weight category was used as the base/reference group. We estimated the exponentiated form of the coefficients and therefore presented the results in terms of multinomial and binomial log-odds (logit) instead of relative risk ratios [39]. Thus, we estimated the odds of being underweight, overweight, obese or having "at risk" WC compared to having normal BMI.

Ignoring the post-stratified sampling weights, inability to account for both unobserved variables and dependence among observations are major identification problems, which could lead to biased estimations in this study. GLLAMM accounting for the sampling weights of the observation and the latent trait in GLLAMM helps to account for unobservable variables leading to unbiased estimates. The SAGE has a hierarchical structure, in which participants were nested within survey clusters. To adjust for dependence because of the clustering in the multivariable analyses, we used GLLAMM and included individual random effects in the model to estimate the magnitude and determine the significance of clustering using Intra Class Correlation (ICC). We determined the ICC as the ratio of the variance at the cluster level to the sum of the variance at the individual and the cluster levels [16]. All analyses were performed using STATA v.15 (Stata Corp., College Station, Texas, USA).

Two models for each sex and each SES factor were developed and were adjusted for covariates that were identified as confounders. Confounders were determined to be covariates if they were associated with the outcome and when included in the model resulted in a change in the parameter estimate by 10% or more [40]. Confounders were age, ethnicity and marital status (included in model 1 for each sex), while location, physical activity, alcohol, and smoking status, as well as fruit and vegetable intake, were used as potential mediators [27]. Both confounders and potential mediators were included in the final model (model 2) for each sex. We reported the results of a third model (Model 3 in Supplementary Table 1) in which household wealth status was included in model 2 separately for parental and individual education, and intergenerational education mobility, to test which of these SES factors remained associated with the categories of BMI. We assessed multicollinearity using variance inflation factors. There was no variance inflation factor higher than 10, suggesting no multicollinearity in both models 1 and 2 [41].

Results

Table 1 presents the characteristics of the study population. In this sample, there were more women (58.5%) compared to men (41.5%). The mean age (standard deviation, SD) of the

Table 1. Characteristics of the sample, by sex in WHO SAGE Ghana Wave 2 (2014/15).

		Men		Women		Population	
		(n)	%	(n)	%	(n)	%
Total Population		1854	41.5	2610	58.5	4464	100
Age [years (SD)]		58.1 (16.8)		56.4 (16.2)		57.1 (16.5)	
Mean Weight [kg (SD)]		64.5 (11.5)		66.0 (16.0)		65.3 (14.2)	
Mean Height [m (SD)]		1.68 (7.59)		1.59 (7.49)		1.63 (8.63)	
Mean Waist Circumference [cm (SD)]		79.7 (12.6)		86.6 (17.7)		83.4 (15.9)	
Mean BMI [kg/m^2 (SD)]		22.9 (3.7)		25.9 (6.1)		24.5 (5.4)	
BMI Categories	Normal Weight	1220	65.8	1248	47.8	2468	55.3
	Underweight	250	13.5	248	9.5	498	11.2
	Overweight	320	17.3	640	24.5	960	21.5
	Obese	64	3.5	474	18.2	538	12.1
‡Central Adiposity (WC ≥ optimal cut-point)		864	46.6	1898	72.7	2762	61.9
Age (years)	18–29	160	8.6	207	7.9	367	8.2
	30–39	107	5.8	216	8.3	323	7.2
	40–49	189	10.2	235	9.0	424	9.5
	50–59	443	23.9	805	30.8	1248	28.0
	60–69	485	26.2	577	22.1	1062	23.8
	≥ 70	470	25.4	570	21.8	1040	23.3
Parental Education	Low	1619	87.3	2205	84.5	3824	85.7
	High	235	12.7	405	15.5	640	14.3
Individual Education	Low	1111	59.9	2047	78.4	3158	70.7
	High	743	40.1	563	21.6	1306	29.3
Intergenerational Education Mobility	Stable Low	1071	57.8	1906	73.0	2,977	66.7
	Stable High	195	10.5	264	10.1	459	10.3
	Upward Mobility	548	29.6	299	11.5	847	19.0
	Downward Mobility	40	2.2	141	5.4	181	4.1
Household Wealth Quintile	Lowest	329	17.8	263	10.1	592	13.3
	Low	421	22.7	538	20.6	959	21.5
	Moderate	342	18.5	609	23.3	951	21.3
	High	390	21.0	615	23.6	1005	22.5
	Highest	372	20.1	585	22.4	957	21.4

‡ sub-Saharan African waist circumference (WC) cut-off point for men (WC≥81.2cm); women (WC≥80.0cm); population level (WC≥81.1cm) [18]

https://doi.org/10.1371/journal.pone.0208491.t001 population was of 57.1 years (SD: 16.5) with a mean height of 1.63m (SD: 8.63), weight of 65.3kg (SD: 14.2), waist circumference of 83.4cm (15.9) and BMI of 24.5kg/m^2 (SD: 5.4). While about 40% of men had high education, only about 22% of women had the same level of education.

The weighted prevalence across the four BMI categories and central adiposity are shown in Table 2. Accounting for sampling weights, 7.2% (95% CI: 6.0%, 8.7%) were underweight; 55.2% (95% CI: 52.1%, 58.2%) were normal weight; 24.7% (95% CI: 22.3%, 27.2%) were overweight; 12.9% (95% CI: 11.2%, 14.8%) were obese by BMI measurement, and 61.9% (95% CI: 60.4%, 63.3%) had elevated central adiposity by waist circumference measurement. Thus, the prevalence of central adiposity that increases cardiometabolic risk was higher compared to the combined prevalence of overweight and obesity in both men and women (Table 2).

Also, the prevalence of obesity exceeded that of underweight in the population. The prevalence of overweight, obesity and central adiposity was higher in women, particularly in all the high SES categories. Tables 3 (men) and 4 (women) show that all the SES markers were associated with BMI and central adiposity. In addition, SES status was found to be associated with covariates such as location and in some cases alcohol intake, low fruit and vegetable intake, and physical activity levels. These covariates were used as mediators in the regression analyses.

Results of the multivariable analyses for the SES markers associated with the BMI categories and central adiposity are shown in Tables 5 and 6 for men and women, respectively. Model 1 in men showed that high parental education was associated with lower odds of underweight but higher odds of both overweight and obesity. In the fully adjusted model, the association was no longer significant except for those in the underweight (OR = 0.40; 95% CI: 0.16, 0.97) and overweight (OR = 1.66; 95% CI: 1.05, 2.65) categories. Parental education was not associated with central adiposity in men. In women, parental education was significantly associated with BMI and central adiposity. High parental education was significantly associated lower odds of underweight (OR = 0.31; 95% CI: 0.12, 0.75), but higher odds of overweight (OR = 1.84; 95% CI: 1.29, 2.62), obesity (OR = 2.59; 95% CI: 1.72, 3.91) and central adiposity (OR = 1.51; 95% CI: 1.04, 2.19) in the fully adjusted model.

While no significant association was found between individual education and BMI or central adiposity in men, a significant association was found in women who were obese and women with central adiposity. High compared to low individual education was associated with higher odds of obesity (OR = 2.05; 95% CI: 1.45, 2.91) and central adiposity (OR = 1.62; 95% CI: 1.16, 2.27). When individual education was independently adjusted for parental education in the full model, high individual education was found to be associated with higher odds of obesity (OR = 1.61; 95% CI: 1.13, 2.30) and central adiposity (OR = 1.51; 95% CI: 1.07, 2.13) only in women (S1 Table). The interaction terms between parental and individual education were not significant for either sex (S1 Table).

Among men, being in the stable high compared to the stable low category of educational mobility was associated with lower odds of underweight (OR = 0.32; 95% CI: 0.12, 0.90) but higher odds of overweight (OR = 1.88; 95% CI: 1.11, 3.19). There was no significant association between educational mobility and obesity or central adiposity in men. Compared to the stable low category in women, all three other categories of educational mobility were associated with higher odds of obesity. Stable high (OR = 1.75; 95% CI: 1.03, 2.98) and upwardly mobile (OR = 1.60; 95% CI: 1.08, 2.37) categories in women were associated with central adiposity. Household wealth status was significantly associated with all categories of BMI and central adiposity in both sexes. In men, high compared to lowest household wealth status was significantly associated with lower odds of underweight but high odds of overweight, obesity and central adiposity in both model 1 and 2 Similar odds and associations were observed in women; however, no significant association was found for underweight. Separately for

Table 2. Prevalence (%) of Body Mass Index (BMI) categories and central adiposity (Waist Circumference ≥ cut-off point) with 95% Confidence Interval in Ghana's adult population (2014/15).

		Underweight	Normal weight	Overweight	Obese	‡ ‡ Central Adiposity (WC ≥ optimal cut-point)
Men	‡**Weighted**	9.1 (6.9, 11.9)	66.2 (61.4, 70.7)	20.7 (17.1, 24.9)	3.9 (2.5, 6.2)	42.7 (38.7, 46.7)
	Unweighted	13.4 (12.0, 15.1)	65.8 (63.6, 67.9)	17.3 (15.6, 19.1)	3.5 (2.7, 4.4)	46.6 (44.3, 48.9)
‡**Parental Education**	Low	9.5 (7.1, 12.5)	66.0 (61.1, 70.5)	20.7 (16.7, 25.3)	3.8 (2.4, 5.9)	42.6 (38.2, 47.2)
	High	8.0 (84.4, 14.0)	66.8 (56.2, 75.9)	20.8 (13.0, 29.8)	4.4 (2.0, 9.5)	42.8 (34.1, 51.8)
‡**Individual Education**	Low	5.6 (3.5, 8.9)	68.4 (61.4, 74.7)	20.6 (16.2, 25.7)	5.4 (2.9, 9.7)	42.6 (37.0, 48.4)
	High	5.6 (3.5, 8.9)	68.4 (61.4, 74.7)	20.6 (16.2, 25.7)	5.4 (2.9, 9.7)	42.6 (37.0, 48.4)
‡**Intergenerational Education Mobility**	Stable Low	12.1 (8.7, 16.6)	64.1 (58.1, .69.7)	21.1 (16.0, 27.2)	2.6 (1.3, 5.2)	43.7 (37.9, 49.7)
	Stable High	5.9 (2.9, 10.8)	67.7 (55.2, 78.1)	21.2 (13.6, 31.6)	5.1 (2.2, 11.6)	45.0 (35.6, 54.7)
	Upwardly	5.4 (3.3, 8.7)	68.9 (61.6, 75.5)	20.1 (15.0, 26.4)	5.6 (2.9, 10.4)	40.8 (34.1, 48.0)
	Downwardly	14.1 (8.0, 23.6)	64.1 (44.6, 79.8)	19.6 (12.0, 26.6)	2.1 (1.0, 6.9)	35.9 (18.8, 50.7)
‡**Household Wealth Quintiles**	Lowest	11.5 (7.0, 18.5)	74.0 (66.7, 80.2)	13.7 (8.5, 21.2)	0.8 (0.2, 3.5)	29.2 (21.1, 38.9)
	Low	8.6 (5.0, 14.3)	76.0 (68.5, 82.1)	12.6 (8.2, 19.0)	2.8 (1.0, 6.2)	41.0 (32.2, 50.5)
	Moderate	13.6 (8.7, 20.5)	62.0 (52.7, 70.4)	22.2 (14.7, 32.3)	2.2 (0.9, 5.6)	50.7 (40.7, 60.6)
	High	10.2 (6.2, 16.4)	65.2 (56.8, 72.7)	20.5 (14.3, 26.4)	4.1 (1.9, 8.6)	39.8 (32.1, 48.1)
	Highest	4.2 (1.5, 10.3)	60.2 (48.9, 70.6)	28.4 (21.4, 36.6)	7.1 (3.4, 14.2)	47.2 (38.5, 56.0)
Women	‡**Weighted**	9.0 (6.6, 12.1)	45.9 (42.6, 49.2)	28.0 (25.2, 31.0)	20.4 (17.8, 23.4)	70.9 (67.1, 74.4)
	Unweighted	9.5 (8.4, 10.7)	47.8 (45.9, 49.7)	24.5 (22.9, 26.2)	18.2 (16.7, 19.7)	72.7 (71.0, 74.4)
‡**Parental Education**	Low	5.3 (4.0, 7.0)	47.9 (44.2, 51.5)	26.9 (23.8, 30.3)	19.9 (17.1, 23.0)	71.7 (67.5, 75.6)
	High	6.8 (3.8, 10.9)	40.2 (33.5, 47.2)	31.0 (25.0, 37.7)	22.0 (16.5, 28.7)	68.3 (60.7, 75.0)
‡**Individual Education**	Low	5.7 (4.2, 7.5)	47.3 (43.4, 51.3)	27.8 (24.6, 31.3)	19.2 (16.1, 22.7)	71.6 (67.4, 75.5)
	High	5.7 (3.2, 9.9)	42.8 (37.0, 48.7)	28.4 (22.7, 34.8)	23.2 (18.3, 28.8)	69.2 (62.2, 75.4)
‡**Intergenerational Education Mobility**	Stable Low	6.0 (4.4, 8.0)	48.3 (44.2, 52.4)	26.3 (23.0, 29.9)	19.4 (16.2, 23.2)	70.9 (66.3, 75.1)
	Stable High	8.5 (4.3, 16.1)	40.2 (32.4, 48.5)	27.2 (20.1, 35.5)	24.2 (17.0, 33.3)	64.1 (54.5, 72.7)
	Upwardly	2.3 (1.0, 5.5)	45.9 (36.8, 55.2)	29.8 (20.9, 40.5)	22.0 (15.7, 29.9)	75.2 (65.4, 83.0)
	Downwardly	3.5 (1.1, 9.2)	40.2 (28.7,50.8)	38.8 (28.1, 48.7)	17.6 (11.2, 26.4)	76.9 (64.6, 85.8)
‡**Household Wealth Quintiles**	Lowest	6.9 (3.6, 13.1)	56.9 (45.5, 67.6)	28.8 (19.9, 39.7)	7.4 (2.8, 14.2)	55.9 (44.1, 67.1))
	Low	7.4 (4.3, 12.6)	53.0 (44.3, 61.5)	26.4 (19.2, 35.3)	13.1 (7.3, 20.2)	68.1 (60.2, 75.1)
	Moderate	5.4 (3.6, 8.2)	52.3 (45.2, 59.4)	27.4 (21.7, 33.8)	14.9 (10.5, 20.7)	73.4 (66.7, 79.3)
	High	7.9 (4.6, 13.3)	37.1 (31.1, 43.5)	32.2 (26.1, 38.9)	22.8 (17.9, 28.6)	73.4 (66.2, 79.5)
	Highest	2.2 (1.0, 5.1)	40.8 (34.0, 48.1)	25.4 (20.1, 31.4)	31.6 (25.2, 38.7)	73.6 (65.7, 80.3)
Total Population	‡**Weighted**	7.2 (6.0, 8.7)	55.2 (52.1, 58.2)	24.7 (22.3, 27.2)	12.9 (11.2, 14.8)	61.9 (60.4, 63.3)
	Unweighted	11.2 (10.3, 12.1)	55.3 (53.8, 56.7)	21.5 (20.3, 22.7)	12.1 (11.1, 13.0)	58.0 (54.8, 61.1)

‡Weighted Prevalence:—Post-stratified person weight applied. Only weighted prevalence is presented for parents and individual education, intergenerational education mobility and household wealth quintiles

‡ ‡ sub-Sahara waist circumference optimal cut-off point for men (WC≥81.2cm); women (WC≥80.0cm); population level (WC≥81.1cm) [18]

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parental and individual education, and intergenerational educational mobility, household wealth was added to the full models (S1 Table). While only household wealth remained significantly associated with BMI and central adiposity in men, high parental education (OR = 1.83; 95% CI: 1.24, 2.70), stable high (OR = 1.90; 95% CI: 1.18, 3.08) and upwardly mobile (OR = 1.89; 95% CI: 1.04, 3.43) categories of educational mobility remained significantly associated with higher odds of obesity in women.

Table 3. Prevalence of covariates (mediators) by education categories and household wealth in men.

	BMI			Central Adiposity	Urban Location	Smoking Status		Alcohol Status		Below recommended ‡ FV intake	Below recommended physical activity levels
	Underweight	Overweight	Obese	(WC≥81.2cm)		Current smoker	Former smoker	Current drinker	Former drinker		
Parental Education											
Low	231	265	52	752	506	155	73	589	128	864	887
High	19	55	12	112	137	15	18	89	22	120	118
P-*value*	<0.01			<0.01	<0.01	0.04		0.61		0.53	0.21
Individual Education											
Low	171	166	30	499	302	124	44	383	82	583	588
High	79	154	34	365	341	46	47	295	68	401	417
P-*value*	<0.01			0.08	<0.01	<0.01		0.01		0.54	0.18
Intergenerational Education Mobility											
Stable Low	165	160	29	485	284	121	41	370	78	562	569
Stable High	13	49	11	98	119	12	15	76	18	99	99
Upwardly	66	105	23	267	222	34	32	219	50	302	318
Downwardly	6	6	1	14	18	3	3	13	4	21	19
P-*value*	<0.01			0.18	<0.01	<0.01		0.15		0.68	0.14
Household Wealth Quintiles											
Poorest	59	38	4	100	21	61	14	127	21	161	160
Poor	63	50	7	194	55	37	17	148	20	237	221
Moderate	60	49	5	168	108	29	18	126	43	191	199
Rich	49	73	21	181	203	28	23	153	29	218	229
Richest	19	110	27	221	256	15	19	124	37	177	196
P-*value*	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.04

‡ FV: Fruits and vegetable intake

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Discussion and conclusion

This study sought to examine associations between key markers of current and lifetime SES and categories of BMI, as well as central adiposity in Ghanaian adults using the most recent data collected by WHO SAGE in Ghana. We found that in men, high parental education and stable high category of intergenerational education mobility were significantly associated with lower odds of underweight but with higher odds of overweight. In women, high compared to low parental and individual education; stable high and upward educational mobility compared to the stable low category were significantly associated with higher odds of obesity and central adiposity. High household wealth status was significantly associated with higher odds of overweight, obesity and central adiposity in both men and women. At the same time, wealthier households were significantly associated with lower odds of underweight making household wealth a protective factor against underweight especially in men. Finally, accounting for the post-stratified person weights, the prevalence of central adiposity was higher compared to the combined prevalence of overweight and obesity in both men and women, and the prevalence of overweight and obesity separately exceeded that of underweight in this population.

Significant findings made in this study were that the prevalence of central adiposity was high, and the prevalence of overweight and obesity separately exceeded underweight in both

Table 4. Prevalence of covariates (mediators) by education categories and household wealth in women.

	BMI			Central Adiposity	Urban Location	Smoking Status		Alcohol Status		Below recommended ‡ FV intake	Below recommended physical activity levels
	Underweight	Overweight	Obese	(WC≥80.0cm)		Current smoker	Former smoker	Current drinker	Former drinker		
Parental Education											
Low	232	517	352	1588	902	17	22	273	136	1158	1319
High	16	123	122	310	276	4	1	54	33	204	263
P-*value*	<0.01			0.03	<0.01	0.30		0.26		0.45	0.05
Individual Education											
Low	221	485	311	1462	815	19	22	263	130	1091	1236
High	27	155	163	436	363	2	3	64	39	271	346
P-*value*	<0.01			<0.01	<0.01	0.05		0.59		0.03	0.66
Intergenerational Education Mobility											
Stable Low	216	438	275	1353	733	16	22	237	114	1028	1136
Stable High	11	76	86	201	194	1	1	28	17	141	163
Upwardly	16	79	77	235	169	1	0	36	22	130	183
Downwardly	5	47	36	109	82	3	0	26	16	63	100
P-*value*	<0.01			0.01	<0.01	0.09		0.04		<0.01	0.06
Household Wealth Quintiles											
Poorest	31	50	14	152	22	0	6	28	9	132	155
Poor	71	106	39	363	112	4	5	76	28	311	338
Moderate	76	139	71	449	244	7	6	62	52	327	361
Rich	50	175	147	465	363	6	1	77	39	312	370
Richest	20	170	203	469	437	4	5	84	41	280	358
P-*value*	<0.01			<0.01	<0.01	0.11		0.03		0.01	0.74

‡ FV: Fruits and vegetable intake

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men and women. The later corroborates previous studies that showed that overweight/obesity exceeded underweight in some developing countries [17]. Historically, the prevalence of obesity in Ghana's population was as low as 0.8% in 1980 [42, 43], it gradually increased to 5.5% in 2003 [44] and 9.8% in 2008 [24]. Our study shows a weighted obesity prevalence of 12.9% and unweighted obesity prevalence about 12% at the time of data collection (2014/2015). In 2003, the weight and height measures used to estimate BMI prevalence were self-reported (as part of SAGE Ghana Wave 0). Weight and height were then objectively measured in 2008 as part of SAGE Ghana Wave 1 (9.8% obese) impeding our ability to compare the prevalence rates in the two waves in 2003 and 2008 [45]. However, the current obesity rate estimated in this study also used objectively measured weight and height, making the current rate comparable to that of Wave 1 from 2008; and this shows an increase even in the case of unweighted prevalence. The increasing obesity rates could be due to several factors such as increased economic growth, rapid urbanization, changing food preference, and availability of healthy foods in Ghana over the past 15 years [46–48]. There is evidence of rapid urbanization in Ghana that has been accompanied by changes in dietary patterns, increase in sedentary lifestyles, increased commuting times due to traffic congestion hence commuters spend long sitting hours in traffic, the loss or lack of open and safe places for physical activities because these spaces are converted

Table 5. Odds ratios (95% confidence intervals, CI) of being underweight, overweight, or obese according to markers of socioeconomic status in men in Ghana (2014/15).

Men	[1]Model 1			[2]Model 2			[1]Model 1	[2]Model 2
	BMI (Ref: normal/healthy BMI)						Central Adiposity ([3]WC≥81.2cm)	
	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Central Adiposity OR [95% CI]	Central Adiposity OR [95% CI]
Parental Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.35 (0.14, 0.87) *	2.06 (1.31, 3.25) **	2.80 (1.16, 5.74) *	0.40 (0.16, 0.97) *	1.66 (1.05, 2.65) *	1.96 (0.82, 4.67)	1.30 (0.86, 1.97)	1.09 (0.72, 1.67)
Individual Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.70 (0.47, 1.03)	1.71 (1.21, 2.43) **	1.64 (0.86, 3.16)	0.79 (0.53, 1.17)	1.41 (0.99, 2.10)	1.28 (0.65, 2.52)	1.25 (0.94, 1.64)	1.09 (0.82, 1.45)
Intergenerational Education Mobility								
Stable Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stable High	0.28 (0.11, 0.77) **	2.52 (1.50, 4.23) ***	3.30 (1.27, 7.55) **	0.32 (0.12, 0.90) *	1.88 (1.11, 3.19) *	2.06 (0.80, 54.29)	1.40 (0.88, 2.23)	1.11 (0.69, 1.79)
Upwardly	0.82 (0.54, 1.23)	1.60 (1.09, 2.37) **	1.24 (0.61, 2.50)	0.91 (0.61, 1.37)	1.36 (0.92, 2.02)	1.04 (0.49, 2.22)	1.23 (0.91, 1.65)	1.11 (0.85, 1.50)
Downwardly	1.03 (0.19, 3.63)	3.70 (0.76, 7.00)	0.35 (0.04, 3.38)	1.16 (0.19, 3.10)	3.34 (0.85, 6.21)	0.35 (0.03, 1.88)	1.75 (0.57, 3.39)	1.70 (0.57, 4.06)
Household Wealth Quintile								
Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low	0.60 (0.38, 0.96) *	1.14 (0.56, 2.31)	1.00 (0.20, 3.12)	0.60 (0.48, 1.23)	0.93 (0.53, 1.67)	0.69 (0.13, 2.77)	2.21 (1.46, 3.33) ***	1.89 (1.15, 3.11) **
Moderate	0.57 (0.34, 0.94) *	1.32 (0.62, 2.81)	2.38 (0.51, 5.62)	0.67 (0.41, 1.04)	1.45 (0.84, 2.52)	2.03 (0.43, 5.07)	2.37 (1.59, 3.55) ***	1.92 (1.23, 3.00) **
High	0.49 (0.30, 0.82) **	2.20 (1.13, 4.30) *	4.28 (2.10, 9.78) ***	0.65 (0.38, 1.11)	1.52 (0.83, 2.82)	3.74 (1.53, 8.66) *	2.49 (1.58, 3.92) ***	2.06 (1.34, 3.15) ***
Highest	0.20 (0.11, 0.38) ***	3.06 (1.64, 6.85) ***	5.36 (3.30, 10.99) ***	0.24 (0.11, 0.49) ***	1.83 (1.01, 3,34) *	4.52 (2.51, 9.95) **	4.46 (2.87, 6.92) ***	2.98 (1.83, 4.83) ***

*p<0.05

**p<0.01

***p<0.001

[1]Model 1- Adjusted for confounders including age, marital status and ethnicity

[2]Model 2- Adjusted for confounders and potential mediators including rural/urban location, whether a respondent was current smoker, former smoker or never smoked, regularly/ currently drinks
alcohol, former or has never drunk alcohol, met the recommended daily fruit and vegetable intake level, and met the recommended weekly level of physical activity.

[3]sub-Sahara waist circumference optimal cut-off point for men (WC≥81.2cm) [18]

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into residential or commercial building spaces, and less engagement in physical activities [46, 47]. Changes in dietary patterns could be associated with the readily available fast-foods as evidenced by almost a doubling of the hospitality sector (which includes restaurants and food services) from 2.9% to 5.5% from the year 2000 to 2010 in Ghana [47]. The combined effect of such conditions could serve as a platform for households to adopt lifestyles that make individuals prone to obesity as has been observed in other settings [17, 49]. However, as a major risk factor for non-communicable diseases, the high prevalence of obesity in this study compared to the historical prevalence emphasizes the need for deliberate actions to prevent obesity, a

Table 6. Odds ratios (95% confidence intervals, CI) of being underweight, overweight, or obese according to markers of socioeconomic status in women in Ghana (2014/15).

Women	[1]Model 1			[2]Model 2			[1]Model 1	[2]Model 2
	BMI (Ref: normal/healthy BMI)						Central Adiposity ([3]WC≥80.0cm)	
	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Underweight OR [95% CI]	Overweight OR [95% CI]	Obese OR [95% CI]	Central Adiposity OR [95% CI]	Central Adiposity OR [95% CI]
Parental Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.28 (0.11, 0.71) **	2.04 (1.46, 2.84) ***	3.34 (2.19, 5.10) ***	0.31 (0.12, 0.75) **	1.84 (1.29, 2.62) ***	2.59 (1.72, 3.91) ***	1.77 (1.23, 2.54) **	1.51 (1.04, 2.19) *
Individual Education								
Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High	0.50 (0.28, 0.89) *	1.52 (1.13, 2.05) **	2.71 (1.90, 3.87) ***	0.56 (0.32, 1.00)	1.34 (0.99, 1.83)	2.05 (1.45, 2.91)	1.87 (1.35, 2.59) ***	1.62 (1.16, 2.27) **
Intergenerational Education Mobility								
Stable Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stable High	0.18 (0.06, 0.52) **	2.16 (1.42, 3.31) ***	4.54 (2.77, 7.43) ***	0.21 (0.07, 0.61) **	1.87 (1.19, 2.93) **	3.15 (1.96, 5.05) ***	2.13 (1.31, 3.49) **	1.75 (1.03, 2.98) *
Upwardly	0.67 (0.17, 1.59)	1.32 (0.88, 1.98)	2.18 (1.44, 3.28) ***	0.73 (0.38, 1.38)	1.17 (0.78, 1.77)	1.71 (1.13, 2.60) **	1.80 (1.20, 2.69) **	1.60 (1.08, 2.37) *
Downwardly	0.43 (0.11, 1.63)	2.06 (1.22, 3.46) **	2.86 (1.61, 5.11) ***	0.42 (0.12, 1.45)	1.92 (1.11, 3.32) **	2.42 (1.30, 4.53) **	1.60 (0.91, 2.81)	1.43 (0.82, 2.50)
Household Wealth Quintile								
Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low	1.09 (0.64, 1.86)	1.26 (0.80, 1.99)	1.39 (0.56, 3.45)	1.01 (0.60, 1.72)	1.19 (0.75, 1.88)	1.19 (0.47, 2.98)	1.51 (1.01, 2.27) *	1.38 (0.92, 2.08)
Moderate	0.99 (0.59, 1.67)	1.61 (1.03, 2.51) *	2.94 (1.84, 7.03) *	1.21 (0.69, 2.11)	1.44 (0.91, 2.28)	2.02 (0.84, 4.89)	2.10 (1.35, 3.27) ***	1.79 (1.15, 2.79) **
High	0.96 (0.54, 1.70)	2.74 (1.74, 4.29) ***	4.91 (2.27, 10.15) ***	1.10 (0.60, 2.02)	2.30 (1.42, 3.71) ***	3.75 (1.93, 7.68) ***	2.36 (1.51, 3.69) ***	1.86 (1.18, 2.93) **
Highest	0.62 (0.31, 1.24)	4.31 (2.64, 7.06) ***	6.29 (2.85, 16.77) ***	0.76 (0.37, 1.58)	3.44 (2.02, 5.88) ***	4.48 (3.49, 9.59) ***	3.19 (1.96, 5.20) ***	2.34 (1.42, 3.85) ***

*$p<0.05$

**$p<0.01$

***$p<0.001$

[1]Model 1- Adjusted for confounders including age, marital status and ethnicity

[2]Model 2- Adjusted for confounders and potential mediators including rural/urban location, whether a respondent was current smoker, former smoker or never smoked, regularly/currently drinks alcohol, former or has never drunk alcohol, met the recommended daily fruit and vegetable intake level, and met the recommended weekly level of physical activity.

[3]sub-Sahara waist circumference cut-off point for women (WC≥80.0cm) [18]

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point which is supported by WHO's position that an increasing prevalence of obesity may contribute to the rising burden of non-communicable diseases in Africa [1, 3, 16].

Another significant finding in this study is the result that especially in women, high compared to low parental and individual education levels were associated with higher odds of overweight and obesity. This finding is consistent with findings in most developing economies where overweight and obesity have been associated with high SES [13, 15, 50–52]. However, this finding is in contrast with results from countries such as Australia, Germany, the United

States and Malaysia in which parental or an individual's high educational attainment has been associated with low BMI, low central adiposity and good health outcomes [8, 10, 53–55]. The situation in Ghana suggests that high education which begins with the completion of SSS/SHS and above is an economic tool for resource acquisition through the generations. Hence, those whose parents had high education were likely to possess the resources needed to afford the 'westernized' lifestyle: increase consumption of fast foods, high sodium diets, and high caloric drinks which are associated with westernized diets and perceived to be major dietary changes that promote obesity [17, 56].

This phenomenon could also be explained by the potentially low level of awareness of the positive effect of maintaining healthy body weight especially among women and thus, suggests the need for nutritional education [57]. Furthermore, this may also be as a consequence of cultural influence, which portrays overweight and obesity instead of normal/healthy BMI as a sign of affluence and high social standing observed in some developing countries [5, 17, 57]. Our finding that high parental education is associated with lower odds of underweight in women supports the notion culture confers on body size and socio-economic status.

In this population and especially among women, having a stable high or upward educational mobility were significantly associated with higher odds of obesity (both defined by BMI and waist circumference). This finding, especially regarding central adiposity, confirms that high SES potentially affected obesity in Ghanaian women [15]. Our results, however, contradict findings in some previous studies conducted mostly in developed countries [8, 10, 11, 53]. For instance, Kuntz and Lampert found no significant increase in the risk of obesity among respondents with potentially upward educational mobility [10]; Gall et al found upward educational mobility was associated with higher healthy life scores that included low BMI in young Australians [8]; Albrecht and Gordon-Larsen reported upward education mobility was associated with low adult mean BMI [53]; Adina et al found high parental and high personal education levels were associated with lower odds of large waist circumference [54]. Thus, the association between educational mobility and obesity seem to differ based on the culture, social location, and economy from which a sample is drawn.

Evidence in this study that high household wealth increased the odds of overweight and obesity is consistent with findings from some developing economies [13, 17, 50]. For example, using educational attainment as an SES marker in 36 countries, Mendez et al [17] found a strong positive association between high SES and overweight/obesity in developing countries; but this association reduced or reversed for developed countries [50].

Another interesting finding in this study is that downward mobility in women compared to the stable low category was associated with higher odds of obesity, although such association was not seen with central adiposity. The sample of downwardly mobile populations overall was small, which is a positive result but may contribute to a relative underestimation of associations in this analysis. Given that, we have accounted for all possible observable factors, included the sampling weights, and used STATA's GLLAMM multilevel multinomial logistic regression that adjusted for clustering and any latent variable, we could, therefore, rule out that this is not a spurious relationship. The finding is consistent with results in other studies in which positive associations were found between downward intergenerational education mobility and health risk outcomes [8, 10, 53].

Significantly low levels of education in women may have affected their food choices, preference, and understanding of the health implications of having unhealthy BMI or central adiposity. For many years to many children, SSS/SHS education was an "elusive dream" mainly due to the cost of obtaining this level of education and girls were mostly affected [31]. However, with increased general and nutrition education, a population is more likely to reduce such health inequalities [58], suggesting the need for increased general, health and nutrition education in the population. Alternatively, the results in this study suggest that education may be protective in reducing health inequalities in the population and thus, an improvement in education enrolment rates, especially in women, may reduce underweight in the population. Consequently, the overall results call for a balance in the implementation of management and preventive measures for all categories of BMI or waist circumference in the population. This notwithstanding, high prevalence of overweight/ obesity and the identified associations in this study coupled with the "obesogenic environment" created due to urbanization, makes it imperative that the public health system is well-resourced to prevent and manage, and further be ready to bear the burden overweight/ obesity may impose on the system.

This study has some limitations. First, the use of cross-sectional data prevented the determination of temporality, and therefore we were unable to discount the possibility of bias due to reverse causality. Second, the use of education to measure mobility for two different generations should be interpreted with caution since the applicability of education and education completion rates may differ in different generations. However, as the educational level is accurately recalled, it is more stable over time compared to other SES markers such as occupation; and the education gradient in health is considered robust when there are preventive and treatment methods for the health risk/outcome such as obesity [6–8]. Also, although the data is representative of the older adult population, analyses omit those observations with missing information such as height and weight, and this may have introduced selection bias which may affect internal validity even though the missing data were relatively minimal (less than 5%). Additionally, the small sample of younger adults aged 18–49 included in the study precludes strong conclusions about the relationship in younger adult ages. Finally, there are a few objective based measures we could not account for, like fast food diet, and occupation due to the scope of our paper and data limitations. Although we have respondents' occupation in our data, it was not included for the following reasons: with regards to socio-economic factors that contribute to risk factors for health, education has shown to be the strongest and most consistent measure [6]; hence, our focus on education first and not occupation. Furthermore, the relationship between occupation and obesity are normally considered in the light of the income earned from such occupation, as well as, whether an individual's occupation makes him/her active or sedentary. Although previous studies did not include factors such as physical activities [8, 15], we included both the level of physical activity determined using the Global Physical Activity Questionnaire (GPAQ) [36] which captures various activities including those at work, and household wealth which is a proxy for economic status of the household from which the individual originates. Thus, although we do not capture occupation in our model, its significance is captured by adjusting for physical activity and household wealth.

We recommend that future studies should adjust for measures such as individual genetic composition, availability of fast food diet, and household composition, which have the potential to influence obesity.

The study also has many strengths. First, we use waist circumference determined by the current SSA optimal cut-off which accounts for central adiposity hence obesity definition was not limited to only BMI. Secondly, we use the most current national dataset that is representative of a wide age group ($\geq$18 years) in both sexes and the use of objectively measured anthropometric data that facilitates our ability to make inferences to the broader population. Finally, our ability to examine the relationship between intergenerational educational mobility and the different BMI categories and central adiposity fills a gap that has rarely been tested in LMICs.

In conclusion, our findings show that the prevalence of central adiposity was higher compared to the combined prevalence of overweight and obesity; and the prevalence of obesity was higher than that of underweight in the Ghanaian adult population. In contrast to studies from high-income countries, we found that high current and lifetime SES were associated with higher odds of overweight, obesity and central adiposity, and with lower odds of underweight in the population.

Supporting information

S1 Table. Sub-analyses between SES variables and BMI as well as central adiposity in Model 3. ‡ WC: Waist circumference.
(DOCX)

S1 File. Strobe statement.
(DOCX)

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Author Contributions

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Appendix 2. Publication of Chapter 3

RESEARCH ARTICLE

Rapidly increasing prevalence of overweight and obesity in older Ghanaian adults from 2007-2015: Evidence from WHO-SAGE Waves 1 & 2

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Data Availability Statement: Data from SAGE Ghana Wave 2 was used for this study. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). The necessary permission was obtained from the World Health Organization to use these data. All files were obtained from the World Health Organization Study on global AGEing and adult health (WHO-SAGE). Details on data can be found

Abstract

Background

Studies on changes in the prevalence and determinants of obesity in older adults living in sub-Saharan Africa are scarce. We examined recent changes in obesity prevalence and associated factors for older adults in Ghana between 2007/08 and 2014/15.

Methods

Data on adults aged 50 years and older in Ghana were drawn from the WHO SAGE 2007/08 (Wave 1; n = 4158) and 2014/15 (Wave 2; n = 1663). The weighted prevalence of obesity, overweight, normal weight and underweight, and of high central adiposity were compared in 2007/08 and 2014/15. Multinomial and binomial logistic regressions were used to examine whether the determinants of weight status based on objectively measured body mass index and waist circumference changed between the two time periods.

Results

The prevalence of overweight (2007/08 = 19.6%, 95% CI: 18.0–21.4%; 2014/15 = 24.5%, 95% CI: 21.7–27.5%) and obesity (2007/08 = 10.2%, 95% CI: 8.9–11.7%; 2014/15 = 15.0%, 95% CI: 12.6–17.7%) was higher in 2014/15 than 2007/08 and more than half of the population had high central adiposity (2007/08 = 57.7%, 95% CI: 55.4–60.1%; 2014/15 = 66.9%, 95% CI: 63.7–70.0%) in both study periods. While the prevalence of overweight increased in both sexes, obesity prevalence was 16% lower in males and 55% higher in females

at http://www.who.int/healthinfo/sage/cohorts/en/. The authors used the GhanaINDDataW1, GhanaHHDataW1, GhanaINDDataW2 and GhanaHHDataW2. The codes for the measured weight and height used to calculate body mass index (BMI), as used in the data are q2506 for weight and q2507 for height. The authors confirm that they had no special access privileges to the data. Interested researchers will have to submit a licensed data request to WHO. Upon approval, the researchers will be granted access licensed data.

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comparing 2007/08 to 2014/15. Female sex, urban residence, and high household wealth were associated with higher odds of overweight/obesity and high central adiposity. Those aged 70+ years had lower odds of obesity in both study waves. In 2014/15, females who did not meet the recommended physical activity were more likely to be obese.

Conclusion

Over the 7-year period between the surveys, the prevalence of underweight decreased and overweight increased in both sexes, while obesity decreased in males but increased in females. The difference in obesity prevalence may point to differential impacts of past initiatives to reduce overweight and obesity, potential high-risk groups in Ghana, and the need to increase surveillance.

Introduction

Obesity is a significant global public health challenge because it is a major risk factor for most noncommunicable diseases (NCDs) and independently predicts overall mortality [1–3]. In adults 25 years or older, epidemiological data have been used to establish a causal relationship between high BMI (defined in this study as overweight and obesity) and some chronic diseases such as cardiovascular disease, diabetes mellitus, chronic kidney disease, many cancers and musculoskeletal disorders [3–5]; increased all-cause mortality; and reduced life expectancy [1, 6–9]. For instance, pooled data from four large cohort studies found that the relative risk for each 5 kg/m^2 higher body mass index (BMI) was 2.32 (2.04–2.63) for diabetes and 1.44 (1.40–1.48) for ischaemic heart disease among those aged 55–64 years [5]. Additionally, high BMI has been associated with poor mental health, reduction in quality-adjusted life years (QALYs), and a high economic burden due to the associated medical and treatment costs [10–16]. In 2015 alone, a total of 603.7 million adults globally were classified to be obese [3]. From 1980 to 2014, obesity has almost doubled among adults in most parts of the world including sub-Saharan Africa [2, 17–19]. Among urban residents in West Africa, the prevalence of obesity has doubled and has consistently increased in both men and women over a period of 15 years from 1992 to 2007 [19, 20].

In Ghana, the increasing prevalence of obesity from 1980 to 2014 among individuals aged 15–49 years has been well-documented [21, 22] and the Ministry of Health found the need to reduce obesity by 2% in the same age group within five years starting from 2008 [23]. However, little is known about the trends in the prevalence of obesity among populations of older adults aged 50 years and above. As a result of improved public health systems, faster fertility transitions, and increased life expectancy, Ghana's population is rapidly transitioning into an ageing population [24]. This is occurring concurrently with improved nutrition but increased availability of energy-dense foods and increasing sedentary lifestyle that has led to recent increases in obesity prevalence and NCDs [22, 25]. The health and productivity of those in the 50–65 years age range are important as they mentor younger colleagues and form the majority labour force for agricultural productivity that is a key sector for sustainable development and poverty reduction in Ghana [26]. Monitoring trends and identifying factors that relate to obesity provide information that allows interventions to be appropriately and effectively targeted [27, 28] but such data among older adults are lacking in Ghana. Thus, this study aimed to investigate recent changes in the prevalence of obesity among Ghana's older adult population and identify contributing factors.

Methods

Study population

Data from the World Health Organization's (WHO) 2007/8 (Wave 1) and 2014/15 (Wave 2) Study on global AGEing and adult health (WHO-SAGE) were used. WHO-SAGE is a longitudinal study on the health and well-being of adult populations aged 50 years and older in six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa [29]. In Ghana, trained SAGE teams collected individual-level data from nationally representative households of adults using a stratified, multistage cluster design. The sampling method used in both 2007/08 and 2014/15 was based on the SAGE Wave 0 (2003) in which the primary sampling units were stratified by region and locality (urban/rural) [30, 31]. Weight, height and waist circumference were measured, exempting pregnant women from weight measurements in both surveys [28].

Data collected in 2007/08 had 5,573 and 2014/15 had 4,735 total survey respondents. The final analytical sample at each level of analysis is shown in Fig 1. The final samples for analysis were determined after missing and biologically implausible weight, height and waist circumference measurements were excluded. Biologically implausible values were height <100cm or >250 cm, weight <30.0 kg or >250.0 kg and waist circumference < 25.0 cm or > 220 cm, and were excluded [32, 33]. Additionally, to examine data in a repeated cross-sectional framework and to meet the assumption of independency, all individuals in 2014/15 who participated in 2007/08 were excluded from the analysis [34–36]. A comparison of the "dropped" subjects with the new respondents in terms of BMI and central adiposity was performed (data not shown) and results suggested that the issue of the representativeness should not represent a potential bias. Individuals aged 50+ years with complete responses were 4,158 (2007/08) and 1,663 (2014/15).

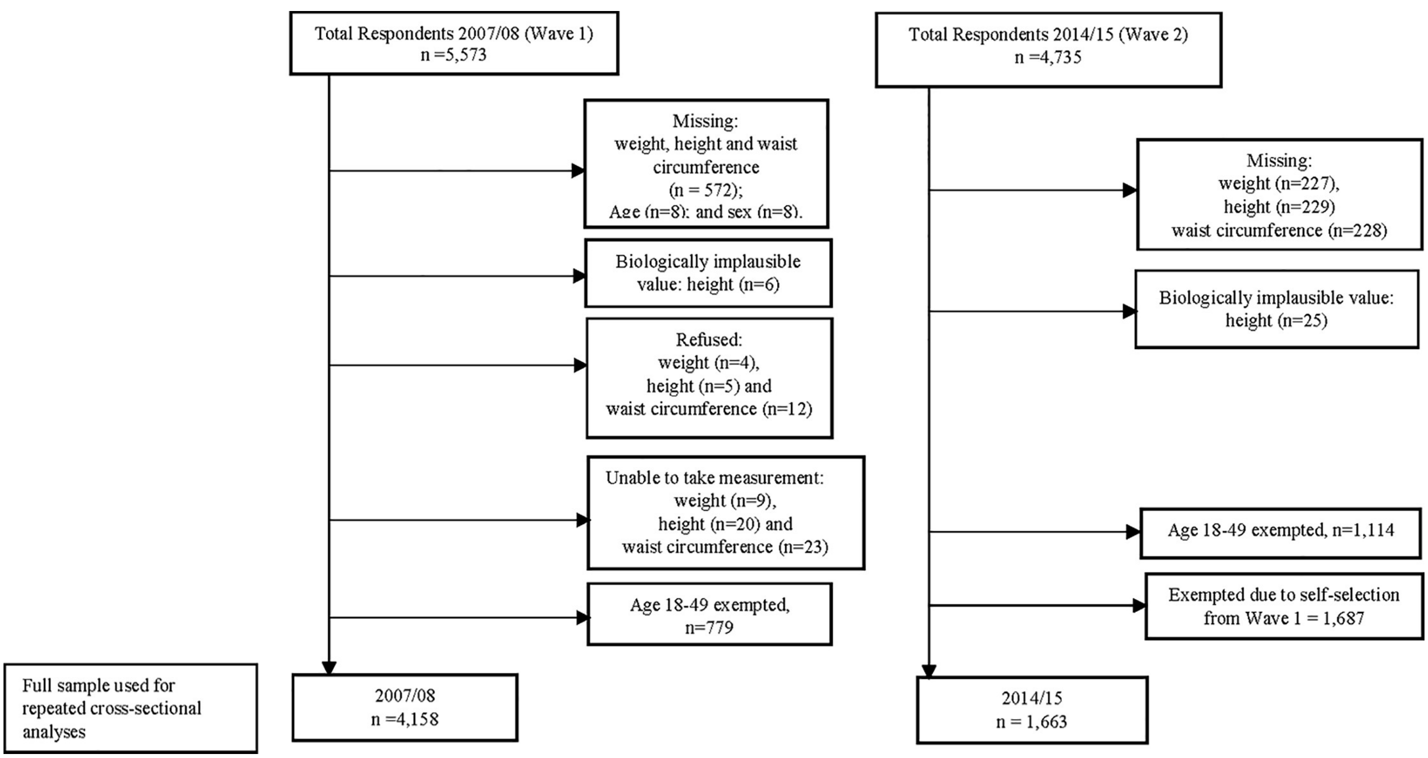

Fig 1. Flowchart showing the analytical sample. Sample extracted from 2007/08 and 2014/15 of the WHO Study on Global AGEing and adult health.

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Measures

Explanatory factors. The definition of explanatory variables used in this study followed the ecological framework developed by Scott *et al* [37] and adapts the causality continuum model for obesity in sub-Saharan Africa [38]. In their ecological framework, Scott *et al* indicated that factors influencing obesity could be situated in the distant, intermediate and proximate tiers. In the framework, the three tiers are found to interact and overlap with each other, and all influence the health outcome. Distant factors include globalization and urbanization, which affect factors such as lifestyle, food habits, and occupation. The intermediate factors include household and community level characteristics (e.g. household income and cultural perception about weight). Finally, the proximate factors include individual factors that directly affect the health outcome such as a genetic composition of the individual, food habits, and physical activity.

Distant factor: The distant factor included in this study was the location of participants' residence, i.e. rural or urban residence. Rural or urban residency, the two main types of localities used were defined based on the populations size. A population size less than 5,000 was classified as rural, and larger than 5,000 classified as urban.

Intermediate factors: Household wealth, a proxy for household income representing the economic status of the household [39], was used as an intermediate factor. Even though household wealth is sometimes seen as a poor index for household consumption or expenditure, there has been a consistent lack of data in most low-and middle-income countries to measure the long-term economic status [39–42]. In this study, household wealth was constructed using principal component analysis from 22 items that considered assets and the derived variable was indexed into five quintiles [43].

Proximate factors: These included sex, age, level of education completed and marital status. We also included smoking status, alcohol consumption, fruit and vegetable servings per day and level of physical activity per week. For estimation of age-specific prevalence, age was classified into 10-year intervals. The level of education was grouped into high education (completion of secondary/high school or higher) and low education (highest level of education completed was less than secondary or high school). Marital status was categorized as (1) single, (2) married/cohabiting and (3) divorced/separated/widowed. Respondents' smoking status was coded as (1) "never smoked", (2) "quitter" and (3) "current smoker". Alcohol consumption status was coded as (1) "never", (2) "quitter" and (3) "current drinker". We categorized responses about fruit and vegetable intake according to international standards [44]. Respondents met the recommendation if they consumed $\geq$5 servings of fruits and/or vegetables per day (equivalent to 400 grams). The level of physical activity was categorised as meeting or not meeting the recommended level of total physical activity per week [45, 46]. Using the Global Physical Activity Questionnaire (GPAQ) instrument that was included in the SAGE, physical activity was estimated by the total metabolic equivalents of task (MET) minutes per week. The analysis guide and STATA syntax was provided by the WHO STEPwise approach to Chronic Disease Risk Factor Surveillance (STEPS) [45]. Meeting the recommended level of total physical activity was defined as engaging in activities including work, during transport and leisure-time for at least 150 minutes of moderate-intensity activity per week or 75 minutes of vigorous-intensity activity per week [46].

Outcome variables

In WHO SAGE, anthropometric measurements of body weight, height, and waist circumference of respondents were taken by trained interviewers using a weighing scale, stadiometer and Gulick measuring tape following standard protocols [31]. BMI was calculated as a person's weight in kilograms divided by the square of their height in meters and obesity was defined using cut-offs following the WHO classification. BMI was classified into four categories and weighted prevalence estimated: underweight, BMI$<$18.50 kg/m^2; normal/healthy weight, BMI$\geq$18.50$<$25.00 kg/m^2; overweight, 25.00$<$30.00 kg/m^2; and obese as BMI$\geq$30.00 kg/m^2 [47]. From the measured waist circumference, high central adiposity was determined using sub-Saharan Africa standards as waist circumference $\geq$81.2 cm for men, and $\geq$80.0 cm for women [48].

Statistical analysis

Accounting for the complex survey design, survey weights were used to estimate age- and sex-specific prevalence of obesity and of high central adiposity. From the cross-sectional datasets, we tested whether the frequency of distribution of the categories of BMI and central adiposity were identical in each wave using the survey Pearson's chi-squared (X^2) test. The absolute and percentage differences in the frequency of each category of BMI and central adiposity between the two waves were calculated for males, females, and both sexes. The categories of BMI and central adiposity were cross-tabulated against the socio-demographic and behavioral factors in S1 and S2 Figs. We fitted survey multinomial and binomial logistic models to estimate odds ratios (OR) and their 95% confidence intervals (CI) of the weight status outcome with sociodemographic and behavioural factors.

The characteristics of the sample are presented in Table 1. Table 2 shows the prevalence, absolute and percentage differences in prevalence. In Tables 3 and 4, the univariable and multivariable regression results are presented in a corresponding manner. BMI categories and central adiposity were the outcome variables whiles the explanatory variables included were age, sex, educational and marital statuses, location of residence, household wealth, smoking and alcohol consumption statuses, fruit and vegetable intake, and total physical activities. Statistical analysis was performed in STATA 15, and a two-tailed *p value*$<$0.05 was determined as statistically significant.

Results

In total, 4,158 persons (52% males) provided complete data in 2007/08 whilst 1,663 new persons (41% males) did so in 2014/15. Table 1 presents the estimated frequencies of the characteristics of the study population in 2007/08 and 2014/15. The population in 2014/15 was estimated to be around five years younger and 3.1kg heavier. Particularly for women, the proportion in the overweight/obese and high central adiposity categories were also higher in 2014/15.

The overall age- and sex-specific weighted prevalence of each BMI category and of high central adiposity in the repeated cross-sectional data are shown in Table 2. Relative to 2007/08, the 2014/15 prevalence of overweight (2007/08 = 19.6%; 95% CI: 18.0–21.4%; 2014/15 = 24.5%; 95% CI: 21.7–27.5%) and obesity (2007/08 = 10.2%; 95% CI: 8.9–11.7%; 2014/15 = 15.0%; 95% CI: 12.6–17.7%) was higher. Obesity increased by about 47% while overweight increased by approximately 25% in the population. More than half of the population had high central adiposity in both waves (2007/08 = 57.7%; 95% CI: 55.4–60.1%; 2014/15 = 66.9%; 95% CI: 63.7–70.0%) with about a 16% increase over the 7 to 8-year period. Underweight reduced by about 43% in the population. In 2014/15, despite a decline in the prevalence of obesity for males (2007/08 = 6.7%; 95% CI: 5.6–8.4%; 2014/15 = 5.6%; 95% CI: 3.4–8.8%), the prevalence of overweight was high for males (2007/08 = 18.3%; 95% CI: 16.2–20.6%; 2014/15 = 23.5%; 95% CI: 18.6–29.2%); and the prevalence of both overweight (2007/08 = 21.1%; 95% CI: 18.9–23.5%; 2014/15 = 25.2%; 95% CI: 22.4–28.2%) and obesity (2007/08 = 13.9%; 95% CI: 11.8–

Table 1. Characteristics of older people (50+ years) with complete responses in repeated cross-sectional data from WHO SAGE 2007/08 & 2014/15.

		Males	Females
2007/08 (n = 4158)			
n		52.7% (2191)	47.3% (1967)
Mean age, y		64.3 (10.8)	64.2 (10.5)
Mean weight (kg)		62.5 (13.8)	59.7 (15.8)
Mean height (m)		1.66 (8.42)	1.58 (7.42)
Mean waist circumference (cm)		83.3 (12.0)	86.4 (13.5)
‡Central Adiposity (WC ≥ optimal cut-point)		50.0% (1090)	66.6% (1317)
Mean BMI (kg/m^2)		22.8 (5.1)	24.0 (6.0)
BMI Categories	Underweight	15.1% (329)	15.2% (301)
	Normal BMI	59.7% (1302)	49.8% (985)
	Overweight	18.3% (399)	21.1% (417)
	Obese	6.9% (150)	13.9% (275)
2014/15 (n = 1663)			
n		41.0% (682)	59.0% (981)
Mean age, y		58.2 (8.4)	59.5 (9.1)
Mean weight (kg)		64.6 (11.5)	64.1 (16.3)
Mean height (m)		1.67 (7.78)	1.58 (7.51)
Mean waist circumference (cm)		82.4 (12.9)	89.7 (18.6)
‡Central Adiposity (WC ≥ optimal cut-point)		54.4% (370)	75.6% (742)
Mean BMI (kg/m^2)		23.1 (3.8)	25.8 (6.7)
BMI Categories	Underweight	9.7% (66)	7.9% (77)
	Normal BMI	61.2% (418)	45.4% (446)
	Overweight	23.5% (160)	25.2% (247)
	Obese	5.6% (38)	21.5% (211)

All are weighted estimates. Data are mean (standard deviation) for continuous variables and percentages (sample, n) for categorical variables. BMI indicates body mass index; and WC, waist circumference.

‡ sub-Sahara waist circumference optimal cut-off points for men (WC≥81.2cm) and women (WC≥80.0cm).

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16.4%; 2014/15 = 21.5%; 95% CI: 18.3–25.2%) were higher for females. The prevalence of high central adiposity was higher in 2014/15 for both males and females (Table 2).

The distribution of prevalence of the BMI categories by socio-demographic and behavioral factors in 2007/08 and 2014/15 are shown in S1 and S2 Figs. Generally, the prevalence of obesity was high in individuals who resided in urban areas and those from households with high/higher wealth status in both waves. While obesity was high in 2007/08 among those with high education, in 2014/15 it was rather high among both males and females with low education. Obesity was low among females who met the recommended physical activity level in both waves.

Results from the univariable analyses are presented in Table 3. In the multivariable analyses in 2007/08, being female (overweight: OR = 1.47, 95% CI: 1.15–1.89; obesity: OR = 2.49, 95% CI: 1.74–3.55; and high central adiposity: OR = 2.03, 95% CI: 1.64–2.51), living in an urban area (obesity: OR = 2.01, 95% CI: 1.41–2.86; and high central adiposity: OR = 1.51, 95% CI: 1.19–1.92) and those from households with moderate, higher or higher wealth (overweight: OR = 4.42, 95% CI: 2.84–6.89; obesity: OR = 4.91, 95% CI: 2.41–10.17; and high central adiposity: OR = 3.70, 95% CI: 1.22–6.85) were associated with higher odds of overweight, obesity and central adiposity (Table 4). However, being in age group 70+ years (overweight: OR = 0.70,

Table 2. Age- and sex-specific prevalence (95% confidence interval) of body mass index (BMI) categories and high central adiposity (WC ≥ optimal cut-off point) for older people in Ghana using data from 2007/08 (n = 4150) and 2014/15 (n = 1663) of SAGE (All subjects with complete responses used from the repeated cross-sections).

		Underweight	Normal weight	Overweight	Obese		‡High Central Adiposity	
		*Pr (95% CI)	Pr (95% CI)	Pr (95% CI)	Pr (95% CI)	*P* Value	Pr (95% CI)	*P* Value
Total Sample	2007/08	15.2 (13.6, 16.8)	55.0 (52.8, 57.2)	19.6 (18.0, 21.4)	10.2 (8.9, 11.7)	<0.001	57.7 (55.4, 60.1)	<0.001
	2014/15	8.6 (7.1, 10.3)	51.9 (48.8, 55.0)	24.5 (21.7, 27.5)	15.0 (12.6, 17.7)		66.9 (63.7, 70.0)	
Absolute difference (95% CI)		-6.6 (-8.6, -4.4)	-3.1 (-6.7, -1.0)	4.9 (1.6, 8.1)	4.8 (2.0, 7.6)		9.2 (5.5, 12.8)	
% difference (95% CI)		-43.4 (-52.9, -31.2)	-5.6 (-11.8, 1.0)	25.0 (9.1, 42.7)	47.1 (21.6, 76.9)		15.9 (10.0, 22.0)	
Males: Age, y -specific prevalence (2007/08, n = 2180; 2014/15, n = 682)								
50–59	2007/08	11.2 (9.0, 13.9)	60.3 (56.3, 64.1)	21.0 (17.9, 24.5)	7.5 (5.8, 9.8)	0.155	51.0 (46.9, 55.1)	0.252
	2014/15	6.7 (4.3, 10.5)	61.4 (54.9, 67.5)	25.5 (19.5, 32.7)	6.3 (3.6, 10.8)		55.0 (48.6, 61.3)	
60–69	2007/08	14.1 (11.2, 17.7)	62.3 (57.8, 66.5)	16.7 (13.6, 20.4)	6.9 (4.9, 9.5)	0.326	48.7 (43.8, 53.7)	0.323
	2014/15	18.2 (11.5, 27.6)	58.0 (48.1, 67.4)	20.3 (13.3, 29.6)	3.5 (1.5, 8.1)		54.2 (44.3, 63.8)	
≥ 70	2007/08	21.0 (17.0, 25.5)	56.7 (51.9, 61.4)	16.3 (12.8, 20.4)	6.1 (4.0, 9.1)	0.607	49.2 (43.9, 54.7)	0.158
	2014/15	16.0 (9.4, 25.9)	65.5 (54.4, 75.1)	14.8 (8.9, 23.5)	3.8 (1.6, 8.8)		50.9 (41.0, 60.7)	
Total Male sample	2007/08	15.1 (13.3, 17.2)	59.7 (57.0, 62.3)	18.3 (16.2, 20.6)	6.7 (5.6, 8.4)	0.022	49.8 (46.8, 52.8)	0.117
	2014/15	9.7 (7.4, 12.8)	61.2 (56.2, 66.1)	23.5 (18.6, 29.2)	5.6 (3.4, 8.8)		54.4 (49.2, 59.5)	
Absolute difference (95% CI)		-5.4 (-8.6, 2.2)	1.5 (-4.0, 7.1)	5.2 (-0.5, 10.8)	-1.1 (-4.4, 1.7)		4.6 (-1.1, 10.4)	
% difference (95% CI)		-35.8 (-52.2, -13.4)	2.5 (-7.0, 13.3)	28.4 (2.4, 64.1)	-16.4 (-51.0, 33.0)		9.2 (-2.3, 22.1)	
Females: Age, y -specific prevalence (2007/08, n = 1398; 2014/15, n = 981)								
50–59	2007/08	9.7 (7.1, 13.2)	45.7 (40.8, 50.6)	24.7 (20.7, 29.1)	20.0 (16.0, 24.6)	0.012	70.6 (66.5, 74.5)	0.014
	2014/15	5.2 (3.7, 7.2)	42.6 (38.2, 47.2)	26.3 (22.7, 30.3)	25.8 (21.6, 30.6)		77.7 (73.3, 81.5)	
60–69	2007/08	12.2 (9.2, 16.1)	53.3 (48.1, 58.5)	22.1 (18.5, 26.2)	12.3 (9.8, 15.5)	0.125	69.6 (64.1, 74.6)	0.389
	2014/15	8.5 (5.3, 13.2)	51.1 (43.6, 58.5)	21.5 (16.6, 27.3)	18.9 (13.0, 26.8)		73.5 (65.7, 80.1)	
≥ 70	2007/08	24.3 (13.0, 19.3)	51.8 (47.4, 56.1)	15.9 (13.0, 19.3)	8.0 (5.8, 10.8)	0.042	59.1 (54.1, 63.9)	0.017
	2014/15	17.9 (12.6, 24.7)	49.1 (41.4, 56.8)	25.5 (18.5, 33.9)	7.6 (4.3, 13.1)		69.8 (62.1, 76.6)	
Total Female Sample	2007/08	15.2 (13.1, 17.5)	49.8 (46.7, 52.8)	21.1 (18.9, 23.5)	13.9 (11.8, 16.4)	<0.001	66.6 (63.6, 69.4)	<0.001
	2014/15	7.9 (7.9, 10.8)	45.4 (41.7, 49.1)	25.2 (22.4, 28.2)	21.5 (18.3, 25.2)		75.6 (71.9, 78.9)	
Absolute difference (95% CI)		-7.3 (-10.0, -4.7)	-4.4 (-8.9, 0.1)	4.1 (0.3, 7.9)	7.6 (3.7, 11.5)		9.0 (4.7, 13.3)	
% difference (95% CI)		-48.0 (-59.4, -34.0)	-8.8 (-16.7, -0.1)	19.4 (2.5, 39.1)	54.7 (26.8, 88.3)		13.5 (7.7, 19.6)	

*Pr (95% CI) means prevalence (95% confidence intervals). All are weighted estimates.

‡High central adiposity measured using sub-Sahara high waist circumference cut-off point for men (WC≥81.2cm) and women (WC≥80.0cm)

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95% CI: 0.54–0.90; obesity: OR = 0.54, 95% CI: 0.36–0.80), currently smoking status (overweight: OR = 0.54, 95% CI: 0.35–0.83; and high central adiposity: OR = 0.69, 95% CI: 0.53–0.90), and current alcohol drinking (overweight: OR = 0.64, 95% CI: 0.50–0.82) were associated with lower odds of overweight/obesity. Also, being in the 70+ years age group (underweight: OR = 2.21, 95% CI: 1.73–2.84) and currently smoking status (underweight: OR = 1.63, 95% CI: 1.18–2.25) were associated with higher odds of underweight while the odds of underweight was low among those with high/higher household wealth. In 2014/15, most associations found in 2007/08 remained the same with minimal changes in magnitude.

An interaction term between the age categories and sex in a multivariable regression showed that the product of age and sex were not significantly associated with the BMI categories for all age groups in both 2007/08 and 2014/15 except for females between the age of 50–59 years in whom there was a significant association for higher odds of obesity (OR = 2.67; 95% CI: 1.34–5.30) in 2007/08. The same interaction using central adiposity as the outcome also revealed significantly higher odds of high central adiposity among females aged 50–59

Table 3. Univariable regressions: Factor associated with BMI categories and central adiposity in year WHO-SAGE 2007/08 and 2014/15.

		Year 2007/08			Year 2014/15			Year 2007/08	Year 2014/15
		Underweight	Overweight	Obese	Underweight	Overweight	Obese	High Central Adiposity	High Central Adiposity
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age Groups, y	50–59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	60–69	1.17 (0.88, 1.53)	0.78 (0.62, 0.98) *	0.66 (0.48, 0.89) **	1.95 (1.21, 3.16) **	0.77 (0.55, 1.07)	0.73 (0.45, 1.18)	0.94 (0.79, 1.12)	0.94 (0.70, 1.26)
	≥ 70	2.11 (1.66, 2.69) ***	0.70, (0.56, 0.87) **	0.51 (0.36, 0.74) ***	2.76 (1.70, 4.49) ***	0.79 (0.53, 1.18)	0.35 (0.20, 0.60) ***	0.77 (0.65, 0.93) **	0.84 (0.63, 1.12)
Sex	Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female	1.20 (0.97, 1.49)	1.39 (1.13, 1.68) **	2.42 (1.84, 3.20) ***	1.09 (0.75, 1.58)	1.45 (1.05, 2.00) *	4.22 (3.14, 8.70) ***	2.01 (1.72, 2.34) ***	2.59 (1.97, 3.40) ***
Educational Status	Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	High	0.80 (0.62, 1.03)	1.38 (1.10, 1.74)	2.14 (1.61, 2.84)	2.43 (1.42, 4.14) **	0.98 (0.67, 1.43)	0.80 (0.53, 1.21)	1.57 (1.30, 1.91)	0.76 (0.55, 1.06)
Marital status	Single	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Married/ cohabiting	0.56 (0.27, 1.17)	1.65 (0.78, 3.49)	1.11 (0.41, 2.98)	1.14 (0.21, 3.31)	1.84 (0.69, 4.85)	0.87 (0.28, 2.73)	1.07 (0.64, 1.80)	0.98 (0.49, 1.96)
	Widow/ divorce	0.79 (0.39, 1.60)	1.59 (0.75, 3.38)	1.72 (0.69, 4.31)	1.65 (0.29, 4.45)	1.18 (0.44, 3.18)	0.95 (0.29, 3.08)	1.48 (0.89, 2.46)	0.98 (0.50, 1.93)
Location	Rural	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Urban	0.62 (0.47, 0.82) **	2.32 (1.82, 2.97) ***	4.06 (2.56, 7.20) ***	0.47 (0.29, 0.78) **	1.89 (1.36, 2.61) ***	3.47 (2.14, 5.62) ***	2.61 (2.05, 3.32) ***	2.35 (1.73, 3.19) ***
Wealth Index	Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Low	0.84 (0.60, 1.16)	1.73 (1.20, 2.51) **	2.76 (1.29, 5.89) **	1.08 (0.65, 1.79)	1.13 (0.64, 1.99)	1.43 (0.43, 3.73)	1.60 (1.27, 2.02) ***	1.49 (0.99, 2.23)
	Moderate	0.70 (0.52, 0.95) *	2.56 (1.76, 3.72) ***	3.25 (2.04, 6.82) ***	1.43 (0.78, 2.63)	2.00 (1.18, 3.40) *	3.72 (1.98, 6.87) **	2.06 (1.59, 2.66) ***	2.24 (1.44, 3.48) ***
	High	0.70 (0.48, 1.01)	2.66 (1.81, 3.91) ***	3.92 (2.32, 7.44) ***	0.88 (0.46, 1.65)	2.56 (1.53, 4.28) ***	4.26 (2.81, 8.25) ***	2.40 (1.84, 3.12) ***	2.78 (1.75, 4.41) ***
	Higher	0.34 (0.21, 0.54) ***	4.26 (2.33, 7.05) ***	4.94 (2.46, 9.54) ***	0.28 (0.31, 0.60) **	3.27 (1.92, 5.58) ***	5.17 (3.07, 10.10) ***	3.95 (2.80, 6.90) ***	3.84 (2.37, 6.22) ***
Smoking status	Never Smoked	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	0.99 (0.71, 1.40)	0.77 (0.57, 1.05)	0.37 (0.23, 0.60) ***	1.58 (0.50, 3.01)	1.08 (0.40, 2.92)	1.84 (0.31, 4.98)	0.97 (0.76, 1.25)	1.02 (0.36, 2.91)
	Currently smoke	1.78 (1.33, 2.38) ***	0.32 (0.22, 0.47) ***	0.34 (0.17, 0.68) **	1.87 (0.88, 3.97)	0.18 (0.07, 0.48) **	0.18 (0.04, 0.81) *	0.67 (0.55, 0.80) ***	0.23 (0.13, 0.41) ***
Alcohol Consumption Status	Never drunk alcohol	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	0.88 (0.64, 1.21)	0.76 (0.56, 1.03)	1.00 (0.70, 1.44)	0.90 (0.43, 1.91)	0.54 (0.30, 0.98) *	1.57 (0.82, 3.01)	0.59 (0.47, 0.73) ***	1.84 (1.03, 3.27) *
	Currently Drinks	1.18 (0.93, 1.51)	0.57 (0.45, 0.71) ***	0.75 (0.55, 1.02)	0.94 (0.58, 1.51)	0.64 (0.42, 0.97) *	0.69 (0.38, 1.26)	0.37 (0.28, 0.47) ***	0.69 (0.49, 0.96) *
Fruit & Vegetable Intake	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.86 (0.66, 1.12)	1.17 (0.95, 1.42)	1.32 (1.02, 1.72) *	0.57 (0.39, 0.84) **	1.23 (0.91, 1.67)	1.32 (0.91, 1.92)	1.61 (1.32, 1.96) ***	1.27 (0.95, 1.71)

(*Continued*)

Table 3. (Continued)

		Year 2007/08			Year 2014/15			Year 2007/08	Year 2014/15
		Underweight	Overweight	Obese	Underweight	Overweight	Obese	High Central Adiposity	High Central Adiposity
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Total Physical Activity	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.85 (0.67, 1.08)	0.88 (0.71, 1.10)	0.64 (0.47, 0.87) **	1.05 (0.72, 1.54)	0.85 (0.62, 1.17)	0.81 (0.55, 1.19)	0.76 (0.63, 0.92) **	0.84 (0.63, 1.11)

*p<0.05

**p<0.01

****p<0.001;* Fruit & Vegetable Intake (serving per day); Total Physical Activity (Minutes per week); Year is the year for completion of data collection

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years (OR = 1.69; 95% CI: 1.10–2.58) and 60–69 years (OR = 1.54; 95% CI: 1.06–2.25) only in 2007/08. We also examined whether respondents sex modified the association between physical activity and BMI categories and central adiposity. No significant associations were found in 2007/08. However, in 2014/15, not meeting the recommended physical activity level among females was associated with higher odds of obesity (OR = 3.23; 95% CI: 1.13–6.23) and high central adiposity (OR = 2.19; 95% CI: 1.32–3.63).

Discussion

This study estimated changes in the prevalence and determinants of BMI and central adiposity in the older adult population of Ghana between year and 2007/08 and 2014/15. We found that over the 7 to 8-year period the prevalence of obesity had increased by 47%, overweight by 25%, but underweight reduced by 43%. However, we found heterogeneity by sex with females showing a 55% increase in the prevalence of obesity compared with a 16% reduction among males over the same period. While we provide estimates of the temporal change in BMI categories and high central adiposity for the total population (males and females combined), there are reasons why the sex-stratified estimates should be prioritised. First, as the ratio of males to females reduced between waves, the estimates for the secular changes at the population level are weighted toward females. Second, we observed a sex difference in the temporal change in obesity where males decreased, and females increased from 2007/08 to 2014/15. Being female, living in an urban area and having high household wealth were associated with higher odds of obesity/high central adiposity while those aged 70+ years was associated with lower odds of obesity. Additionally, in 2014/15, not meeting the recommended physical activity among females was associated with higher odds of obesity and central adiposity.

Our findings show that while the prevalence of underweight reduced over the period, overweight, obesity and central adiposity increased over the same period. The increased prevalence of overweight, obesity (in females) and central adiposity could have a negative public health implication as obesity buttresses the increasing burden of NCDs in most low-and middle-income countries. Even though most previous studies in sub-Saharan Africa were cross-sectional studies, most of the studies found a higher prevalence of overweight/obesity in the female population compared to their male counterparts [19, 22, 49, 50]. This phenomenon has been attributed to the body preference of most females [19, 50–53]. However, a recent study of African-Americans suggested that being male with West-African ancestry genes could be protective against obesity specifically, high central adiposity and hence could be a reason for the male/female disparities [54]. Furthermore, high odds of overweight/obesity among African

Table 4. Multivariable regressions: Predictors of overweight, obesity and central adiposity in year WHO-SAGE 2007/08 and 2014/15.

		Year 2007/08			Year 2014/15			Year 2007/08	Year 2014/15
		Underweight	Overweight	Obese	Underweight	Overweight	Obese	High Central Adiposity	High Central Adiposity
		OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age Groups, y	50–59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	60–69	1.17 (0.88, 1.55)	0.79 (0.61, 1.10)	0.67 (0.49, 0.91) *	1.94 (1.19, 3.18) **	0.77 (0.55, 1.09)	0.59 (0.36, 0.97) *	1.01 (0.83, 1.23)	0.93 (0.71, 1.22)
	≥ 70	2.21 (1.73, 2.84) ***	0.70, (0.54, 0.90) **	0.54 (0.36, 0.80) **	2.45 (1.49, 4.04) ***	0.87 (0.57, 1.31)	0.34 (0.18, 0.62) **	0.86 (0.70, 1.07)	0.94 (0.68, 1.29)
Sex	Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Female	1.23 (0.88, 1.71)	1.47 (1.15, 1.89) **	2.49 (1.74, 3.55) ***	0.81 (0.52, 1.26)	1.70 (1.16, 2.49) **	4.65 (2.65, 9.09) ***	2.03 (1.64, 2.51) ***	3.36 (2.42, 4.68) ***
Educational Status	Low	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	High	1.34 (1.02, 1.78) *	0.97 (0.73, 1.28)	1.15 (0.83, 1.60)	1.86 (1.00, 3.42)	1.22 (0.80, 1.86)	0.94 (0.61, 1.46)	1.17 (0.93, 1.47)	0.74 (0.49, 1.14)
Marital status	Single	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Married/ cohabiting	0.60 (0.29, 1.23)	2.00 (0.92, 4.35)	1.60 (0.64, 3.96)	1.17 (0.17, 2.93)	2.25 (0.81, 4.21)	1.61 (0.63, 4.11)	1.25 (0.69, 2.25)	1.54 (0.69, 3.43)
	Widow/ divorce	0.74 (0.37, 1.08)	1.50 (0.68, 3.31)	1.65 (0.69, 3.95)	1.39 (0.19, 3.94)	1.20 (0.44, 3.28)	1.11 (0.43, 2.84)	1.16 (0.67, 2.02)	1.10 (0.46, 2.23)
Location	Rural	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Urban	0.79 (0.57, 1.08)	1.44 (1.08, 1.92) *	2.01 (1.41, 2.86) ***	0.53 (0.32, 0.87) *	1.38 (0.96, 1.98)	1.73 (1.03, 2.89) *	1.51 (1.19, 1.92) **	1.91 (1.33, 2.74) **
Wealth Index	Lowest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Low	0.87 (0.62, 1.21)	1.52 (1.05, 2.21) *	2.40 (1.13, 5.13) *	1.12 (0.65, 1.91)	1.13 (0.66, 1.95)	1.53 (0.45, 3.21)	1.31 (1.02, 1.69) *	1.43 (0.93, 2.20)
	Moderate	0.77 (0.51, 1.17)	2.01 (1.33, 3.04) **	3.17 (1.50, 6.68) **	1.91 (1.04, 3.50) *	2.03 (1.16, 3.55) *	3.17 (1.87, 6.31) **	1.56 (1.18, 2.07) **	1.66 (1.02, 2.69) *
	High	0.71 (0.51, 0.97) *	2.15 (1.46, 3.16) ***	3.79 (1.96, 7.93) ***	1.20 (0.68, 2.67)	2.57 (1.50, 4.42) **	3.76 (2.27, 7.28) ***	1.57 (1.16, 2.11) **	2.33 (1.42, 3.81) **
	Higher	0.40 (0.23, 0.68) **	4.42 (2.84, 6.89) ***	4.91 (2.41, 10.17) ***	0.52 (0.22, 1.21)	3.29 (1.89, 5.74) ***	4.67 (2.39, 8.53) ***	3.70 (3.22, 6.85) ***	2.45 (1.39, 4.32) **
Smoking status	Never Smoked	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	1.08 (0.74, 1.57)	0.92 (0.68, 1.26)	0.53 (0.30, 0.92) *	1.68 (0.50, 3.64)	1.73 (0.61, 4.95)	3.48 (0.86, 6.19)	0.77 (0.59, 0.10)	1.06 (0.43, 2.60)
	Currently smoke	1.63 (1.18, 2.25) **	0.54 (0.35, 0.83) **	0.88 (0.46, 1.69)	1.66 (0.69, 4.00)	0.31 (0.11, 0.90) *	0.48 (0.10, 2.23)	0.69 (0.53, 0.90) **	0.44 (0.22, 0.88) *
Alcohol Consumption Status	Never drunk alcohol	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Quitter	0.88 (0.63, 1.23)	0.71 (0.51, 0.97)*	0.85 (0.57, 1.29)	0.68 (0.32, 1.43)	0.56 (0.30, 1.06)	1.47 (0.64, 3.38)	0.96 (0.74, 1.24)	2.52 (1.38, 4.59) **
	Currently Drinks	1.19 (0.93, 1.54)	0.64 (0.50, 0.82) ***	0.95 (0.68, 1.31)	0.91 (0.56, 1.49)	0.78 (0.48, 1.27)	1.21 (0.70, 2.08)	0.86 (0.72, 1.03)	1.11 (0.78, 1.58)
Fruit & Vegetable Intake	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.98 (0.75, 1.27)	1.05 (0.85, 1.29)	1.16 (0.90, 1.49)	0.57 (0.37, 0.86) **	1.16 (0.85, 1.60)	1.25 (0.82, 1.90)	1.51 (1.23, 1.84) ***	1.27 (0.92, 1.72)
Total Physical Activity	Below requirement	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Met requirement	0.81 (0.64, 1.02)	1.01 (0.80, 1.27)	0.78 (0.57, 1.08)	1.12 (0.73, 1.71)	0.82 (0.59, 1.14)	0.72 (0.49, 1.08)	0.82 (0.67, 0.99) *	0.89 (0.66, 1.20)

*p<0.05

**p<0.01

****p<0.001;* Fruit & Vegetable Intake (serving per day); Total Physical Activity (Minutes per week); Year is the year for completion of data collection

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females in many parts of sub-Saharan Africa and elsewhere, have also been largely attributed to general cultural preference in which overweight/obesity is regarded as a source of beauty and a sign of affluence [49, 52]. In Ghana, this could also be attributed to generally low levels of physical activities in the population [49, 55]. This corroborates our finding that low physical activities in females was associated with higher odds of obesity and central adiposity suggesting that promotion of physical activity may support efforts to reduce obesity in females in Ghana as in other population [28, 56].

Overweight and obesity prevalence in both waves was high in females in all age groups with a decline noted after age 59 years. In males, we observed non-significant declines for obesity and increases for high central adiposity across all age groups. The observed difference in trends for obesity and high central adiposity in males was unexpected but could be attributed to the following reasons. First, the differences could reflect where the respective cut-offs for BMI and waist circumference lie on their distributions. As shown in Table 2, whereas about half of the male population had high central adiposity, less than 10% were obese in both waves. Second, this difference could also reaffirm that BMI may not be as sensitive to changes in excess adiposity compared with waist circumference [57].

While obesity prevalence was found to generally increase with age in some developed countries, in most developing countries, it was found to peak around age 50 years, then decline afterward [58]. In this study, a decline in obesity prevalence rates was found after age 59 years in females. Such trends may demand deliberate attention as those aged over 50 years supply the majority of the labour force for agricultural productivity, which has played a major role in sustainable development and poverty reduction in Ghana [26]. Increased obesity prevalence in this age group may lead to higher NCDs and consequently increase overall mortality as well as increasing the medical cost of care [12]. This can further lead to increased absenteeism from work and reduced work productivity, negatively impacting the economy [12, 59].

Urban residency was also associated with higher odds of overweight/obesity and central adiposity in both waves. Residing in an urban area has shown a similar association with obesity in previous studies in Africa and elsewhere [19]. Urban residency is mostly associated with changes in diets and food availability, increased dependence on mechanized transportation, especially in older people coupled with an increasingly sedentary lifestyle and the loss or lack of open and safe places for physical activities [37, 60]. Dietary transition from nutritious foods to the consumption of easily accessible cheap calorie-dense foods as well as longer hours spent on buses and in cars in traffic may have been key drivers of increasing obesity prevalence in urban areas [55, 60, 61], and this is likely to be the same in Ghana. Older people, especially those over the ages 65 years, tend to rely heavily on their children and grandchildren for activities of daily living [62]. These activities include food preparation and timely food supply. These children, who may be busy on the labour market, may be restricted in their ability to prepare home-made foods for them. They may, therefore, resort to purchasing calorie-dense fast-foods. It is also possible that the reliance on others for food sources/preparation amongst those aged over 70 years may contribute to loss of weight, which agrees with our finding that those aged 70+ years had higher odds of underweight.

The finding that high household wealth is associated with higher odds of overweight/obesity and central adiposity in both waves in this population concurs with findings in other low- and middle-income countries [49, 63]. Our finding is the opposite of what is observed in most developed countries where individuals from socioeconomic disadvantaged households tend to be at increased risk of obesity [64, 65]. Household wealth, a proxy for household income, was expected to have a positive impact resulting in good health outcomes for the individuals within a household as it has been in most developed countries [64]. Our findings support Philipson and Posner's [63] argument that income has a positive impact on weight in less-developed economies; however, as economic development improves, this relationship tends to become negative in the long term. It is suspected that because rich households in LMICs can afford many varieties of foods, increased household wealth could potentially contribute to changes in food preference, increased food consumption and poor choices regarding dietary intake [66].

As part of lifestyle factors, our finding that smoking was associated with lower odds of overweight has been found in previous studies where current smokers were less likely to have increased body weight compared to those who have never smoked before [67]. In 2007/08 quitting smoking was associated with lower odds of obesity however in 2014/15, currently smoking was rather associated with lower odds of overweight which agrees with previous findings in a randomized control trial [68]. As our findings are from repeated cross-sectional studies, we are unable to confer causality. Further studies are necessary to confirm the strength and direction of the association.

This study has several strengths. First, missing from the extant literature is a study that tracks trends in obesity prevalence among older adults in Ghana. We used the most current data to measure prevalence, changes in prevalence and factors associated with overweight/obesity among older adults about whom little is known in sub-Saharan Africa. Second, the prevalence estimates will be useful in establishing and predicting the future economic burden of obesity on health in this population. Third, the inclusion of waist circumference, a marker of central adiposity and a prime marker of cardiometabolic diseases, provides added confirmation of our findings. Finally, the use of a population-based data that is representative of the older adult population, and uses objectively measured rather than self-reported weight, height, and waist circumference to determine obesity in the population are major strengths.

This study had some limitations. First, given that this study uses data from cross-sectional studies, results focused on associations and not causality [49]. Second, the study focuses only on those who were 50 years and above and does not cover the entire population. Therefore, conclusions from this study is limited to the population of 50 years and above. Finally, although the data is representative of the population aged 50 years and over, the analysis omits observations with missing data (13% in 2007/08 and 4.8% in 2014/15) on variables such as weight, height and waist circumference. Hence, there is a chance for selection bias to be introduced that might have affected external validity. However, the analytical sample was large, and the use of the post-stratified persons' weight supported the analysis.

Conclusion

We found a decline in underweight among Ghanaian older adults, an increase in overweight among males and females, and an increase in obesity among females only. The Ghana NCDs management strategy 2012–2016 focused on reducing by 2% the overweight and obesity prevalence in females age 15-49years, neglecting those aged 50+ years. However, the exponential increase in the current estimates of overweight and obesity prevalence suggest the need for policy initiatives aimed at reducing overweight and obesity, especially among females aged 50 + years and the importance of advancing surveillance. This study also identifies some factors associated with high obesity prevalence such as being female, living in an urban area and having high household wealth that could inform prevention and intervention programs in improving the health and well-being of older adult populations in sub-Saharan Africa.

Supporting information

S1 Fig. Distribution of underweight, overweight and obesity by socio-demographic factors in the older adult population of Ghana in 2007/08 and 2014/15.
(DOCX)

S2 Fig. Distribution of underweight, overweight and obesity by behavioral factors in the older adult population of Ghana in 2007/08 and 2014/15.
(DOCX)

S1 File. Prevalence STROBE statement.
(DOCX)

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Appendix 3. Publication of Chapter 4

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Patient-Reported Outcomes

Evaluation of the Association Between Health State Utilities and Obesity in Sub-Saharan Africa: Evidence From World Health Organization Study on Global AGEing and Adult Health Wave 2

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ABSTRACT

Background: Obesity is a major public health challenge and its prevalence has increased across the age spectrum from 1980 to date in most parts of the world including sub-Saharan Africa. Studies that derive health state utilities (HSUs) stratified by weight status to support the conduct of economic evaluations and prioritization of cost-effective weight management interventions are lacking in sub-Saharan Africa.

Objectives: To estimate age- and sex-specific HSUs for Ghana, along with HSUs by weight status. Associations between HSUs and overweight and obesity will be examined.

Study Design: Cross-sectional survey of the Ghanaian population.

Methods: Data were sourced from the World Health Organization Study of Global AGEing and Adult Health (WHO SAGE), 2014 to 2015. Using a "judgment-based mapping" method, responses to items from the World Health Organization Quality-of-Life (WHOQOL-100) used in the WHO SAGE were mapped to EQ-5D-5L profiles, and the Zimbabwe value set was applied to calculate HSUs. Poststratified sampling weights were applied to estimate mean HSUs, and a multivariable linear regression model was used to examine associations between HSUs and overweight or obesity.

Results: Responses from 3966 adults aged 18 to 110 years were analyzed. The mean (95% confidence interval) HSU was 0.856 (95% CI: 0.850, 0.863) for the population, 0.866 (95% CI: 0.857, 0.875) for men, and 0.849 (95% CI: 0.841, 0.856) for women. Lower mean HSUs were observed for obese individuals and with older ages. Multivariable regression analysis showed that HSUs were negatively associated with obesity (−0.024; 95% CI: −0.037, −0.011), female sex (−0.011; 95% CI: −0.020, −0.003), and older age groups in the population.

Conclusions: The study provides HSUs by sex, age, and body mass index (BMI) categories for the Ghanaian population and examines associations between HSU and high BMI. Obesity was negatively associated with health state utility in the population. These data can be used in future economic evaluations for Ghana and sub-Saharan African populations.

Keywords: health economic evaluations, health state utilities, obesity, sub-Saharan Africa, WHO SAGE Wave 2.

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Introduction

Overweight and obesity, hereafter referred to as high body mass index (BMI), has become a major public health challenge with increasing prevalence reported among adults aged 18 years and older in most parts of the world, including sub-Saharan Africa, between 1980 and 2014.[1] In particular, the prevalence of obesity among adults in urban West African populations has doubled over a period of 15 years since 1990,[2,3] an indication for the need to institute sustainable prevention and management measures. BMI is widely used to determine whether someone is in a healthy weight range for a given height. It is calculated as body mass (measured in kilograms) divided by the square of body height (measured in meters). The World Health Organization (WHO)

Conflict of interest: The authors declare that no competing interests exist.

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Table 1. Summary statistics of study participants in WHO-SAGE Wave 2 (2014-2015).

Number of participants	3966
BMI (kg/m^2)	25.1 (5.1)
BMI categories	
Normal BMI	59.5
Overweight	26.6
Obese	13.9
Age, years	40.2 (14.9)
Sex	
Males	44.8
Females	55.2
Age group	
18-49 years	77.8
50-64 years	15.0
65+ years	7.2
Education status	
Low	60.1
High	39.9
Marital status	
Married/cohabiting	59.5
Divorced/separated	15.5
Single	25.0
Place of residence	
Rural	47.9
Urban	52.1
Household wealth quintile	
Lowest	10.6
Low	17.0
Moderate	19.0
High	25.0
Highest	28.4
Smoking	
Never smoked	94.7
Quitted smoking	2.0
Currently smokes	3.3
Found to have chronic disease	
No	91.9
Yes	8.1

Note. All values are weighted. Data are mean (standard deviation) for continuous variables and percentages for categorical variables. BMI denotes body mass index calculated as weight in kilograms divided by squared height in meters.

Table 2. EQ-5D-5L dimensions (%) stratified by body mass index categories in the Ghanaian adult population (2014-2015).

EQ-5D-5L profiles	Normal weight	Over weight	Obese	Total
N	2468	960	538	3966
Mobility				
No problem	80.5	85.0	78.4	81.4
Slight problem	14.0	10.7	14.0	13.1
Moderate problem	4.2	3.4	5.5	4.2
Severe problem	1.2	1.0	2.1	1.3
Unable to do	0.2	0.0	0.2	0.1
Self-care				
No problem	88.3	93.8	93.8	90.2
Slight problem	9.5	5.2	5.2	8.0
Moderate problem	1.9	0.7	0.7	1.5
Severe problem	0.1	0.1	0.1	0.2
Unable to do	0.1	0.1	0.1	0.1
Usual activity				
No problem	79.0	83.7	81.5	80.6
Slight problem	14.5	9.8	9.4	12.5
Moderate problem	4.9	4.5	6.8	5.1
Severe problem	0.7	0.5	0.7	0.6
Unable to do	1.0	1.4	1.7	1.2
Pain/discomfort				
No problem	67.8	71.1	59.0	67.4
Slight problem	22.7	19.5	22.9	21.9
Moderate problem	7.7	6.9	14.4	8.4
Severe problem	1.4	2.2	3.6	1.9
Unable to do	0.3	0.3	0.2	0.3
Anxiety/depression				
No problem	72.5	78.6	77.1	74.8
Slight problem	19.8	14.3	15.5	17.7
Moderate problem	6.7	6.4	4.6	6.3
Severe problem	0.9	0.7	4.6	1.1
Unable to do	0.2	0.0	0.2	0.1

Note. All are weighted estimates.

defines overweight as a BMI $\geq$ 25.00 and $<$ 30.00 kg/m^2 and obesity as a BMI $\geq$ 30.00 kg/m^2.[4] Although high BMI is often regarded culturally as a source of beauty and a sign of affluence in some developing countries,[2,5] it is associated with many chronic diseases, including type 2 diabetes mellitus, hypertension, lipid disorders, osteoarthritis, gallbladder disease, strokes, some cancers, heart disease, and obstructive sleep apnoea in addition to reduced life expectancy.[6,7] Internationally, several studies have reported that high BMI has further been associated with a reduction in quality-adjusted life-years (QALYs) and a high economic burden owing to the associated medical and treatment costs.[8–10]

Health state utilities (HSUs) indicate the numerical strength of preference for a health state and are globally accepted as health-related quality of life weights.[11,12] Age- and sex-specific HSUs for a population can be used to calculate QALYs, a common measure of effectiveness used in cost-utility analyses (CUA).[13] CUA is a common approach used in health economic evaluations to inform and support decision making.[14] CUA is preferred over cost-effectiveness analysis (CEA) by many health economic evaluation entities because CUA allows for comparisons across different health interventions and diseases and incorporates more aspects of health and well-being.[14,15]

Several outcome measures can be used in CUA, including disability-adjusted life-years, health-adjusted life-years, healthy years equivalent, and QALYs.[13] QALYs, one of the most commonly used outcomes, combines HSUs with survival time. The HSU scale ranges from 0 (corresponding to death) to 1 (corresponding to perfect health), with negative values representing states worse than death.[13]

Preference-based measures for health outcomes are used to estimate HSUs with a prescored multi-attribute health status classifications system.[13,16,17] Nevertheless, generic preference-based measures are not often used in clinical trials of new therapies, and it is more common that a non–preference-based measure is adopted to measure the health status of interest. In this case, mapping or cross-walking from non–preference-based measure to preference-based measure can be used to statistically estimate the HSUs.[13,17–20] In recent times, many mapping models have been developed to estimate HSUs. These models use a range of statistical methods, including ordinary least squares, 2-part models, ordinal logit or multinomial logit regression models, cart analysis, and the censored least absolute deviation model.[17]

Table 3. Age- and sex-specific health state utilities (HSUs) using EQ-5D-5L in the adult population of Ghana.

Age group (years)	Males HSU (SD)				Females HSU (SD)
	(95% CI)				(95% CI)
	Normal weight	Overweight	Obese	Total	Normal weight
Total	0.866 (0.089) (0.857, 0.875)	0.867 (0.081) (0.853, 0.881)	0.849 (0.099) (0.815, 0.941)	0.866 (0.088) (0.858-0.874)	0.852 (0.092) (0.841-0.861)
18-29	0.895 (0.064) (0.884-0.906)	0.904 (0.022) (0.895-0.913)	0.900* *	0.896 (0.059) (0.887-0.906)	0.881 (0.072) (0.864-0.898)
30-39	0.891 (0.062) (0.875-0.907)	0.879 (0.068) (0.841-0.918)	0.861 (0.061) (0.786-0.935)	0.886 (0.064) (0.872-0.901)	0.870 (0.067) (0.854-0.887)
40-49	0.857 (0.090) (0.839-0.875)	0.876 (0.065) (0.853-0.899)	0.875* *	0.863 (0.082) (0.849-0.878)	0.855 (0.083) (0.835-0.876)
50-59	0.837 (0.097) (0.821-0.852)	0.840 (0.094) (0.813-0.866)	0.797 (0.162) (0.722-0.871)	0.834 (0.102) (0.819-0.850)	0.807 (0.101) (0.792-0.823)
60-69	0.822 (0.101) (0.809-0.836)	0.815 (0.102) (0.783-0.847)	0.832 (0.130) (0.764-0.899)	0.821 (0.102) (0.807-0.834)	0.793 (0.107) (0.775-0.810)
70+	0.763 (0.134) (0.743-0.782)	0.729 (0.176) (0.669-0.789)	0.715* *	0.766 (0.142) (0.736-0.775)	0.737 (0.132) (0.719-0.756)

Note. All are weighted estimates.
*Data in this age group were not enough to estimate standard deviation and confidence intervals. The subsample for obese males in age group 18-29 years (n = 1), 40-49 years (n = 7), and ≥70 years (n = 13).

Although HSUs are essential for CUA, they are lacking in most low- and middle-income countries, including sub-Saharan Africa, largely because preference-based measures have not been included in data collections.[21] In addition, the absence of algorithms and value sets has been a further barrier.[21] In such situations, algorithms and value sets from similar populations have previously been adopted as proxies for more precise local utilities.[9,20,22,23]

To achieve the Universal Health Coverage and the Sustainable Development Goal 3 on health, Ghana has identified the need to improve the quality and efficiency in its healthcare services to provide fair and equitable access to health.[24,25] Nevertheless, the lack of parameters, including those to measure effectiveness, has been a major challenge hindering the course of conducting health economic evaluations in the population,[26] hence the need to develop these parameters. Our study aims to address one aspect of this by providing HSU estimates for both the general population of Ghana and for BMI categories. HSU data for the general population can be used across a broad range of health economic evaluations in Ghana and similar countries that lack such data. This can be particularly useful when evaluating new interventions for which short-term trial data are available. As many health economic evaluations adopt medium- to long-term time horizons, estimates of general population HSUs can be used for the period after the trial. For example, in a cost-effectiveness analysis of intensive versus standard blood pressure control,[27] long-term HSUs were based on general population HSUs from the Medical Expenditure Panel Survey. Also, in the cost-effectiveness analysis of screening for osteoporosis in Chinese women, the age-specific HSUs for the female general population were retrieved from the National Health Services Survey 2008—a population-wide survey for the comparator.[28] As such, the HSUs reported in this study will be critical to future health economic evaluations in the Ghanaian population. Thus, our estimated HSUs are intended for use in a range of health economic models, including those that will simulate progression through the BMI health states to assess the impact of changing prevalence on clinical and economic outcomes.

HSUs may differ based on factors such as age, sex, and BMI status.[9,29,30] Generating these HSUs could differentiate the quality of life of men and women across different ages and BMI categories and hence improve the accuracy of the cost-effectiveness results. Thus, our study aims to derive the first age- and sex-specific HSUs and HSUs stratified by weight status (ie, healthy weight, overweight, obese) for Ghanaian adults. In addition, we examine the extent to which HSUs are associated with overweight and obesity.

Methods

Study Population

Data for persons aged ≥18 years from Wave 2 of the World Health Organization's Study on global AGEing and adult health (WHO SAGE) in Ghana were used.[31,32] Details on data can be found at http://www.who.int/healthinfo/sage/cohorts/en/. We used the GhanaINDDataW2 and GhanaHHDataW2. Briefly, SAGE collected individual-level data from nationally representative households of adults using a stratified, multistage cluster design. The primary sampling units were stratified by region and location of residence (urban/rural) with samples selected from 250 enumeration areas. This study used responses from the individual questionnaire in the individual dataset. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). Further information on WHO SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

Of the 4735 survey respondents, 229 had missing data for height, 227 for weight, and 207 for one or more EQ-5D-5L dimensions. Also, biologically implausible values (height <100 cm

Table 3. Continued

Females HSU (SD) (95% CI)			Total Mean HSU (SD) (95% CI)			
Overweight	Obese	Total	Normal weight	Overweight	Obese	Total
0.857 (0.081) (0.849-0.866)	0.831 (0.096) (0.815-0.847)	0.849 (0.090) (0.841-0.856)	0.860 (0.091) (0.852-0.867)	0.861 (0.081) (0.853-0.869)	0.834 (0.097) (0.818-0.849)	0.856 (0.090) (0.850-0.863)
0.890 (0.040) (0.879-0.901)	0.892 (0.031) (0.881-0.903)	0.885 (0.096) (0.875-0.896)	0.889 (0.068) (0.878-0.899)	0.894 (0.036) (0.886-0.902)	0.893 (0.029) (0.883-0.903)	0.890 (0.060) (0.883-0.898)
0.875 (0.048) (0.862-0.889)	0.844 (0.094) (0.804-0.884)	0.866 (0.070) (0.853-0.879)	0.879 (0.066) (0.867-0.891)	0.877 (0.055) (0.862-0.892)	0.847 (0.090) (0.811-0.882)	0873 (0.068) (0.863-0.884)
0.856 (0.078) (0.837-0.876)	0.833 (0.072) (0.809-0.856)	0.848 (0.078) (0.835-0.862)	0.856 (0.087) (0.842-0.871)	0.865 (0.073) (0.849-0.881)	0.838 (0.070) (0.815-0.861)	0.856 (0.080) (0.845-0.867)
0.805 (0.103) (0.786-0.825)	0.795 (0.105) (0.772-0.818)	0.804 (0.103) (0.792-0.815)	0.824 (0.099) (0.812-0.836)	0.821 (0.100) (0.804-0.839)	0.796 (0.118) (0.772-0.819)	0.818 (0.104) (0.807-0.829)
0.802 (0.096) (0.782-0.823)	0.754 (0.132) (0.708-0.800)	0.786 (0.112) (0.769-0.803)	0.809 (0.1104) (0.797-0.821)	0.809 (0.099) (0.790-0.828)	0.764 (0.134) (0.721-0.808)	0.803 (0.109) (0.790-0.816)
0.733 (0.149) (0.701-0.765)	0.710 (0.187) (0.654-0.766)	0.733 (0.144) (0.716-0.750)	0.750 (0.133) (0.735-0.764)	0.732 (0.158) (0.702-0.761)	0.711 (0.218) (0.662-0.760)	0.743 (0.143) (0.729, 756)

or >250 cm, and weight <30.0 kg or >250.0 kg) were excluded using listwise deletion.[33,34] A total of 229 (4.8%) respondents who had missing data and 25 (0.005%) with biologically implausible values were excluded from the analyses. Because the focus of this study was on those with high BMI, those who were underweight (weighted proportion = 7%) were excluded from our analyses. In total, 16% of observations were excluded from the analyses. Consequently, 3966 (84%) participants who had complete responses were included in the final estimation sample for this study.

Variables

Outcome variable: health state utilities

Ideally, the collection of primary data using a preference-based measure is used to calculate HSUs. Nevertheless, preference-based measures have not been used in large population surveys in Ghana: the WHO SAGE employed the WHOQOL-100, a non–preference-based measure. The items on the WHOQOL-100 have been used in more than 100 studies worldwide to measure quality of life.[35] Nevertheless, WHOQOL-100 is a non–preference-based instrument, and HSUs cannot be directly calculated. To calculate HSUs, a 2-step approach was used. First, using a judgment-based method,[12,19,36] items from the WHOQOL-100 questionnaire in the WHO SAGE individual questionnaire were mapped onto the European Quality-of-Life (EQ-5D-5L), a preference-based measure (see Appendix I in Supplemental Materials found at https://doi.org/10.1016/j.jval.2019.04.1925). Second, according to the responses in the WHOQOL-100, we assigned a HSU for each individual using the EQ-5D-5L scoring algorithm.

A valid judgment-based mapping could be achieved in one of two ways[19]: first, the dimensions of the preference-based measure must be included in the source measure, for example, survey, and items must correspond to those of the preference-based measure. The mapping could be conducted using the dimensions or items. Another approach is to choose specific health states described in the source measure and assign them onto a generic health state descriptive system or the preference-based measure. Because of the subjectivity associated with this method,[19] and structural challenges especially, when response levels are condensed, empirical mapping methods[13] are preferred. Nevertheless, the judgment-based method of mapping is a useful alternative to generate HSUs where a non–preference-based measure is the only measure included in a study, as in the case of WHO SAGE. Despite the usefulness of the judgment-based mapping in such conditions, this method should not supersede the empirical methods of mapping when data are available from both preference and non–preference-based measure for the same population, and this weakness should be considered when interpreting our results.

The EQ-5D-5L instrument is a simple and widely used generic preference-based measure used to estimate HSUs. The EQ-5D-5L comprises 5 domains: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, with 5 response options[37] (1 for no problems, 2 for slight problem, 3 for moderate problems, 4 for severe problems, and 5 for extreme problems/unable to perform activity). The WHOQOL-100 instrument is an international, cross-cultural comparable tool that covers 24 facets hierarchically organized within 6 domains: physical, psychological, level of independence, social relationships, environment, and spirituality, with an additional facet representing overall quality of life and health. For each item under the domains, 5 response options are available (1 for none or no problem, 2 for mild, 3 for moderate, 4 for severe, and 5 for extreme).[35] Under the domains, there are items that address mobility, self-care, usual activities, pain or discomfort, and anxiety or depression. Thus, the EQ-5D-5L and WHOQOL-100 have domains and response items that closely correspond to each other.

The EQ-5L-5L responses were mapped with 1 through 5 corresponding to 1 through 5 on the WHOQOL-100 item responses. We were then able to assign values and utility weights derived from the EQ-5D-5L value set. Judgment-based mapping of the WHOQOL-100 items to EQ-5D-5L was advantageous because each WHOQOL-100 item had 5-level responses that corresponded directly to the responses on the EQ-5D-5L. Furthermore, use of the

Table 4. Multivariable regression estimates (β) and 95% confidence intervals of association between health state utility and categories of body mass index and other covariates in Ghanaian adults, 2014-2015.

	Univariable		Multivariable	
	β (95% CI)	P	β (95% CI)	P
BMI categories				
Normal BMI	Reference		Reference	
Overweight	0.002 (−0.008 to 0.011)	.720	0.003 (−0.006 to 0.012)	.479
Obese	−0.026 (−0.042 to −0.010)	.002	−0.024 (−0.037 to −0.011)	<.001
Sex				
Males	Reference		Reference	
Females	−0.017 (−0.026 to −0.008)	<.001	−0.011 (−0.020 to −0.003)	.009
Age group				
18-49 years	Reference		Reference	
50-64 years	−0.056 (−0.066 to −0.046)	<.001	−0.047 (−0.057 to −0.036)	<.001
65+ years	−0.113 (−0.124 to −0.100)	<.001	−0.101 (−0.114 to −0.087)	<.001
Education status				
Low	Reference		Reference	
High	0.026 (0.017-0.035)	<.001	0.007 (0.001-0.016)	.099
Marital status				
Married/cohabiting	Reference		Reference	
Divorced/separated	−0.019 (−0.032 to −0.006)	.004	0.006 (−0.004 to 0.016)	.261
Single	0.043 (0.034-0.053)	<.001	0.026 (0.016-0.036)	<.001
Place of residence				
Rural	Reference		Reference	
Urban	0.011 (−0.002 to 0.023)	.092	−0.001 (−0.014 to 0.012)	.878
Household wealth quintile				
Lowest	Reference		Reference	
Low	0.015 (−0.004 to 0.034)	.131	0.015 (−0.004 to 0.033)	.119
Moderate	0.021 (0.002-0.040)	.026	0.020 (−0.003 to 0.038)	.025
High	0.033 (0.014-0.053)	.001	0.028 (0.009-0.048)	.004
Highest	0.039 (0.019-0.059)	<.001	0.035 (0.015-0.057)	.001
Smoking				
Never smoked	Reference		Reference	
Quitted smoking	−0.008 (−0.036 to 0.019)	.543	0.010 (−0.016 to 0.035)	.462
Currently smokes	−0.014 (−0.049 to 0.020)	.416	−0.010 (−0.046 to 0.026)	.580
Found to have chronic disease				
No	Reference		Reference	
Yes	−0.043 (−0.062 to −0.023)	<.001	−0.015 (−0.032 to 0.001)	.068
Constant	—	—	0.847 (0.828-0.867)	

EQ-5D-5L instead of the EQ-5D-3L had the advantage of reducing the ceiling effect and improved the discriminatory effect.[38,39] In addition, aside from mapping closely corresponding questions from both instruments, directly mapping 5-level WHOQOL-100 to 5-level EQ-5D-5L rather than condensing the WHOQOL-100 5-level responses to match the EQ-5D-3L 3-level responses helps to overcome any structural and response rating challenges.[12,36] We used the Zimbabwe EQ-5Q-5L value set and the calculator from the EuroQol Group's crosswalk project[39] because Ghana currently does not have its own dataset.

Explanatory and other variables

The main explanatory variables were overweight and obesity with normal weight as the base category. In the WHO SAGE, anthropometric measurements of body weight and height of respondents were taken using standard protocols.[31] BMI were categorized according to WHO classifications as follows: normal BMI, BMI = 18.50 to ≤25.00 kg/m^2; overweight, BMI = 25.00 to ≤30.00 kg/m^2; obesity, BMI ≥30.00 kg/m^2.[4]

Covariates were included based on previous literature,[9,40] and these included age, sex, educational level, marital status, locality (rural/urban), household wealth status, smoking status, and having been found to have a chronic disease.

Statistical Analysis

Accounting for the poststratified person's weight, age-, sex-, and BMI-specific mean HSUs were generated using the Zimbabwe EQ-5D-5L value set. Sampling weights provided in the WHO SAGE data were used.[32] Univariable and multivariable survey linear regression models were used to examine the association between HSUs and high BMI using normal weight as the reference category.[41] A 2-tailed *P*-value <.05 was considered as statistically significant. All statistical analyses were conducted using STATA version 15.0 (Stata Corp, College Station, Texas, USA).

Ethics Approval and Consent to Participate

The WHO SAGE study was approved by the WHO's Ethical Review Board and the University of Ghana Medical School Ethics and Protocol Review Committee in Ghana.[32] Therefore, we were not required to obtain a separate ethics approval for this study. We used the GhanaINDDataW2 and the SAGE Individual Questionnaire. All files are available from the WHO database.

Results

The sample used in the analyses comprise 3966 adults aged 18 to 110 years (84% of the total sample). Sampling weights were applied throughout the analyses. HSUs could not be calculated for 207 respondents who had missing data for one or more EQ-5D-5L dimensions. Of the 207 respondents, 31% were female, 10% obese, 38% overweight, and 65% were aged below 50 years. In the final sample of 3966 adults, the mean (standard deviation) age was 40.2 (14.9) years, and BMI was 25.1 (5.1) kg/m^2. Most respondents resided in urban areas (52%), were female (55%), had normal BMI (59.5%), were with low education (60%), and were from households with the highest level of wealth (28.4%) (Table 1). Table 2 shows the proportion who reported problems for each level of the 5 EQ-5D-5L domains for the BMI categories. Around one-fifth of the sample, respectively, reported that they experienced slight pain or discomfort (21.9%) and slight anxiety or depression (17.7%). Few respondents reported any problems in the self-care domain. In all, 44% of males and 56% of females reported no problems across all EQ-5D-5L health domains.

Age- and BMI-specific mean HSUs stratified by sex and for the population are presented in Table 3. The mean HSU (95% confidence interval) for the population was 0.856 (95% CI: 0.850, 0.863), 0.866 (95% CI: 0.858, 0.874) for males, and 0.849 (95% CI: 0.841, 0.856) for women. In general, whereas HSUs were slightly higher for persons who were overweight compared with normal weight and higher as household wealth increased, HSUs were lower for women and obese participants and decreased with age. In univariable analysis, factors that were significantly associated with HSU were obesity, sex, age, marital status, household wealth, and being found to have a chronic disease (Table 4). These factors were then used in the multivariable regressions. Although the inclusion of these variables attenuated the coefficients for the obesity categories, they remained statistically significant. Other factors also remained significantly associated with HSU in the multivariable analysis. Being obese was associated with significantly lower HSU ($\beta = -0.024$; 95% CI: −0.037, −0.011), whereas overweight was associated with higher HSU; however, this was not statistically significant. HSUs for women were 0.011 (95% CI: 0.003, 0.020) lower than for men, and higher in those with moderate, high, or higher household wealth compared with those within the lowest income quintiles.

Discussion

For the Ghanaian population, few studies have focused on finding the effect of BMI on health-related quality of life, and to-date, no studies have generated age- and sex-specific HSUs and HSUs stratified by weight status or studied the extent to which HSUs are associated with high BMI.[2,42,43] Nevertheless, in most low- and middle-income countries, particularly in sub-Saharan Africa, increasing prevalence of obesity has been reported, which in turn is a major risk factor for non-communicable diseases.[44–46] The lack of HSUs for the population underscores the difficulties in conducting economic evaluations to support the effective prioritization of health programs or health technology assessments within the Ghanaian and other sub-Sahara African populations. This study bridges this gap by generating age- and sex-specific HSUs and HSUs by weight status and by examining the associations between HSUs and high BMI in a sub-Sahara African setting. Most importantly, the weighted age- and sex-specific HSUs can be used to calculate QALYs, which may be used for economic evaluations for the Ghanaian context. In addition, HSUs generated by weight status can be used to support cost-effectiveness evaluations of measures, policies, or interventions to address overweight or obesity in this setting.

In this study, around two-fifths of respondents reported slight problems with pain and discomfort or anxiety and depression, and the least problems were reported for self-care. We found that HSUs were significantly lower in persons who were obese compared with normal weight, women compared with men, and in older age groups compared with younger age groups. In addition, HSUs were significantly higher for respondents who were single compared with married and higher as household wealth increased. Although the association was not significant, the results showed that HSUs were positively associated with overweight in the population. HSUs were also not significantly associated with respondents' education, place of residence, smoking, or having a chronic disease.

In most countries where HSUs have been calculated, mean individual HSUs were slightly lower than our study reported.[9,29,30] We found a strong negative association between HSU and obesity; controlling for other factors made only a small difference. Our findings of lower HSUs for obese respondents and for older respondents are consistent with previous studies.[8,9,30,40,47,48] Nevertheless, contrary to findings in previous studies, we found that both the unadjusted and adjusted HSUs for overweight were higher compared with normal BMI, although this was not significant.[9,29,30]

The negative associations found between HSU and obesity but not overweight may be an effect of general awareness of the health consequences of obesity.[49] In most settings in low- and middle-income countries, such as Ghana, the recognition of high BMI as a public health problem is a more recent phenomenon[2]; however, the burden associated with this may have existed over a longer period. Just like in most developing countries, to some people in Ghana, high BMI may be considered as beautiful and as a sign of affluence,[2,5] despite the associations with many chronic diseases and reduced life expectancy. Although recent improvements in public health activities have likely increased awareness around the health problems associated with overweight and obesity, addressing these societal norms will be a critical aspect of future public health initiatives.

The key strength of this study is the attempt to generate age- and sex-specific HSUs and HSUs by weight status and to determine the associations between HSU and high BMI for the Ghanaian population. The set of age- and sex-specific HSUs that we have generated can be used to calculate QALYs for CUA in the general Ghanaian population and in similar sub-Saharan countries. Specifically, the BMI-specific HSUs can be used to calculate QALYs for economic evaluations that are required to guide decision making around policy and preventative and management measures for overweight and obesity in sub-Saharan Africa. Instead of condensing the WHOQOL-100 responses and mapping onto the EQ-5D-3L responses, we used judgment-based mapping for the WHOQOL-100 five-level responses to the EQ-5D-5L, an instrument that reduces ceiling and floor effects.[38,39] We also used objectively measured weights and heights rather than self-reported. Although we used the most current population-based data to calculate HSUs—rarely available in sub-Saharan Africa—

our study has several limitations. First, we used a non–preference-based instrument (WHOQOL-100) to indirectly estimate HSUs. Employing mapping models is the second-best method to obtain utility values. In the WHO SAGE, because only a non–preference-based instrument was implemented during data collection, we used the judgment-based method to map items and responses to the EQ-5D-5L; this may reduce the precision of the HSUs obtained. Our results only provide interim HSUs that will be useful in cost-utility analyses in the Ghanaian population. To provide more reliable HSUs, we recommend that future studies use direct HSU elicitation methods or preference-based measures to generate a better population HSUs in Ghana. The second limitation is the use of the Zimbabwe value set as the surrogate. The Zimbabwe EQ-5D-5L value set was derived from the existing EQ-5D-3L, which was based on data collected from 2488 high-density urban dwellers in 2000.[39,50] Because of the differences in economic and political environment between Ghana and Zimbabwe,[51] both of which may affect health outcomes in the populations, the preference weights might vary. Health states valued differently in the Ghanaian population will result in biased HSUs in our study. Nevertheless, this value set was used because the characteristics of this population are much closer to that of the Ghanaian population in comparison to other existing value sets. Finally, the WHO SAGE data are cross-sectional, and therefore we could not estimate the effect of changes in high BMI and subsequent HSUs. Although the data are representative of the older adult Ghanaian population, because we omitted participants with missing anthropometric or EQ-5D-5L dimensions data, we may have introduced selection bias. Nevertheless, missing data accounted for less than 5% of the total sample,[52] and our use of sampling weights in the analyses reduced the potential for selection bias.

Despite these limitations, we have used the most robust statistical methods available to generate HSUs for the population. QALYs, an important outcome measure recommended by national bodies such as National Institute for Health and Care Excellence (NICE), can be estimated by combining HSU and survival/life expectancy. In turn, these QALYs can be used in CUA. Until a population-based study is conducted to determine HSUs for the Ghanaian population, these estimates can provide baseline HSUs for use in future CUA for Ghana.

In conclusion, our study provides age- and sex-specific HSUs and HSUs by weight status, and investigates associations between HSU and high BMI. We found HSUs to be negatively associated with obesity, to be lower among women, and to be lower among those of older age. The age- and sex-specific HSU can be used to calculate QALYs, which may be used for a range of health economic evaluations for the population. The study also provides HSUs by weight status, which will be important in studies to evaluate the cost-effectiveness of preventative and management actions for overweight and obesity.

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Supplemental Materials

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.jval.2019.04.1925.

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Appendix 4. Publication of Chapter 5

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Original Article

OXFORD

Health service utilization and direct healthcare costs associated with obesity in older adult population in Ghana

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An earlier draft of this article was submitted and has been accepted for a long oral presentation at one of the most prestigious health economics conferences, the 2019 International Health Economics Association in Basel, Switzerland.

Also, an earlier draft of this article was presented at the 2018 Australia Health Economics Association in Hobart, Australia. We are thankful to all anonymous reviewers who made this feat possible.

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Abstract

Obesity is a major risk factor for many chronic diseases and disabilities, with severe implications on morbidity and mortality among older adults. With an increasing prevalence of obesity among older adults in Ghana, it has become necessary to develop cost-effective strategies for its management and prevention. However, developing such strategies is challenging as body mass index (BMI)-specific utilization and costs required for cost-effectiveness analysis are not available in this population. Therefore, this study examines the associations between health services utilization as well as direct healthcare costs and overweight (BMI $\geq$25.00 and $<$30.00 kg/m^2) and obesity (BMI $\geq$30.00 kg/m^2) among older adults in Ghana. Data were used from a nationally representative, multistage sample of 3350 people aged 50+ years from the World Health Organization's Study on global AGEing and adult health (WHO-SAGE; 2014/15). Health service utilization was measured by the number of health facility visits over a 12-month period. Direct costs (2017 US dollars) included out-of-pocket payments and the National Health Insurance Scheme (NHIS) claims. Associations between utilization and BMI were examined using multivariable zero-inflated negative binomial regressions; and between costs and BMI using multivariable two-part regressions. Twenty-three percent were overweight and 13% were obese. Compared with normal-weight participants, overweight and obesity were associated with 75% and 159% more inpatient admissions, respectively. Obesity was also associated with 53% additional outpatient visits. One in five of the overweight and obese population had at least one chronic disease, and having chronic disease was associated with increased outpatient utilization. The average per person total costs for overweight was $78 and obesity was $132 compared with $35 for normal weight. The NHIS bore approximately 60% of the average total costs per person expended in 2014/15. Overweight and obese groups had significantly higher total direct healthcare costs burden of $121 million compared with $64 million for normal weight in the entire older adult Ghanaian population. Compared with normal weight, the total costs per person associated with overweight increased by 73% and more than doubled for obesity. Even though the total prevalence of overweight and obesity was about half of that of normal weight, the sum of their cost burden was almost doubled. Implementing weight reduction measures could reduce health service utilization and costs in this population.

Keywords: Obesity, older adults, health service utilization, direct healthcare costs, WHO-SAGE Wave 2, Ghana

Key Messages

- No study has examined the utilization and direct costs of health services associated with overweight and obesity in the older adult population in Ghana. We analysed the most current data collected from a nationally representative multi-stage sample of people aged 50+ years in the World Health Organization's Study on global AGEing and adult health (WHO-SAGE) Ghana Wave 2.
- Overweight and obesity both were associated with additional health service utilization as well as high incremental direct healthcare costs of which the government's cost share was about 60% per person.
- Even though the combined prevalence was 36%, the total cost burden of overweight and obesity was almost double that of normal weight.
- The results suggest the need for preventative and weight management programmes to mitigate the high cost burden of overweight and obesity.

Introduction

Whilst obesity is among the leading risk factors for non-communicable diseases (NCDs) globally, the prevalence of obesity has substantially increased since 1980 (Mendis *et al.*, 2014; Global Burden of Disease 2015 Obesity Collaborators, 2017). Obesity (body mass index, BMI $\geq$30 kg/m^2) has immediate negative health consequences (Global Burden of Disease 2016 Disease and Injury Incidence and Prevalence Collaborators, 2018), and a complex aetiology that ultimately results in increased morbidity, disability, mortality and reduced quality of life (Prospective Studies Collaboration *et al.*, 2009; Konig *et al.*, 2015). In many developing countries, mortality of older adults (50+ years) is commonly due to NCDs rather than infectious or parasitic diseases (World Health Organization, 2014). In other countries, it has been established that overweight and obesity and obesity-related conditions in the older population siphon considerable resources from the health system due to the associated increased health services utilization and healthcare costs (Colagiuri *et al.*, 2010; Doherty *et al.*, 2012; Wilkins *et al.*, 2012; Hugh *et al.*, 2015; Konig *et al.*, 2015; Musich *et al.*, 2016; Suehs *et al.*, 2017). Even though overweight and obesity prevalence are increasing (Agyemang *et al.*, 2015; Lartey *et al.*, 2019a), there is no way to estimate whether the current prevalent rates among the older population have similar effects on health service utilization and costs in Ghana. Also, there are few studies that have examined such effects globally (Saeed *et al.*, 2016; Awoke *et al.*, 2017). In addition, this has been a major concern for policymakers, stakeholders and financiers of healthcare who can only speculate an increase in health resource utilization and cost, without any published estimates.

Healthcare in Ghana is financed mainly by the government, development partners and households (Wang *et al.*, 2017). To improve equity in healthcare delivery and sustainable health financing, the Government of Ghana in 2003 introduced the National Health Insurance Scheme (NHIS; Nsiah-Boateng *et al.*, 2017) and commenced implementation in 2005. Administered by the government's National Health Insurance Authority (NHIA), the scheme is financed through the national health insurance levy and deductions by Social Security and National Insurance Trust (SSNIT); and funds are largely expended through claims (Wang *et al.*, 2017). Since the introduction of the NHIS, increase health service utilization and costs to the government have been reported (Nsiah-Boateng *et al.*, 2017; Wang *et al.*, 2017). Yet there is no evidence of how overweight and obesity have influenced the process.

As Ghana is among the few countries in Africa experiencing an ageing population (He *et al.*, 2016) in addition to increasing life expectancy (World Health Organization, 2014). Therefore, a concurrently increasing obesity prevalence (Agyemang *et al.*, 2015; Ofori-Asenso *et al.*, 2016; Lartey *et al.*, 2019a) which may increase the risk of chronic diseases (Singh *et al.*, 2013) will likely impose major financial costs (World Health Organization, 2005; Akazilia *et al.*, 2017), especially to the government's NHIS. Due to a lack of adequate healthcare cost data reported in many developing countries, it is difficult to estimate the cost burden overweight (25 $\geq$BMI $<$30 kg/m^2) and obesity impose on households and the health systems. However, such research is essential for forecasting, planning and development of cost-effective and sustainable obesity interventions. Estimating utilization and costs can be used in health economic modelling studies, including those that will simulate progression impact of changing prevalence obesity on economic outcomes.

Since results from modelling are to inform healthcare decisions and resource allocation in specific populations, it is important that the parameters such as costs, utilization and health state utilities used are developed basically from the same or very similar population (Briggs *et al.*, 2012). This is because the circumstances like economic or political conditions and how populations value their health differ. Therefore, using parameters such as BMI-specific utilization and costs from different countries in economic evaluation and using its results to inform local healthcare decisions and resource allocation might lead to choosing unaffordable, inaccessible and unsustainable interventions. As evidence of association among utilization, costs and high BMI are porous in Ghana, this study aimed to examine the associations among health service utilization, healthcare costs and excess weight in the older adult population of Ghana in 2014/15.

Methods

Study sample

Data from a sub-sample of 3350 respondents aged ≥50 years with complete responses from the World Health Organization's Study on global AGEing and adult health (WHO-SAGE) Wave 2 were used. SAGE used a stratified multistage cluster design to collect data that yielded national and subnational estimates with acceptable precision using region and locality type (rural/urban) as the primary sampling unit (Kowal *et al.*, 2012; Charlton *et al.*, 2016). Of the 4735 survey respondents, a final sample for analysis was determined after missing weight (227) and height (229) measurements and biologically implausible weight and height measurements (25) were excluded. Biologically implausible values (BIVs) were determined to be height <100 cm or >250 cm, weight <30.0 kg or >250.0 kg and waist circumference <25.0 cm or >220 cm, and were excluded (Subramanian *et al.*, 2011; Cois and Day, 2015). Overall, 246 (5.2%) missing anthropometric measurements and 25 (0.5%) BIVs were excluded. Out of this, only 160 (4.8% of 3350) were excluded from those 50 years and above. Since the focus of the study was those aged 50 years and above, person below age 50 years (1114) were excluded from this study. Thus, the final sample for analysis was 3350.

We used the GhanaINDDataW2 that had responses to the individual questionnaire in this study. Further information on the WHO-SAGE can be found at http://www.who.int/healthinfo/sage/cohorts/en/.

Outcome variables

This study focused on four outcome variables. We examined the annualized health service utilization and total direct healthcare costs including costs that were stratified by out-of-pocket (OOP) and NHIS costs.

Health service utilization

The SAGE questionnaires included information on self-reported health service utilization in the 12 months prior to data collection. This included the number of visits to a specific type of health facility (this includes pharmacy, health centre, clinic, polyclinic, district hospital, regional hospital, teaching/tertiary hospital), for outpatient visits and inpatient admissions over the period. Based on the assumption that those who did not provide response to visiting a health facility did not make any visits, their missing values were considered to be zero in the analysis. The number of unreported inpatient admissions was 3010 (90% of the 3350) and outpatient visits was 980 (29% of the 3350).

OOP costs

Respondents who have had inpatient and/or outpatient visits were asked to indicate the OOP costs they incurred during the most recent visit. This included fees for healthcare provider, medication, laboratory tests, transportation and other incidental costs related to the hospital visit. These costs were summed and multiplied by the total number of visits a respondent made to a health facility in the past 12 months. Using the health-related mean consumer price index for years 2015 and 2017, these costs were converted into real costs in 2017 in Ghana cedi (Ghana Statistical Service, 2012, 2017; Konig *et al.*, 2015).

NHIS costs

Where an insured respondent had an inpatient admission, or an outpatient visit and indicated in the OOP costs sections that this was 'free', it was acknowledged that the NHIS as a public health insurance system covered the costs of such services (healthcare provider and medication fees). People who visited a health facility and incurred transport, laboratory tests or other incidental costs but not health provider or medication fees, were assumed to have incurred both OOP and NHIS costs. The NHIS reimburses healthcare providers mostly for health services and medication costs per person per visit using their diagnosis, the level of the facility visited dosage of medication consumed. These services and medication costs were based on the Ghana Diagnosis Related Groupings (G-DRG), 2015 and fee-for-service payment methods, respectively (Wang *et al.*, 2017). The NHIS costs were calculated in four steps: (1) diseases that were reported as the main reason for outpatient visit or inpatient admission in a health facility in the WHO-SAGE were mapped to diseases in the G-DRG, stratifying by level of health facility. Minimum costs were assigned based on the service and type of health facility visited (Supplementary Appendix SA1); (2) to obtain medication costs, claims data on mean medication costs were accessed from five districts stratifying these by outpatient or inpatient services for the 2017 fiscal year (Supplementary Appendix SA2; NHIA, 2018). These NHIS claims data were the most current and validated data that used the 2015 G-DRG. Claims data from two districts (Gonja East and Shai-Osudoku) were excluded because service costs were not separated from medication costs. It is important to note that the costs of medications do not vary by district, rather the costs depend on the dosage prescribed for specific diagnosis (Wang *et al.*, 2017); (3) the NHIS costs were calculated as the sum of service (from the G-DRG) and medication costs (mean of medication costs from the districts) per visit based on the purpose of visit, the department (inpatient or outpatient) and level of health facility visited;

and (4) finally, the NHIS costs obtained per visit per person was then multiplied by the total number visits the respondent made to a health facility in the past 12 months for which health provider and medication fees were free.

Total healthcare costs

These were estimated as the sum of the OOP and NHIS costs per person in the 12 months prior to the study. All costs were converted into US dollars ($) equivalent using the 2017 mean exchange rate ($1≈ GHS 4.3562; Bank of Ghana, 2018).

Explanatory variable

Overweight and obesity

Overweight and obesity were the main explanatory variables. In the WHO-SAGE data, anthropometric measurements of body weight and height of respondents were taken by trained assessors using standardized protocols (World Health Organization, 2006). BMI was calculated as weight in kilograms divided by the square of height in metres (kg/m^2; National Institute of Health, 1998). BMI was classified into four categories: underweight, BMI < 18.50 kg/m^2; normal weight, 18.50≥BMI < 25.00/m^2; overweight, 25.00≥BMI <30.00 kg/m^2; and obesity, BMI ≥30.00 kg/m^2 (National Institute of Health, 1998; World Health Organization, 2000).

Covariates

Covariates considered as confounders included age, sex, marital status, educational level, location, employment status, household wealth, having health insurance and being diagnosed with at least one chronic disease or none. Covariates were specified based on Andersen behavioural model for studying factors that facilitate or impede health service utilization (Andersen, 1995) and factors that affect costs (Brinda *et al.*, 2015; Konig *et al.*, 2015). In particular, the Andersen model shows that the individual accesses and utilizes health services depending on three groups of characteristics described below: (1) predisposing factors, also known as the socio-cultural characteristics of the person including age, gender, marital status, educational level, occupation; (2) enabling factors focus on the operational or logistical requirements needed to seek care such as individual or family income, having health insurance, availability of health personnel and facilities; and (3) need factors that are the immediate cause for which a person seeks care including diseases or disabilities.

In this study, sex was categorized as male/female while age was a continuous variable. Educational level was grouped into low education where the highest level of education was less than secondary or high school, and high education where a person completed secondary/high school and above. Marital status was coded as (1) single, (2) married/co-habiting and (3) divorced/separated/widow/widower. Location of residence was coded as rural or urban residence; and employment status was categorized as employed or not employed. Furthermore, household wealth index served as a proxy for household economic status (Filmer and Pritchett, 2001; Rutstein and Staveteig, 2014). This was constructed using principal component analysis from a total of 22 assets/characteristics/items (Rutstein and Staveteig, 2014; Lartey *et al.*, 2019b). These included having radio, television, refrigerator, computer, mobile or fixed telephone, livestock, land, jewellery, bicycle, motorcycle, car; access to utilities such as electricity, having improved sanitation facility, having improved source of drinking water, cooking fuel and housing characteristics, such as the type of floor or wall materials. The Cronbach's alpha for the 22 assets/characteristics/items that measured household wealth was 80.8%, indicating that assets/characteristic/items included measured wealth appropriately. The derived index was converted into wealth quintiles coded as quintile one representing the lowest household status; with quintile two as low; quintile three representing moderate; quintile four representing high, and quintile five representing highest household wealth status. Insurance status was defined uninsured or insured. A respondent was insured if he had an unexpired insurance card. From previous studies, having obesity-related medical conditions included diabetes (ICD-9-CM code 250 for type 2 or unspecified type); hypertension (ICD-9-CM code 401-405); unspecified angina pectoris (ICD-9-CM 413.9); arthritis (ICD-9-CM code 716.9 for unspecified arthritis); stroke or cerebral artery occlusion (ICD-9-CM 434.91); and depression (ICD-9-CM code 311; Kortt and Clarke, 2005). Thus, having chronic disease was defined as yes if a respondent had at least one of these diseases.

Statistical analysis

As population health service utilization typically has many zero values, we employed survey zero-inflated negative binomial regression models in univariable and multivariable analyses to examine the association between healthcare usage and BMI categories. Characteristic of population healthcare cost data, cost was a continuous outcome variable and right skewed with excess zeroes (Finkelstein *et al.*, 2009; Brinda *et al.*, 2015). Therefore, we employed a survey two-part regression model in univariable and multivariable analyses to explore associations between costs and the BMI categories (Duan *et al.*, 1984). The two-part model involved two steps: the first step estimated the probability of having a health cost; then the second step estimated the total costs conditional on having positive costs. We employed a two-part model that used a logit model in the first part and a generalized linear model with gamma distribution and a log link function in the second part (Manning and Mullahy, 2001; Finkelstein *et al.*, 2009).

We report the exponentiated coefficients [incidence rate ratios (IRR) of health service usage, and predicted mean and incremental costs]. We applied the WHO post-stratified person weights to all estimations. A two-tailed P-value < 0.05 was considered as statistically significant.

As costs incurred during the last visit were used to calculate annual costs, a sensitivity analysis around costs was conducted by varying the average per person costs by ±20% (Briggs *et al.*, 2012). All analyses were performed using STATA v.15 (Stata Corp., College Station, TX, USA).

Results

Of the 3350 respondents aged 50+ years used in this analysis, approximately 53% were female, of mean (standard deviation) age 62 (9.9) years, 48% lived in urban areas and 72% were insured (Table 1). Ten percent were underweight, 54% had normal weight, 23% were overweight and 13% were obese. Twenty-three percent of the 3350 respondents came from the highest-income households and 17% were diagnosed with at least one chronic disease. Twenty-three percent (P-value = 0.001) forming about one in five of the total number of respondents who were overweight or obese (1209) had at least one chronic disease.

Health service utilization

Of the 3350 respondents, 1703 (51%) made at least one visit in the 12 months prior to data collection. At least one inpatient admission was reported by 182 (5%) of which 10% were underweight, 24% were overweight and 12% were obese. About half of the sample (49%, n = 1631) reported at least one outpatient visit; of this group, 11% were underweight, 22% were overweight and 13% were obese (Table 1). Among the overweight group who visited any health facility, the unadjusted mean number of inpatient admissions was 2.1 (95% CI: 1.8, 2.2) and outpatient visits was 2.8 (95% CI: 2.4, 3.2; Table 2). In the obese group, the unadjusted mean number of inpatient stays was 2.5 (95% CI: 2.4, 2.6) and outpatient visits was 3.7 (95% CI: 3.4, 4.2; Table 2). The univariable and multivariable associations between annual health service utilization and BMI categories showed that both overweight and obesity were associated with significantly higher health services (Table 3). However, the magnitude reduced in the multivariable analysis where persons who were obese had 53% (IRR = 1.53; 95% CI: 1.19, 1.98) more outpatient visits and 159% (IRR = 2.59; 95% CI: 1.20, 5.51) more inpatient admissions compared with those of normal weight. Being overweight was also associated with 75% (IRR = 1.75; 95% CI: 1.21, 2.53) more inpatient admissions compared with those of normal weight. Underweight was not significantly associated with any health service utilization domain. Another important factor that was associated with high outpatient utilization was having at least one chronic disease (IRR = 1.38; 95% CI: 1.07, 1.78). Other factors associated with more outpatient visits included being female, high education and high household wealth. Being unemployed and having high or higher household wealth were associated with more inpatient admissions.

Table 1 Characteristics of older adult (50+ years) respondents, WHO-SAGE Wave 2 (2014/15)

Characteristics	Weighted prevalence (%)
Sample, *n* (%)	3350 (100)
Sex	
Males	47.1
Females	52.9
BMI	
Underweight	10.1
Normal	53.8
Overweight	22.9
Obesity	13.2
Educational level	
Low	70.3
High	29.7
Marital status	
Single	2.7
Married/co-habiting	63.5
Divorced/separated/widow	33.8
Location	
Rural	51.7
Urban	48.3
Employment status	
Employed	69.5
Unemployed	30.5
Household wealth status	
Lowest	13.0
Low	19.7
Moderate	22.0
High	22.0
Highest	23.4
Health insurance	
Uninsured	28.3
Insured	71.7
Has a chronic disease	
No	83.3
Yes	16.7

All estimates are weighted.

Healthcare costs

Table 4 shows the annualized costs of direct healthcare. In this population, the unadjusted annualized average costs per person incurred through either OOP or NHIS were higher among persons who were overweight or obese vs. those with normal weight. Government bore approximately 60% of the total direct healthcare costs per person in 2014/15 (Figure 1). Results of the sensitivity analyses around the per person costs are presented in Supplementary Appendix SA3. Based on the estimated prevalence (Table 1) and the entire 50+ years population in year 2015 (Ghana Statistical Service, 2014), the prevalence-based unadjusted mean total direct healthcare costs for normal weight were estimated to be $64 817 248, overweight were $61 442 129 while those of obesity was $60 276 468 (Table 5). Overweight and obese groups had significantly higher total direct healthcare costs burden compared with that for normal weight in the entire older adult Ghanaian population.

Table 6 shows the univariable and multivariable analyses of the association between annual healthcare costs and BMI categories. Overweight and obesity were significantly associated with higher costs vs. normal weight in all cost domains. In the multivariable analyses, the mean annualized direct healthcare costs for the normal weight reference group was $51.79 (95% CI: 46.35, 57.22) per person for total costs including $21.16 (95% CI: 17.51, 25.84) for OOP and $30.24 (95% CI: 27.73, 32.75) for NHIS costs. However, being overweight was associated with $37.86 (95% CI: 26.71, 49.02) additional total costs per person, $17.68 (95% CI: 9.67, 25.68) additional OOP costs and $20.13 (95% CI: 15.08, 25.18) increase in NHIS costs. Being obese was associated with total

Table 2 Health service usage, by weight status among older adult (50+ years) respondents in Ghana, WHO-SAGE Wave 2 (2014/15)

	Utilization (mean number of visits per year)			
	Outpatient visits		Inpatient services	
Weight status	No.	Mean (95% CI)	No.	Mean (95% CI)
Full sample				
Underweight	429	0.8 (0.7, 1.0)	429	0.1 (0, 0.2)
Normal	1854	1.0 (0.8, 1.2)	1854	0.1 (0, 0.2)
Overweight	683	1.5 (1.3, 1.7)	683	0.1 (0, 0.3)
Obese	384	2.2 (1.9, 2.4)	384	0.1 (0, 0.5)
Only those who visited health facility				
Underweight	179	2.0 (1.7, 2.5)	19	1.9 (0.9, 2.3)
Normal	874	2.0 (1.8, 2.2)	98	1.3 (1.0, 1.5)
Overweight	360	2.8 (2.4, 3.2)	44	2.1 (1.8, 2.2)
Obese	218	3.7 (3.4, 4.2)	21	2.5 (2.4, 2.6)

All estimates are weighted.
CI, confidence interval.

Table 3 Factors associated with health service utilization among older adult population in Ghana, 2014/15

	Annual outpatient utilization[a]				Annual inpatient utilization[a]			
	Univariable		Multivariable		Univariable		Multivariable	
Characteristics	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
Weight status (Ref: normal)								
Underweight	0.90	0.68, 1.18	0.83	0.66, 1.06	1.58	0.52, 4.76	1.66	0.71, 3.87
Overweight	1.44**	1.14, 1.83	1.15	0.92, 1.42	2.20***	1.46, 3.32	1.75**	1.21, 2.53
Obesity	2.17***	1.74, 2.70	1.53**	1.19, 1.98	2.70**	1.48, 4.93	2.59*	1.20, 5.51
Sex (Ref: male)								
Female	1.77***	1.50, 2.09	1.60***	1.33, 1.92	1.20	0.77, 1.87	1.08	0.72, 1.62
Age, years								
Age	1.02***	1.01, 1.03	1.02**	1.01, 1.03	1.01	0.98, 1.03	1.01	0.99, 1.02
Educational level (Ref: low)								
High	1.26*	1.04, 1.53	1.35**	1.09, 1.68	1.56*	1.06, 2.29	1.20	0.84, 1.87
Marital status (Ref: single)								
Married/co-habiting	1.97*	1.10, 3.53	2.20*	1.19, 4.05	0.96	0.11, 3.40	1.17	0.20, 4.92
Divorced/separated/widow	3.24***	1.82, 5.77	2.66**	1.47, 4.82	1.18	0.12, 4.36	1.06	0.18, 4.38
Location (Ref: rural)								
Urban	1.22	0.98, 1.51	0.82	0.66, 1.02	2.09**	1.30, 3.34	1.23	0.75, 2.02
Employment status (Ref: employed)								
Unemployed	1.70***	1.41, 2.06	1.40**	1.15, 1.69	1.91**	1.22, 2.99	1.53*	1.11, 2.44
Household wealth status (Ref: lowest)								
Low	1.97***	1.35, 2.87	1.81***	1.31, 2.50	1.87	0.74, 4.74	1.39	0.52, 3.70
Moderate	2.26***	1.61, 3.20	2.07***	1.49, 2.87	3.52**	1.50, 5.25	2.34	0.90, 6.10
High	2.44***	1.82, 3.31	2.14***	1.52, 3.01	5.40**	2.05, 6.18	2.82*	1.02, 6.89
Highest	3.29***	2.39, 4.52	2.68***	1.86, 3.85	5.83***	2.36, 7.41	3.62*	1.25, 7.20
Health insured (Ref: uninsured)								
Insured	1.44**	1.15, 1.80	1.19	0.96, 1.48	1.95	0.96, 3.94	1.79*	1.09, 2.96
Having chronic disease (Ref: no)								
Yes	1.84***	1.43, 2.37	1.38*	1.07, 1.78	1.79**	1.28, 2.50	1.17	0.81, 1.70
Intercept[b]	0.87***	0.76, 1.00	0.58***	0.10, 0.89	0.63***	0.51, 0.79	0.15	0.01, 1.61

[a]Annual mean utilization estimated as the sum of outpatient visits and inpatient stays 12 months prior to data collection.
[b]Intercept for univariate pertains to only BMI categories.
IRR, incident rate ratio; CI, confidence interval.
$^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

incremental costs of \$63.96 (95% CI: 48.71, 79.20), \$28.16 (95% CI: 18.83, 37.48) as OOP and \$34.64 (95% CI: 26.92, 42.36) as NHIS costs. Total costs increased with age, high education and high household wealth.

Discussion

In this study, we examined the association between annual health service utilization as well as annual direct healthcare costs and four BMI categories in the older adult population of Ghana. We found that people who were overweight or obese had increased annual health service utilization and costs compared with those of normal weight, despite making up only 36% of the population. Being obese was associated with about 53% more outpatient visits and 159% more inpatient admissions compared with those with normal weight. Being diagnosed with at least one chronic disease was also associated with 38% additional outpatient visits. Similarly, overweight was associated with 73% more inpatient admissions compared with those of normal weight, but there was no significant association for outpatient visits. Despite that the prevalence of overweight and obesity was only about half of the normal weight, total healthcare costs burden was almost doubled. The total per person direct healthcare costs associated with overweight increased by 73% and for obesity, these costs were more than double in all cost domains compared with persons with normal weight.

Our findings are consistent with previous international studies which have shown that health service utilization among the overweight and obese among older adults are higher compared with normal weight (Doherty *et al.*, 2012; Hugh *et al.*, 2015; Konig *et al.*, 2015; Musich *et al.*, 2016; Suehs *et al.*, 2017). For example, a comparison of healthcare utilization by weight status in the USA found those with obesity to be more likely to have more inpatient admissions and orthopaedic procedures compared with those of normal weight (Musich *et al.*, 2016). Similarly, in Ireland, Doherty *et al.* (2012) found overweight and obesity to be associated with significantly higher outpatient visits and inpatient admissions which translated to higher healthcare costs in those who were overweight or obese compared with those of normal weight. Increased healthcare utilization associated with overweight or obese in our study could be attributed to a possible increased burden in prevalence of NCDs (Adeboye *et al.*, 2012). This could be the case as we also found that one out of five in the overweight or obese population had at least one chronic disease; and having a chronic disease was associated with increased utilization.

Our findings that 20% (one out of five) of overweight or obese respondents had at least one chronic disease, and that having a chronic disease was associated with increased hospital utilization may imply a substantial but avoidable burden on the health system. This result is consistent with previously published research, which has shown obesity increases the risk of developing chronic diseases

Table 4 Annualized direct healthcare cost per person by OOP costs, NHIS and total by weight status among older adult (50+ years) respondents in Ghana, WHO-SAGE Wave 2 (2014/15)

Sample used	Weight status	OOP cost per person [mean (95% CI)]			NHIS cost per person [mean (95% CI)]			Total Costs per person (OOP +NHIS) [mean (95% CI)]
		Outpatient visits	Inpatient services	Total OOP	Outpatient visits	Inpatient services	Total NHIS	Total costs
Whole Full Sample	Underweight	8.6 (6.3, 10.8)	9.3 (1.7, 19.1)	17.9 (10.0, 28.0)	15.6 (13.8, 19.0)	5.1 (2.7, 7.7)	22.1 (18.7, 25.5)	41.1 (30.4, 51.9)
	Normal	13.9 (6.4, 20.3)	4.3 (1.8, 6.8)	14.5 (10.3, 18.6)	13.5 (12.2, 14.8)	4.5 (3.4, 5.6)	20.3 (18.8, 21.7)	34.8 (29.9, 39.5)
	Overweight	19.4 (13.0, 25.7)	10.9 (1.5, 20.2)	30.2 (18.9, 41.5)	27.0 (23.6, 30.4)	20.3 (12.6, 27.1)	47.3 (41.7, 53.0)	77.5 (55.6, 95.8)
	Obese	33.3 (25.1, 41.5)	14.9 (6.0, 36.2)	48.2 (25.6, 70.8)	50.9 (44.6, 57.2)	18.9 (9.6, 28.1)	83.6 (60.7, 96.40)	131.9 (107.7, 162.1)
Only those who visited health facility	Underweight	17.4 (15.2, 25.5)	223.1 (52.5, 417.6)	233.5 (63.5, 429.8)	40.2 (38.3, 42.8)	121.6 (94.7, 141.5)	146.1 (116.7, 170.5)	379.6 (213.3, 567.2)
	Normal	18.1 (15.0, 21.2)	95.0 (48.7, 139.4)	116.4 (48.5, 196.6)	31.0 (29.7, 32.3)	99.0 (93.4, 110.3)	120.9 (111.6, 130.1)	234.0 (168.9, 317.9)
	Overweight	42.8 (30.5, 43.1)	220.8 (60.2, 390.0)	245.9 (82.3, 418.6)	59.7 (57.7, 61.0)	225.6 (229.6, 277.6)	292.3 (263.4, 317.0)	538.2 (373.4, 707.9)
	Obese	65.3 (53.8, 75.8)	326.8(124.5, 657.0)	381.7 (98.3, 722.0)	99.8 (95.3, 106.4)	413.6 (386.5, 534.6)	486.9 (457.7, 616.1)	868.6 (510.1, 1224.2)

Government bore for each person approximately 60% share of the total direct healthcare costs in the older adult population in 2014/15.
CI, confidence interval.

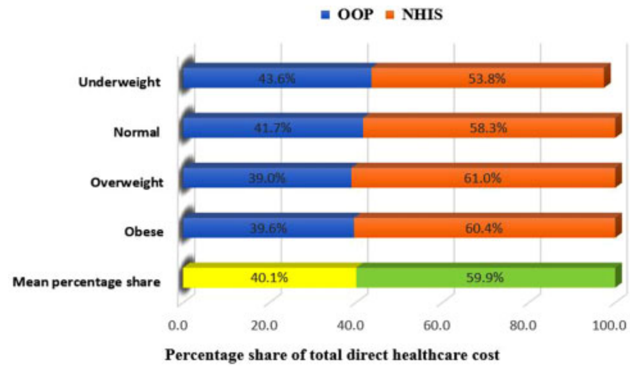

Figure 1 Percentage cost share per person between OOP and the NHIS costs, among older adult population in Ghana WHO-SAGE 2014/15. For each person, Government bore approximately 60% share of the total direct healthcare costs in the older adult population in 2014/15. Mean percentage cost share for OOP and that of NHIS are shown in the last bar.

(Singh *et al.*, 2013; Global Burden of Disease 2015 Obesity Collaborators, 2017) and the presence of chronic disease is associated with increased health service utilization, especially among older populations (Oostrom *et al.*, 2014; Brinda *et al.*, 2015; Global Burden of Disease 2015 Obesity Collaborators, 2017; Suehs *et al.*, 2017).

As obesity mediates the occurrence and exacerbation of chronic diseases, an increasing prevalence of overweight and obesity in the older adult population (Lartey *et al.*, 2019a) would likely increase health service utilization. Like most low- and middle-income countries, Ghana is facing a rapidly increasing burden of NCDs; however, the country's health systems are under-resourced and unprepared (de-Graft Aikins *et al.*, 2014; Baldwin, 2015; Ofori-Asenso *et al.*, 2016). The Ministry of Health's NCDs management strategy aimed to reduce overweight and obesity prevalence by 2% for people aged 15–49 years (Ministry of Health, 2012), with no plans for those aged 50 years and above. It can be argued that this strategy that neglects the 20% of the adult population of Ghana aged 50+ years—in whom the prevalence of overweight and obesity are rapidly increasing—is mistaken and requires urgent attention. Our study highlights the increasing burden and associated costs of overweight and obesity amongst these older age groups. These findings can be used by clinicians to increase surveillance on NCD markers and by decision-makers to develop evidence-based strategies for overweight and obesity in Ghana.

Another significant result was the finding of a positive association between overweight and obesity and a higher additional annualized healthcare cost. This finding agrees with previous international studies which also found that people who were overweight/obese relative to those with normal weight were associated significantly higher healthcare costs (Wang *et al.*, 2011; Wilkins *et al.*, 2012; Sturm *et al.*, 2013; Buchmueller and Johar, 2015; Dee *et al.*, 2015; Musich *et al.*, 2016; Suehs *et al.*, 2017). Overweight and obesity have been associated with increased healthcare costs that ranged from 19% to 95% that were in some instances more than doubled those of persons whose weights were normal (Finkelstein *et al.*, 2009; Buchmueller and Johar, 2015; Konig *et al.*, 2015; Suehs *et al.*, 2017). We found that relative to normal weight, overweight was associated with 73% additional total cost, and obesity was associated with more than a doubling of the total cost. This finding is also consistent with reports that such costs are driven by increased inpatient and outpatient utilization (Raebel *et al.*, 2004; Konig *et al.*, 2015; Suehs *et al.*, 2017). Finally, our finding that the government

Table 5 Prevalence-based NHIS and total direct healthcare costs (2014/15), by BMI categories among older adult population (50+ years) in Ghana

	Weight status			
	Underweight	Normal	Overweight	Obesity
Prevalence, %	10.1	53.8	22.9	13.2
2015 total adult population (aged 50 + y) = 3,462,016.00, *n*	349,664	1,862,565	792,801	456,986
Prevalence-based NHIS costs[a] (95% CI)	7,727,565.91 (6,538,709.62, 8,916,422.21)	37,810,061.54 (35,016,214.63, 40,417,651.99)	37,499,518.71 (33,059,829.39, 42,018,488.19)	38,204,038.96 (27,739,057.00, 44,053,461.20)
Prevalence-based total costs[a] (95% CI), $	$14 371 175 (10 629 774, 18 147 542)	$64 817 248 (55 690 682, 73 571 302)	$61 442 129 (44 079 773, 75 950 399)	$60 276 468 (49 217 404, 74 077 449)

[a]Prevalence-based costs estimated from total costs by weight status categories for full sample.
Population source: Ghana Statistical Service.
CI, confidence interval.

covered 60% of the total direct healthcare costs per person in 2014/15, suggests that high prevalence of overweight and obesity in the population potentially poses a substantial burden on the health budget.

Our study has some limitations. First, we used mean costs estimated from five districts of Ghana to estimate the NHIS costs for medications. Although the WHO-SAGE data are representative of the older adult population (Biritwum *et al.*, 2013) and medication prices do not change by district, medication costs from five districts may not be fully representative of the whole of Ghana. However, only these five districts provided complete claims data. In addition, unlike service-related costs that were estimated based on diagnoses, type of services and the level at which service was accessed, mean medication costs were assumed to be the same for all purposes but only differentiated based on outpatient or inpatient services. This may result in overestimating the medication costs if majority who visited the facilities required medications with lower costs or underestimate the medication costs if majority of people used medications that had higher costs. However, medication costs based on diagnosis for each person were not available at the time of data collection.

Second, service utilization and OOP costs in the WHO-SAGE were self-reported hence may be subject to recall bias. Any over- or under-reporting of the utilization and specific costs will likely introduce some degree of measurement error; although in WHO-SAGE, these data were reasonably well-reported (Kowal *et al.*, 2012) and this recall period may not have major effect (Kjellsson *et al.*, 2014; Dalziel *et al.*, 2018). Annual costs were estimated from costs incurred during the last health facility visit which was available from the WHO-SAGE. However, due to factors such as the season of visit and level of facility last visited, costs may be over- or underestimated. To provide additional scenarios around the costs, sensitivity analyses on annual costs were conducted by varying the unit (OOP, NHIS and total) costs by ±20%. Findings from the sensitivity analyses show that costs burden may differ based on the dispersion around the average costs. However, the significantly high costs burden due overweight and obesity compared with normal weight would remain the same. In addition, since this is population-based and not hospital data, our study may not have accounted for some specific healthcare costs directly associated with obesity from sections, such as physiotherapy and dietician services. Therefore, we propose that future health services utilization and healthcare costs evaluations use hospital data that would most likely capture all costs. Regarding costs, this study could not account for indirect costs including those associated with absenteeism or presenteeism as these were not captured in the WHO-SAGE. Even though the data are representative of the population aged 50 years and above, the analysis omits observations with missing data and BIVs. Hence, there is a chance for selection bias to be introduced that might have affected external validity. However, missing data formed <5% of the total sample, which is likely to have minimal effect on the analysis (Dong and Peng, 2013). Lastly, as this is a cross-sectional study the results are indicative of associations rather than causal relationships.

To the best of our knowledge, evidence of association between health service utilization as well as costs and BMI have been predominantly conducted in developed economies (Doherty *et al.*, 2012; Buchmueller and Johar, 2015; Dee *et al.*, 2015; Hugh *et al.*, 2015; Konig *et al.*, 2015; Suehs *et al.*, 2017) but are scarce especially, in sub-Saharan Africa. A major strength of this study is the effort made to extend such analyses to a sub-Sahara African setting where prevalence of overweight and obesity is reported to be on the increase.

Conclusion

This study provides evidence of the utilization and cost burden of overweight and obesity in Ghana. The results demonstrate that overweight and obesity were associated with increased health service utilization and direct healthcare costs. One in five respondents in the overweight or obese population had at least one chronic disease, and having chronic disease was associated with increased outpatient utilization. In addition, our study showed that even though the combined prevalence of overweight and obesity was 36%, the total cost burden was almost double that of normal weight. This cost burden to the government was high since it may have to bear more than half the healthcare costs per person. The results provide a compelling evidence to include those 50+ years in the Ministry of Health NCDs strategy and thus suggest the need for cost-effective and sustainable preventative and weight management programmes to mitigate the associated increased health service utilization and high-cost burden of overweight and obesity.

Data availability statement

Data from SAGE Ghana Wave 2 were used for this study. WHO-SAGE was approved by the WHO Ethics Review Committee

Table 6 Factors associated with direct healthcare costs (annualized cost per person) among older adult population in Ghana, 2014/15

	Annualised total costs (predicted incremental costs)				OOP costs (predicted incremental costs)				NHIS costs (predicted incremental costs)			
	Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate	
	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI
Weight status (Ref: normal)												
Underweight	20	−4.66, 37.47	20.35	−7.19, 19.88	10.81	−5.00, 22.60	9.48	−6.38, 11.35	12.6	−1.30, 6.49	10.51	−1.51, 8.53
Overweight	39.57***	24.96, 54.18	37.86***	26.71, 49.02	18.00**	6.47, 29.53	17.68***	9.67, 25.68	21.57***	15.90, 27.24	20.13***	15.08, 25.18
Obesity	87.68***	59.55, 115.81	63.96***	48.71, 79.20	35.98***	13.16, 58.79	28.16***	18.83, 37.48	51.71***	40.04, 63.37	34.64***	26.92, 42.36
Sex (Ref: male)												
Female	17.04**	7.16, 26.93	14.03	−1.52, 22.32	1.5	−7.61, 8.6	1.06	−5.57, 10.77	16.53***	12.59, 20.48	7.75***	3.60, 11.89
Age, years	3.4	−.09, 8.95	1.81**	0.91, 3.30	1.32	−0.15, 3.79	1.45**	1.30, 7.55	1.18	−2.02, 3.84	1.34**	0.13, 2.55
Educational level (Ref: low)												
High	31.61***	16.05, 47.17	17.19**	7.23, 27.16	23.63***	10.71, 36.54	12.21***	5.76, 18.67	7.98**	2.68, 13.28	5.64	−0.99, 8.26
Marital status (Ref: single)												
Married/Co-habiting	20	−9.31, 49.56	34.11*	0.27, 67.96	7.19	−10.20, 24.68	9.29	−6.03, 24.61	12.93*	0.35, 25.51	23.70**	5.91, 41.49
Divorced/separated/Widow	36.47*	6.92, 66.02	42.47*	9.80, 75.14	11.19	−6.00, 28.37	11.62	−2.55, 25.79	25.28***	12.06, 38.50	28.48**	10.53, 46.42
Location (Ref: rural)												
Urban	16.11*	3.92, 28.31	10.97	−2.57, 24.37	5.70	−3.57, 15.00	6.16	−2.20, 17.11	10.41***	5.26, 15.56	7.91	−2.73, 12.92
Employment status (Ref: unemployed)												
Employed	21.43**	6.68, 36.18	9.1	−0.59, 8.78	13.95	1.81, 26.08	5.94*	1.50, 11.37	7.48**	2.08, 12.89	3.17	−2.38, 6.71
Household wealth status (Ref: lowest)												
Low	11.47**	4.37, 18.58	15.11*	1.63, 28.58	3.5	−0.05, 7.04	4.22	−3.55, 11.99	7.97**	3.46, 12.49	8.57*	1.95, 16.20
Moderate	23.07***	13.12, 33.01	28.72**	11.96, 45.47	9.31	2.82, 15.81	14.31*	3.06, 25.56	13.75***	8.67, 18.83	12.34**	4.70, 19.99
High	41.54***	30.38, 52.71	38.24***	22.73, 53.75	16.87	9.34, 24.41	18.86***	8.81, 28.91	24.67***	18.52, 30.82	18.30***	10.45, 26.16
Highest	65.97***	46.00, 85.94	45.73***	29.53, 61.93	34.24	18.27, 50.21	24.57***	13.74, 35.40	31.72***	23.93, 39.52	19.28***	10.84, 27.73
Health insured (Ref: uninsured)												
Insured	13.19*	1.70, 28.07	7.34	−2.63, 17.31	−2.09	−8.97, 10.79	3.53	−10.00, 5.91	15.27***	10.91, 19.63	12.52***	8.23, 16.81
Having chronic disease (Ref: no)												
Yes	27.15*	5.73, 48.58	18.01	−1.09, 25.07	10.85*	2.11, 28.81	7.45	−8.08, 18.13	16.30***	7.80, 24.80	10.84	−3.78, 16.81
Intercept	51.54***	45.75, 57.32	51.79***	46.35, 57.22	21.47***	17.04, 25.91	21.16***	17.51, 25.84	30.06***	27.55, 32.58	30.24***	27.73, 32.75

CI, confidence interval.
$^*P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

(reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). The necessary permission was obtained from the World Health Organization to use these data. All files were obtained from the World Health Organization Study on global AGEing and adult health (WHO-SAGE). Details on data can be found at http://www.who.int/healthinfo/sage/cohorts/en/. The authors used the GhanaINDDataW2 and GhanaHHDataW2. The codes for the measured weight and height used to calculate BMI, as used in the data are q2506 for weight and q2507 for height. The authors confirm that they had no special access privileges to the data. Interested researchers will have to submit a data request to WHO. Upon approval, the researchers will be granted access.

Supplementary data

Supplementary data are available at *Health Policy and Planning* online.

Authors' contribution

S.T.L., B.d.G., C.G.M., L.S. and A.J.P. conceived and designed the study. S.T.L., L.S., B.d.G., and A.J.P. analysed the data. S.T.L., L.S., C.G.M., B.d.G., G.O.B., M.A. and A.J.P. wrote the original draft. S.T.L., B.d.G., C.G.M., G.O.B., M.A., N.M., P.K., L.S. and A.J.P. validated the results, reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Conflict of interest statement. None declared.

Ethical approval. WHO-SAGE was approved by WHO's Ethical Review Committee (reference number RPC149) and the University of Ghana Medical School Ethics and Protocol Review Committee in Ghana (Kowal *et al.*, 2012). Secondary analyses of data were done for this study; therefore, the authors were not required to obtain a separate ethics approval. The NHIS claims data used to estimate medication costs in this study is secondary data that did not require ethical approval from the Ghana Health Service Ethical Review Committee (GHSERC). However, permission was obtained from the NHIA to use the data for this study.

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Appendix 5. Publication of Chapter 6

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Annual transition probabilities of overweight and obesity in older adults: Evidence from World Health Organization Study on global AGEing and adult health

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ABSTRACT

Overweight/obesity is becoming increasingly prevalent in sub-Saharan Africa including Ghana. However, transition probabilities, an essential component to develop cost-effective measures for weight management is lacking in this population. We estimated annual transition probabilities between three body mass index (BMI) categories: normal weight (BMI ≥18.5 and < 25.0 kg/m^2), overweight (BMI ≥25.0 and < 30.0 kg/m^2), and obesity (BMI ≥30.0 kg/m^2), among older adults aged ≥50 years in Ghana. Data were used from a nationally representative, multistage sample of 1496 (44.3% females) older adults in both Waves 1 (2007/8) and 2 (2014/15) of the Ghana WHO SAGE. A multistage Markov model was used to estimate annual transition probabilities. We further examined the impact of specific socio-economic factors on the transition probabilities. At baseline, 22.8% were overweight and 11.1% were obese. The annual transition probability was 4.0% (95% CI: 3.4%, 4.8%) from normal weight to overweight, 11.1% (95% CI: 9.5%, 13.0%) from overweight to normal weight and 4.9% (95% CI: 3.8%, 6.2%) from overweight to obesity. For obese individuals, the probability of remaining obese, transitioning to overweight and completely reverting to normal weight was 90.2% (95% CI: 87.7%, 92.3%), 9.2% (95% CI: 7.2%, 11.6%) and 0.6% (95% CI: 0.4%, 0.8%) respectively. Being female, aged 50–65 years, urban residence, having high education and high wealth were associated with increased probability of transitioning into the overweight or obese categories. Our findings highlight the difficulty in transitioning away from obesity, especially among females. The estimated transition probabilities will be essential in health economic simulation models to determine sustainable weight management interventions.

1. Introduction

Globally, the prevalence of obesity is progressively increasing and has almost doubled in those aged ≥18 years between 1980 and 2014 (Mendis et al., 2014). This trend is also seen in sub-Saharan Africa including Ghana, where females and urban dwellers have relatively high overweight/obesity prevalence (Agyemang et al., 2015; Biritwum et al., 2013; Lartey, et al., 2019a,b,c). Nationally representative studies in Ghana suggest that the prevalence of overweight/obesity increases with age (Biritwum et al., 2013; Ghana Statistical Service GSS, Ghana Health Service GHS, & ICF International, 2015). High and increasing prevalence of overweight/obesity has implications for physical (Global

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Burden of Disease, 2015 Obesity Collaborators, 2017; Prospective Studies Collaboration et al., 2009; The Lancet Neurology, 2013) and mental health (Barry et al., 2008; Pickering et al., 2011), quality of life (Keating et al., 2013; Kortt and Clarke, 2005) and hence the potential to increase cost burden on the health system and the general economy (Daniels. et al., 2014; Lehnert et al., 2013; Tremmel et al., 2017; Tucker et al., 2006). These implications of obesity may be exaggerated among older adults (50+ years) (The Global Burden of Disease 2015 Obesity Collaborators, 2017).

Given the high prevalence of overweight/obesity and the difficulty in returning to normal/healthy weight once classified as overweight or obese (Avery et al., 2016), coupled with the impact overweight/obesity has on the health of older adults, economic evaluation and implementation of weight reduction strategies have become increasingly important in affected populations. When conducting economic evaluations, health economists are interested in both health resource management and the health outcomes of a given intervention. . A higher interest in economic evaluations arises when there is resource scarcity but greater investment into a preventive or treatment strategy. The pharmaceutical industry uses economic evaluations for decision making prior to large investment in various trials to decide the chances that a new drug would be cost effective (Briggs and Sculpher, 1998). Health economic evaluation is used to determine whether a health technology is cost-effective. There are three ways of conducting a health economic evaluation, i.e. clinical trial-based, economic modelling-based and a combined (Drummond et al., 2015). Health economic evaluation modelling (e.g. the Markov model) is mostly useful for chronic diseases and it is used to synthesize key parameters used for decision making. In this, the risk factor/disease is divided into distinct states and transition probabilities assigned for the movement between states (Briggs and Sculpher, 1998). Attaching the transition probabilities in economic evaluation ensures appropriate estimation of long-term costs and health effects. Additionally, reliable estimation of transition probabilities is required for the correct implementation of such models, and the models are mostly used to determine cost-effective interventions for the risk factor or disease (Olariu et al., 2017). On their own, transition probabilities and sojourn times would provide very essential information on both short and in particular long term risk (s), health and cost implications of each distinct health state.

An increasing prevalence of obesity in Ghana (Lartey et al., 2019a,b,c; Ofori-Asenso et al., 2016) calls for urgent information on the distinct state risks, health and costs implications. Such information is essential for health education; public health/clinicians prescription of interventions; and government and health systems preparedness as obesity is a major risk factor for NCDs. Additionally, the trends in prevalence demands for the development of evidence based cost-effectiveness analysis of preventive strategies for weight reduction. This will ensure "value-for-money" in the choices of alternative strategies. However, cost effectiveness analysis of interventions in obesity is lacking in Ghana due to a limited number of transition probabilities in obesity health economics models. As a consequence, prediction of the course of weight gain or reduction in patients who suffer from obesity-related diseases such as diabetes is challenging.

Key challenges to estimating transition probabilities are the lack of necessary data and previously unclear methods for estimation (Ahmad et al., 2018; Avery et al., 2016; Jackson, 2011). The WHO SAGE provides current appropriately structured data which makes estimating transition probabilities possible. Additionally, in recent years, there are a wide range of multistate modelling methods to estimate transition probabilities and some of these methods can also be used to examine the effects of covariates on the obtained probabilities (Foucher et al., 2007; Jackson, 2011; Kassteele et al., 2012; Welton and Ades, 2005). Thus, this study aimed to estimate the annual transition probabilities between normal weight, overweight, and obesity among the older adult population in Ghana; and investigated factors associated with these transition probabilities. To the best of the authors' knowledge, this is the first study that estimates the BMI-specific annual transition probabilities for the Ghanaian population.

1.1. Transitions in disease stages

Obesity is associated with a burden of health risks as well as negative economic consequences for individuals, communities, and nations (Boateng et al., 2017; Global Burden of Disease, 2015 Obesity Collaborators, 2017; Tremmel et al., 2017). For instance, people with obesity are at a higher risk of several chronic diseases, poor quality of life, and overall mortality (Keating et al., 2013; Prospective Studies Collaboration et al., 2009). It is also accompanied by a higher cost in health management which is a burden to households and puts pressure on publicly financed healthcare systems (Lartey et al., 2019a,b,c; Musich et al., 2016; Suehs et al., 2017). These effects have worsened over the years due to the shifting age structure of the global population and changing trends in urbanization and lifestyle in developing countries, which have culminated in the prevalence of adult obesity nearly doubling from 1980 to 2014 (Global Burden of Disease, 2015 Obesity Collaborators, 2017). The continual increase in obesity prevalence requires that households and nations have the capacity to plan for financial management of these health problems if life expectancies are to continue to increase.

Medically, it is known that individuals transition between disease stages for most diseases or risk factors experienced (Engeda et al., 2018; Jackson, 2011). Diseases such as cancer do progress in stages from 0 to 4 for many types of cancer, with the higher number generally indicative of the greater extent to which the cancer has spread (American Cancer Society, 2015). Similarly, there are three stages of human immunodeficiency virus (HIV) infection. Stage 1, signifying an initial acute infection; stage 2, the asymptomatic stage; and stage 3, the symptomatic stage, where the person's immune system is severely damaged (Hernandez-Vargas and Middleton, 2013). These stages of diseases and progression between stages helps physicians determine the survival rate of patients, the kind of treatment to give, predict the effectiveness of treatments, and how to manage the disease. Such classifications also facilitate the estimation of the cost to be incurred by either the individual and/or a healthcare system depending on whether the person is insured or not insured (Finkelstein et al., 2012). Although several simulation studies have been used to determine how a person progresses from one disease stage to the other, most of these have been explained from a medical standpoint.

From a social science perspective, there are fewer studies that focus on estimating the probability of transitioning from one disease stage to another (Fleurence and Hollenbeak, 2007). In the area of predisposing health risks such as obesity, the lack of knowledge of transition probability makes it difficult for health economists to conduct health economic evaluations for policy makers to decide which health intervention to fund. If effective and cost-effective health interventions are unable to be determined, obesity-associated NCDs might cause long term comorbidities and mortality (Singh et al., 2013) over time given the increasing trend of obesity in Ghana (Lartey et al., 2019a,b,c). In low and middle-income countries the increasing obesity prevalence, a major risk factor of NCDs, is likely to lead to increasing burden of NCDs (Baldwin, 2015; Singh et al., 2013; World Health Organization, 2005) and dwindling health gains as obesity will reduce life expectancy (Lung et al., 2018). If clinicians, public health practitioners and the patient are aware of the chances of transitioning from a lower BMI to a higher BMI and sojourn times, reaching a particular BMI state would serve as a signal for appropriate sustained action. Additionally, availability of transition probability to support economic evaluation would identify specific cost-effective strategy to prevent or manage high BMI.

Diseases or risk factors such as obesity with dire health and economic consequences (Campbell et al., 2019; Lartey et al., 2019a,b,c; Lehnert et al., 2013; Lung et al., 2018; Singh et al., 2013) can be prevented if health economists can find cost-effective interventions. Also, awareness of transitions, key populations affected, and cost-effective measures could lead to a more informed health education and risk prevention implementation (O'Loughlin et al., 1999), and improve general and targeted surveillance of obesity and obesity-related diseases in the population. Also, the estimates will be used to support the development of sustainable and cost-effective measures if data on transition probabilities and average sojourn times are available. This is because transition probabilities are among essential parameters used to develop models which are normally used to predict long-term effects and for cost-effective analysis of alternative strategies (Drummond et al., 2015; Graaff et al., 2017). Additionally, as it signals the health and costs implications in specific health states, knowledge of sojourn times will support health systems and financial preparedness and planning for both the affected individual and the health sector. This is because transition probabilities also show the proportion of the population at risk who move over a particular period of time into adjourning health states (Briggs and Sculpher, 1998; Miller and Homan, 1994). Thus, the estimates can inform health financing policies designed to ameliorate health disparities (Avery et al., 2016).

So far, in sub-Saharan Africa, such evidence as to how adults move between various BMI categories termed as the health states, factors that influence such movement and how long an individual will spend in a particular health state are unknown. Consequently, this study seeks to use a Markov theory to estimate the probability of progressing between the different stages of weight gain – normal weight, overweight, to obesity. The theory, which is explained further in the methods section assumes that the future state of a particular event only depends on the current state and not the previous states (Jackson, 2011). Briefly, Fig. 1 suggests that individuals who have normal weight may remain in the same BMI category or can transition to overweight; the same can transition into obesity only after entering the overweight category. Similarly, those who are overweight can transition in time to normal weight or to obese.

Previous studies have emphasized the difficulty in transitioning away from high BMI (Avery et al., 2016; Basu, 2010) while others have shown the sojourn time which is essential in revealing the implications of obesity (Moreira et al., 2018). Even though the characteristics of obesity may not differ in populations, manifestations such as who are the affected, proportion affected and duration of the impact may differ due to local factors (Basu, 2010; Bowden and Mosley, 2012; Low et al., 2009; Subramanian et al., 2011). On the basis that findings from previous studies may differ from those in the Ghanaian populations (Avery et al., 2016; Fildes et al., 2015; Moreira et al., 2018), for the first time using Ghanaian data we hypothesize that in a year.

1) individuals who are obese will have a higher probability of staying obese than transitioning to overweight.
2) the sojourn time at the stage of obesity before transition will be higher than the sojourn time at overweight.
3) individuals who are overweight will have a higher probability of transitioning to obese than to normal weight.
4) individuals who are normal weight will have a higher probability of staying normal than transitioning to overweight.

2. Methods

2.1. Study population

Data from the World Health Organization Study on global AGEing and adult health (WHO SAGE) in Ghana were used in this study. The WHO SAGE is a longitudinal study on the health and well-being of adult populations aged ≥50 years in six countries: China, Ghana, India, Mexico, Russian Federation, and South Africa. It also collects sample data of younger adults, aged 18–49 years for comparison. In Ghana, WHO SAGE collected individual-level data from nationally representative households of adults using stratified, multistage cluster design. The sampling technique used in both Waves 1 (2007/08) and 2 (2014/15) was based on the WHO SAGE wave 0 in which the primary sampling units were stratified by region and locality (urban/rural) (Biritwum et al., 2013; Charlton et al., 2016; World Health Organization, 2006). Systematic replacement was used in Wave 2 to account for losses to the sample from Wave 1.We used the socio-demographic characteristics and the anthropometrics measurements covered in the individual questionnaire (Biritwum et al., 2013).

2.2. Classification of body mass index

Body weight and height of respondents were measured by trained assessors using standard protocols (Ghana Statistical Service GSS, Ghana Health Service GHS, & ICF International, 2015; World Health Organization, 2006). Pregnant women were exempted from weight measurements in both surveys (World Health Organization, 2006). BMI was calculated as a person's weight in kilograms divided by the square of their height in meters (kg/m^2). WHO classifications were used to categorize BMI as follows: normal/healthy weight, BMI $\geq$18.5 and $<$ 25.0 kg/m^2; overweight, BMI = 25.0 and $<$ 30.0 kg/m^2; and obesity as BMI $\geq$30.0 kg/m^2 (National Institute of Health, 1998).

2.3. Covariates

Covariates used in this study included sex, categorized as male/female; age, recorded as 50–65 years and above 65 years; and the level of education which was categorized as low education where educational level completed was less than secondary or high school, and high education where a person completed secondary/high school and above. Location of residence was coded as rural/urban residence; and household wealth index constructed from a total of 22 assets/characteristics/items were converted into wealth quintiles (Filmer and Pritchett, 2001; Lartey et al., 2016; Lartey, et al., 2019a,b,c).

2.4. Statistical analysis

Characteristics of the cohort used were described. Annual transition probabilities from the cohort were estimated using a validated multi-state continuous-time Markov model in the "msm" package in R (Jackson, 2011). A transition probability meets the requirement of the Markov assumption that future evolution only depends on the current

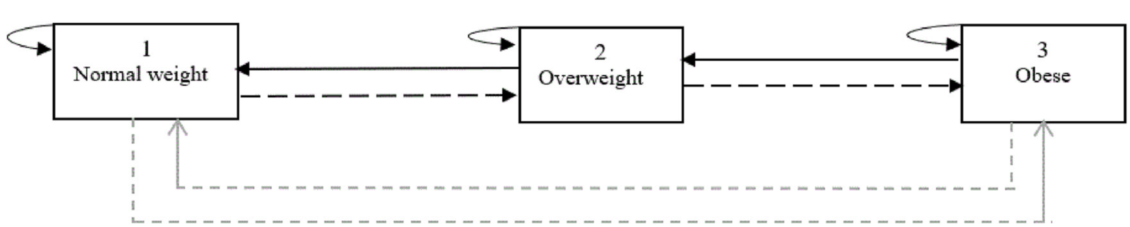

Fig. 1. Allowable transitions between BMI states used to estimate annual transition possibilities. The arrows illustrate the possible transitions between states. State transition can be a transition into the immediate next state, previous or into itself. A bidirectional transition is allowed. A two-step movement is allowed; however, the subject may pass through the immediate adjacent state first. Respondent can be in only one state at a time. Movement from normal weight to obese state and vice versa are shown in grey colours to show that these movements are possible; however, the individual will have to first pass through the overweight state.

Table 1
Sample characteristics.

		Wave 1 (2007/08)	Wave 2 (2014/15)
		n (%)	n (%)
N		1496	1496
[a] BMI category	Normal weight	989 (66.1)	981 (65.6)
	Overweight	341 (22.8)	340 (22.7)
	Obese	166 (11.1)	175 (11.7)
Sex	Females	664 (44.3)	664 (44.3)
	Males	834 (55.8)	834 (55.8)
Age group	50–65	1096 (73.3)	793 (53.0)
	> 65	400 (26.7)	703 (47.0)
Educational status	High	432 (28.9)	436 (29.1)
	Low	1064 (71.1)	1060 (70.9)
Location	Rural	884 (59.1)	890 (59.5)
	Urban	612 (40.9)	606 (40.5)
Wealth status	Lowest	251 (16.8)	168 (11.2)
	Low	291 (19.5)	349 (23.3)
	Moderate	327 (21.9)	295 (19.7)
	High	311 (20.8)	351 (23.5)
	Higher	316 (21.1)	333 (22.3)

[a] BMI: body mass index.

state. The Markov model has been applied and validated in several previous clinical studies (Ahmad et al., 2018; Majer et al., 2011; Mdala et al., 2014; Moreira et al., 2018). In this study, we applied a three-BMI-states model using the previously defined normal weight, overweight and obese categories (Fig. 1). In this model, the underlying progression into a specific state rather than the observed progression is emphasized since transition may have mostly occurred outside the follow-up dates and a two-step movement (i.e. movement into the next two states) is not necessarily instantaneous. Thus, a person with normal weight at time $t = 0$, may pass through the overweight state before ending in the obese state at time $t = 1$.

Since the exact time of transition is not observed but evolved continuously in time and is presumed to have occurred before the next assessment, the state-to-state transitions are interval-censored (Jackson, 2011; Mdala et al., 2014; Moreira et al., 2018). Thus, due to unknown exact transition time and irregular follow-up times for assessment among individual observations, the standard multistate model could not be used. Rather, we employed the time-homogenous continuous-time Markov model that can accommodate such irregularities to calculate transition intensities and probabilities (Jackson, 2011). At time t in the model, the individual is in state S(t). Movement into the next state is guided by a set of transition intensities, (i.e. the rate at which an individual has the likelihood of moving from one state i to another state j at a given time t). The intensities form a “3 x 3” matrix Q whose rows sum to zero. The diagonals of the matrix are the rates at which individuals do not transition and remain in their state whereas the off-diagonals represent the rates at which individuals transition into other states (Jackson, 2011; Mdala et al., 2014; Moreira et al., 2018). The model specified that an individual transitioning to a nonadjacent state (e.g. from normal weight to obese state) must have passed through the immediate adjacent state (i.e. overweight state) rather than a direct movement to a nonadjacent state. Therefore, the maximum likelihood estimate was zero for the nonadjacent states (i.e. a two-step movement).

Under the assumption that Q is constant over time, the transition probability P(t), which is the chance of transitioning from one stage to the other is calculated by taking the matrix exponential of the scaled transition intensity matrix as follows:

$$\mathbf{P(t)} = \mathbf{Exp(tQ)} \quad t \geq 0$$

In this study, the annual transition probabilities were calculated. Additionally, using the unadjusted model, we calculated the mean sojourn times (i.e. the average time spent in a specific state before transitioning into another state) for each state. Due to the model flexibility, covariates including sex, age, educational level, location of residence and household wealth status were fitted in separate models to examine if these factors changed the probabilities.

To validate the estimated transition probabilities, a Markov model was developed in TreeAge Pro (2018) (TreeAge Software Inc. Williamstown, Massachusetts, USA). Four Markov states were included in the model, i.e. normal BMI, overweight, obesity and died. Subjects moved between states on the basis estimated transition probabilities. The starting cohort was set according to the baseline of the WHO SAGE cohort, i.e. age was 50 years, prevalence of normal weight was 66.2%, overweight was 22.8%, obesity was 11%. Age-specific mortality risk was taken from the Ghanaian life table (World Health Organization (Global Health Observatory data repository)). Cohort analysis was run with a 5-year interval and prevalence of the three BMI states was compared to the observed prevalence in Wave 2 (Mdala et al., 2014). The probabilities were valid if the observed prevalence in Wave 2 fell within the 95% CI of the estimated expected prevalence or if the observed prevalence in Wave 2 falls 1% lower or higher above the expected prevalence.

Statistical analyses were performed using R (Foundation for Statistical Computing, Vienna, Austria) (R Development Core Team, 2016) and TreeAge Pro 2018 (TreeAge Software Inc., Williamstown, Massachusetts, USA).

3. Results

A total of 1496 respondents aged 50+ years with complete anthropometric measurements and responses to covariates in both Wave 1 (2007/08) and Wave 2 (2014/15) of the WHO SAGE in Ghana were analysed (Table 1). At baseline, 56% were males, 73.3% were aged 50–65years, 22.8% were overweight and 11.1% were obese. Table 2 shows the frequency of transitions observed in each of the three BMI states at time 1 (2007/08) and time 2 (2014/15). Transitions occurred between all three BMI states. One hundred and ninety-one people transitioned from normal weight to a high BMI state (overweight or obese), while 77 people transitioned from the obese state to a less severe BMI state (normal weight or overweight). One hundred and forty-two individuals transitioned from overweight to normal weight, 142 people remained in the overweight state, while 57 moved from the overweight to the obese state.

The transition intensity matrix showing the maximum likelihood estimates (95% confidence intervals) over an average period of seven years is presented in Table 3. The results show that even though individuals with normal weight were more likely to transit to the overweight state (0.045) and transition from overweight into an obese state (0.056), the likelihood increased for a transition from overweight into the normal weight (0.124) and from the obese state to overweight state (0.106). From the estimated intensities, the mean sojourn time for normal weight was 22.2 years, 5.6 years for overweight, and 9.4 years for obese.

The estimated annual transition probabilities are shown in Table 4. The annual transition probability from normal weight to overweight was 4.0% (95% CI: 3.4%, 4.8%) and from normal weight to obesity was

Table 2
The beginning to end transition (n = 1496) between the three BMI states.

First Assessment		Last Assessment		
		Time 2 (Wave 2)		
		Normal weight	Overweight	Obesity
Time 1 (Wave 1)	Normal weight	798	162	29
	Overweight	142	142	57
	Obesity	41	36	89

Table 3
Transition Intensity matrix for a Multistate Markov Model of the Transition Between Normal Weight, Overweight and Obesity Across Older Adults (50+ years) in Ghana (2007/08–2014/15). The Mean Time Spent in the Normal Weight State Before a Transition was Made Into Another State was −1/(-0.045) = 22.2 years, a Mean of −1/(-0.180) = 5.6 years for Overweight and a Mean of −1/(-0.106) = 9.4 years for Obese.

From	To					
	Normal		Overweight		Obese	
	MLE[a]	95% CI	MLE	95% CI	MLE	95% CI
Normal	−0.045	−0.053, −0.038	0.045	0.0378, 0.053	0[b]	–
Overweight	0.124	0.104, 0.148	−0.18	−0.209, −0.155	0.056	0.043, 0.073
Obese	0[b]	–	0.106	0.082, 0.137	−0.106	−0.137, −0.082

[a] MLE indicates maximum likelihood estimation.
[b] MLE was zero for the nonadjacent states (i.e. a two-step movement). Thus, the model specified that an individual transitioning to a nonadjacent state (e.g. from normal weight to obese state) must have passed through the immediate adjacent state (i.e. overweight state) rather than a direct movement to a nonadjacent state. The diagonals of the matrix are the rates at which individuals do not transition and remain in their state whereas the off-diagonals represent the rates at which individuals transition into other states (Jackson, 2011; Mdala et al., 2014; Moreira et al., 2018).

0.1% (95% CI: 0.0, 0.2%). After one year, the transition probability from overweight to normal weight was 11.1% (95% CI: 9.5%, 13.0%) and overweight to obese was 4.9% (95% CI: 3.8%, 6.2%). For obese individuals, the probability of remaining obese was 90.2% (95% CI: 87.7%, 92.3%), the probability of transitioning to overweight was 9.2% (95% CI: 7.2%, 11.6%) and the probability of reverting to normal weight was 0.6% (95% CI: 0.4%, 0.8%).

A validity check of the model estimated prevalence showed good concordance with the observed prevalences. The Markov model calculated prevalences (95% CI) in Wave 2 were 64.6% (63.5%, 65.7%) for normal weight, 23.2% (23.0, 23.6%) for overweight and 12.2% (11.5, 12.8%) for obese. The corresponding observed Wave 2 prevalences were 65.6%, 22.7% and 11.7% for normal weight, overweight and obesity respectively.

The impact of specific socio-economic factors on one year transition probabilities are presented in Appendix 1. Being female was associated with increased probability of transitioning from normal weight to overweight (5.7%; 95% CI: 4.5, 7.1), from overweight to obese (5.1%; 95% CI: 3.8, 6.7) and remaining obese (93.3%; 95% CI: 90.9, 95.1) over a one-year period (Table 4). However, the transition probability associated with males who transitioned from overweight to obesity was higher compared to females (males: 6.6%; females 5.1%). The probability of moving from obesity to overweight was lower for females (6.3%; 95% CI: 4.5, 8.6), although higher for males (23.7%; 95% CI: 14.0, 37.9). Thus, whereas females had the higher probability to remain obese (93%), for males this was lower (75%). Transition probabilities relating to age showed variable associations; for adults aged 50–65 years, the probability of transitioning from normal weight to overweight was higher when compared to those aged over 65 years. Meanwhile, the probability of transitioning from obese to overweight was lower for those aged 50–65 years when compared with those aged over 65 years. Those with a high education compared to low education, living in urban areas compared to rural areas, and higher wealth compared to lower wealth showed an increased probability of transitioning from normal weight into the overweight or obese category in the next 12 months (Appendix 1).

Statistically significant hazard ratios were estimated for sex, urban living and household wealth (Appendix 2). The ratios were mostly significant for the progressive transitions, that is, female sex, living in urban area and having higher wealth were associated with a transition from normal weight to overweight.

4. Discussion and conclusion

To the best of the authors knowledge, this is the first study that provides transition probabilities for older adults and applies a multistate Markov transition model to older adults' BMI status in sub-Saharan Africa with a specific focus on Ghana. Key findings from this study are discussed as follows: first, the annual transition probabilities showed that after one-year persons who began the year as obese had 90% chances of remaining obese at the end of the year while the probability of reverting to normal weight in the same year from obese was 0.6%; and obese persons were more likely to remain in the same state for nine and half years before transitioning into any adjacent state. Second, individuals were more likely to transition from overweight to normal weight, followed by obese to overweight, overweight to obese and then normal weight to overweight. However, after one year, the estimated probabilities of normal weight individuals moving into the obese state and obese individuals becoming normal weight were marginal. Finally, factors including being female, higher education, urban residence and higher wealth index were associated with higher probabilities of transitioning from normal weight to higher BMI categories and remaining in high BMI category after one year.

First, the estimated probabilities show that individuals were more likely to be stable in their BMI status after one year. For example, the probability of remaining obese was 90% and such individuals who remained obese were more likely to be in this state for a much longer period before making any transition into adjacent states. This suggests the probability of transitioning from obesity to normal weight within one year was very slim. This is further supported by the findings on the average sojourn times; the obese older adult will stay in the obese state for approximately nine and half years before transitioning into another state while the average sojourn time was approximately six years for overweight state. With obesity as a major risk factor for NCDs, a higher probability of remaining obese and longer average sojourn time for

Table 4
One Year Transition Probabilities (95% Confidence Intervals) Between Normal Weight, Overweight and Obesity Across Older Adults (50+ years) in Ghana (2007/08–2014/15).

	To						
	From	Normal Weight		Overweight		Obese	
		Probabilities	95% CI	Probabilities	95% CI	Probabilities	95% CI
Total	Normal Weight	0.959	0.951, 0.965	0.040	0.034, 0.048	0.001	0.0, 0.002
	Overweight	0.111	0.095, 0.130	0.840	0.819, 0.858	0.049	0.038, 0.062
	Obese	0.006	0.004, 0.008	0.092	0.072, 0.116	0.902	0.877, 0.923

Note: One-year transition probabilities between normal weight, overweight and obesity among older adults estimated using Wave 1 (2007/8) and Wave 2 (2014/15) of the WHO-SAGE.

obese individuals could have implications on NCDs burden of disease and ultimately on productivity and government health expenditure. Hence, the dire need for public health planning and cost-effective interventions that prevent transitions to overweight or obese state.

Second, more older adults were likely to transition from overweight to normal weight (11%) compared to a transition from overweight to obesity (5%). International studies have shown similar trends but with different magnitudes in their estimates (Basu, 2010; Fildes et al., 2015). Thus, in the US, while 16% of adults reverted from overweight to normal weight, 12% and 0.7% transitioned into obese class 1 ($30.0 \leq BMI < 35.0 kg/m^2$) and 2 ($35.0 \leq BMI < 40.0 kg/m^2$) respectively, from overweight (Basu, 2010). Furthermore, compared to findings in the US, our finding of 4% one-year transition probability from normal weight to overweight, 5% from overweight to obese state, 9% from obese to overweight, and 11% from overweight to normal weight were relatively small (Basu, 2010). Additionally, the transition probability from normal weight to obese (0.1%) or obese to normal weight (0.6%) was marginal in our study. Thus, generally while the probability of transitioning into the immediate adjacent weight state (for example from normal weight to overweight) was higher, the probability of transitioning into a nonadjacent weight status or a two-step movement remains small (for example, from obese to normal weight status) within one year.

Our study highlights factors associated with transitions. We observed that being female compared to male was associated with higher probabilities of transitioning from normal weight to overweight. Additionally, the probability of an obese female reverting to overweight (6.3%) or to normal weight (0.4%) was lower compared to the probabilities for males (obese to overweight = 23.7%; and obese to normal = 1.6%). Thus, females had the higher probability to remain obese (93%) compared to males (75%), suggesting that being male seems to protect older adults from remaining obese. Our results agree with findings in a previous study in which the probability of attaining weight reduction was higher in males compared to females (Fildes et al., 2015). The lower probability of transitioning from normal weight into overweight and the higher probability of transitioning from obese to overweight in those over 65 years compared to those lower than 65 years is also consistent with previous findings (Hajek et al., 2015). Our findings of how education, place of residence and wealth status were associated with the probability of transitioning to and from different BMI statuses will be useful in targeting high risk older adults for weight reduction programs, and in the development of health economic simulation models that will identify cost-effective interventions for weight management in Ghana.

As the major strength of this study, data from WHO SAGE, which is one of the most current and a longitudinal study that collects a nationally representative data of older people was used to estimate annual transition probabilities; and the calculation was validated using a multistate Markov model. This is the first study within a sub-Saharan African context that has estimated BMI-specific annual transition probabilities. The estimated transition probabilities will be useful to estimate, extrapolate and monitor the burden of overweight/obesity which has previously been monitored only using prevalence studies. Our findings highlight the difficulty in transitioning away from obesity especially for females, once they become obese they are very likely to stay obese. Additionally, findings of the average sojourn time for especially obese persons would provide a platform for policy makers to amend strategies to prevent overweight/obesity in the older adult population, retool health practitioners to actively monitor BMI and help prevent the consequences of overweight/obesity in this population. Apart from age and sex, findings of associated factors which most studies did not consider (Basu, 2010; Chen et al., 2015; Fildes et al., 2015; Moreira et al., 2018) will be useful in targeting preventive measures. Finally, the estimated transition probabilities can form an integral part of health economic evaluations both to develop cost-effective weight reduction measures and for any disease in which overweight and obesity play a significant role, e.g. diabetes or hypertension (Basu, 2010).

The study has some limitations that are worth noting. First, this study may be limited by the period from which estimates were gathered; future changes in prevalence may alter the estimated probabilities. The estimated transition probabilities were estimated in adults aged over 50 years and residing in Ghana such that inferences may not apply to other populations due to different environmental and social factors. Second, previous studies have shown that measuring obesity using BMI does not fully capture important aspects such as central adiposity and therefore, other anthropometric measures are suggested to provide more accurate measures (Boateng et al., 2017; Ekoru et al., 2018; Klein et al., 2007). Due to data inadequacy and availability of full information on respondents with complete information of BMI, we used BMI as the measure of obesity in this study. Also, even though the use of BMI is associated with limitations (Ekoru et al., 2018), it has been considered as the gold standard measuring obesity (Klein et al., 2007). Also, given that there could be an issue of loss-to-follow-up, which could not be fully accounted for due to the lack of variables to track reasons for such loss, we used a complete data set for our analysis. Finally, the scope of this study did not include the evaluation of intentions of weight gain or weight loss in this population. Therefore, this study did not account for unintentional weight loss in older populations which could be due to factors such as the presence of chronic disease or bereavement.

This is the first study to provide transition probabilities between normal, overweight, and obese states in the context of sub-Saharan Africa. These estimates are useful to policy makers responsible for dealing with obesity, a major risk factor for non-communicable diseases. Additionally, factors that influence transition probabilities were identified to support the appropriate targeting of interventions. The estimation of these transition probabilities provides an important input for future economic evaluations through which cost-effective weight reduction and maintenance program choices can be made and implemented in the population.

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Disclosure

An abstract from this paper was accepted for presentation at the 2019 International Society for Pharmacoeconomics and Outcomes Research (ISPOR), New Orleans, LA, USA. Part of this work was also submitted to the American Public Health Association 2019 meetingheld in Philadelphia, PA, USA.

Ethics and permissions

Data from SAGE Ghana Waves 1 and 2 was used for this study. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). The necessary permission was obtained from the World Health Organization to use these data.

Data availability statement

Data from SAGE Ghana Waves 1 & 2 were used for this study. WHO SAGE was approved by the WHO Ethics Review Committee (reference number RPC149) with local approval from the University of Ghana Medical School Ethics and Protocol Review Committee (Ghana). All files were obtained from the World Health Organization Study on global AGEing and adult health (WHO SAGE). Details on data can be found at http://www.who.int/healthinfo/sage/cohorts/en/. The authors used files GhanaINDDataW1, GhanaHHDataW1, GhanaINDDataW2, and GhanaHHDataW2. The codes for the measured weight and height used to calculate body mass index (BMI), as used in the data are q2506 for weight and q2507 for height. The authors confirm that they had no special access privileges to the data. Interested researchers can apply to WHO to access data (http://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/sage/about).

Authors' contribution

STL developed the research plan, conceptualised the paper, conducted the statistical analyses, wrote the manuscript and co-ordinated revisions and submission. LS, BdG, CGM, and AJP contributed to the formulation of the initial research idea and designed the study. STL, RBB, NM and PK worked to acquire the data. LS, GOB and PO contributed to analysing the data. NM, PK and AJP validated the results. LS, PO, GOB, BdG, CGM, and AJP contributed to writing the original paper. All authors critically reviewed and edited the manuscript. All authors approved the final version. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Declaration of competing interest

The authors declare that no competing interests exist.

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Appendix 1

The impact of specific socio-economic factors on one year transition probabilities.

			To					
		From	Normal Weight		Overweight		Obese	
			Probabilities	95% CI	Probabilities	95% CI	Probabilities	95% CI
Total		Normal Weight	0.959	0.951, 0.965	0.040	0.034, 0.048	0.001	0.0, 0.002
		Overweight	0.111	0.095, 0.130	0.840	0.819, 0.858	0.049	0.038, 0.062
		Obese	0.006	0.004, 0.008	0.092	0.072, 0.116	0.902	0.877, 0.923
Sex	Females	Normal Weight	0.942	0.927, 0.954	0.057	0.045, 0.071	0.002	0.001, 0.003
		Overweight	0.110	0.085, 0.141	0.839	0.803, 0.866	0.051	0.038, 0.067
		Obese	0.004	0.003, 0.006	0.063	0.045, 0.086	0.933	0.909, 0.951
	Males	Normal Weight	0.968	0.960, 0.975	0.030	0.024, 0.038	0.001	0.0, 0.002
		Overweight	0.110	0.092, 0.142	0.820	0.764, 0.859	0.066	0.037, 0.116
		Obese	0.016	0.009, 0.029	0.237	0.140, 0.379	0.747	0.596, 0.850
Age group	50–65	Normal Weight	0.955	0.945, 0.963	0.044	0.036, 0.054	0.001	0.0, 0.002
		Overweight	0.108	0.089, 0.131	0.845	0.820, 0.868	0.047	0.034, 0.061
		Obese	0.006	0.004, 0.008	0.089	0.068, 0.118	0.905	0.875, 0.927
	> 65	Normal Weight	0.966	0.954, 0.975	0.033	0.024, 0.045	0.001	0.0, 0.003
		Overweight	0.122	0.088, 0.166	0.822	0.769, 0.863	0.055	0.034, 0.089
		Obese	0.007	0.004, 0.013	0.101	0.059, 0.164	0.892	0.824, 0.936
Educational Status	High	Normal Weight	0.950	0.933, 0.962	0.049	0.037, 0.065	0.002	0.001, 0.003
		Overweight	0.101	0.074, 0.135	0.837	0.793, 0.872	0.062	0.042,0.089
		Obese	0.005	0.003, 0.008	0.089	0.058, 0.131	0.906	0.862, 0.938
	Low	Normal Weight	0.962	0.954, 0.969	0.037	0.031, 0.045	0.001	0.0, 0.002
		Overweight	0.116	0.096,0.139	0.841	0.812, 0.864	0.043	0.031, 0.058
		Obese	0.006	0.004,0.009	0.095	0.069, 0.125	0.899	0.866, 0.926
Location	Rural	Normal Weight	0.970	0.963, 0.976	0.029	0.023, 0.036	0.001	0.0, 0.002
		Overweight	0.119	0.096, 0.146	0.836	0.800, 0.864	0.045	0.029, 0.070
		Obese	0.011	0.007, 0.017	0.160	0.110, 0.232	0.829	0.752, 0.883
	Urban	Normal Weight	0.931	0.913, 0.946	0.067	0.052, 0.084	0.002	0.001,0.004
		Overweight	0.110	0.085, 0.141	0.834	0.798, 0.863	0.056	0.041, 0.074
		Obese	0.004	0.003, 0.007	0.068	0.049, 0.093	0.928	0.901, 0.948

Wealth Index	Lowest	Normal Weight	0.975	0.960, 0.984	0.024	0.016, 0.038	0.001	0.0, 0.003
		Overweight	0.135	0.086, 0.212	0.821	0.712, 0.880	0.044	0.012, 0.137
		Obese	0.022	0.007, 0.059	0.268	0.088, 0.580	0.710	0.350, 0.904
	Low	Normal Weight	0.965	0.946, 0.978	0.035	0.022, 0.053	0.001	0.0, 0.002
		Overweight	0.168	0.116, 0.238	0.794	0.715, 0.851	0.037	0.015, 0.083
		Obese	0.017	0.007, 0.034	0.165	0.080, 0.292	0.818	0.680, 0.911
	Moderate	Normal Weight	0.947	0.925, 0.962	0.052	0.037,0.073	0.001	0.0, 0.003
		Overweight	0.133	0.092, 0.185	0.822	0.764, 0.865	0.046	0.027, 0.075
		Obese	0.007	0.004,0.014	0.095	0.052, 0.167	0.898	0.821, 0.944
	High	Normal Weight	0.959	0.943, 0.971	0.039	0.028,0.055	0.001	0.0, 0.002
		Overweight	0.102	0.071, 0.139	0.841	0.790, 0.879	0.057	0.035, 0.088
		Obese	0.005	0.002, 0.009	0.079	0.045, 0.135	0.916	0.857, 0.952
	Higher	Normal Weight	0.930	0.906, 0.950	0.067	0.048, 0.091	0.002	0.001,0.004
		Overweight	0.081	0.056, 0.114	0.859	0.819,0.894	0.059	0.040, 0.089
		Obese	0.004	0.002,0.006	0.079	0.054, 0.115	0.917	0.879, 0.944

Note: One-year transition probabilities between normal weight, overweight and obesity among older adults estimated using Wave 1 (2007/8) and Wave 2 (2014/15) of the WHO-SAGE.

Appendix 2

Hazard Ratios from Multistate Markov Model Fitted Separately for Covariates for Transitions between Normal Weight, Overweight and Obesity across Older Adults (50+ years) in Ghana (2007/08–2014/15).

Covariate		Hazard ratios (HR) and 95% CI							
		From Normal weight to Overweight		From Overweight to Normal weight		From Overweight to Obese		From Obese to Overweight	
		HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Sex	Males	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Females	1.87[a]	1.32, 2.64	0.97	0.67, 1.38	0.67	0.31, 1.43	0.23[a]	0.11, 0.48
Age group	50–65	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	> 65	0.76	0.52, 1.11	1.14	0.77, 1.69	1.21	0.67, 2.20	1.16	0.63, 2.12
Educational Status	High	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Low	0.75	0.52, 1.09	1.14	0.77, 1.69	0.69	0.41, 1.18	1.07	0.62, 1.84
Location	Rural	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Urban	2.36[a]	1.66, 3.36	0.95	0.66, 1.37	1.17	0.66, 2.08	0.40[a]	0.23, 0.68
Wealth Index	Lowest	1.00	Referent	1.00	Referent	1.00	Referent	1.00	Referent
	Low	0.91	0.50, 2.87	1.69	0.97, 2.95	0.72	0.25, 2.09	2.27	0.90, 5.73
	Moderate	1.35	0.80, 2.27	1.33	0.76, 2.31	0.83	0.39, 1.75	1.22	0.52, 2.88
	High	1.54[a]	1.02, 2.65	0.95	0.46, 1.67	0.91	0.46, 1.89	1.14	0.50, 2.43
	Highest	1.72[a]	1.03, 2.87	0.80	0.47, 1.38	1.04	0.54, 2.00	0.98	0.49, 1.99

[a] Significant result at $P < 0.05$.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2020.112821.

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