Neighbourhood deprivation and adult adiposity in South Africa

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DECLARATION

I, ***Masimba Dube*** hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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Abstract

Over the past three decades there has been a significant increase in adiposity - prevalence of accumulation of excess fat around some human organs - globally. This has been characterised by an increase of body mass index (BMI) among men and women. In Sub-Sahara Africa, South Africa has one of the highest prevalence of obesity and the country currently experiences some epidemiological transitions.

Excess adiposity is a major risk factor for a number of non-communicable diseases creating a burden for individuals, families, the health care system and society at large (Colditz, 1999). Therefore, there are both direct and indirect costs that can be averted by effectively controlling the obesity epidemic. Still this can only be achieved when there is a good understanding of its determinants. This study sought to investigate association between neighbourhood deprivation and adult adiposity (a combination of body mass index and waist circumference), the association of neighbourhood deprivation and body mass index and waist circumference individually and to examine individual and household level determinants impacting adult adiposity.

The study utilised the South African National Income Dynamic Survey (NIDS) 2012 (wave 3) and the ward level South African Index of Multiple Deprivation 2011 (SAIMD 2011) produced by Southern Africa Labour and Development Research Unit (SALDRU) and the Southern African Social Policy Research Institute/Insights (SASPRI) respectively. Individuals with high body mass index (BMI $\geq$ 25kg/m^2) and an expanded waist circumference (WC $\geq$ 102cm for men and WC $\geq$ 88cm for women) were considered as having high adiposity. Multilevel logistic regression was used for data analysis due to hierarchical nature of the data to allow simultaneous examination of the impact of some socio-economic factors influencing adiposity.

The results showed that individuals that were living in districts that are in quintile 3 (OR= 0.659; 95% CI 0.461, 0.942) of the multiple deprivation score had significantly lower odds of having high adiposity as compared to those living in the least deprived districts. Those living in districts that are in quintiles 3 (OR= 0.652; 95% 0.449, 0.945) and 4 (OR= 0.621; 95% 0.393, 0.983) of the multiple deprivation score were at significantly lower odds of having high BMI as compared to those living in the least deprived districts. When the analysis was stratified by gender the results showed that women living in districts in that are in quintiles 3 (OR= 0.654; 95% 0.450, 0.951) and 4 (OR= 0.624; 95% 0.394, 0.986) of the multiple deprivation score were at lower odds of having high adiposity as compared to women living in the least deprived

district. The results for men on the other hand showed no association between adiposity and district level deprivation.

Our results show that individual level characteristics and neighbourhood level deprivation regardless of how far distal has an impact on adiposity. Neighbourhood affluence seems to be a buffer that promotes weight gain. The impact of neighbourhood deprivation on adiposity is stronger among women as compared to men. However, further studies that employ a smaller area metric of analysis (preferably ward level) are required to better inform policy prescriptions of neighbourhood deprivation and adiposity.

Dedication

To my beautiful wife Thuto and our son Mandla.

Acknowledgements

I would like to whole heartedly thank my supervisor Dr Olufunke Alaba for her support throughout the writing of this thesis and assistance in the initial conceptualisation of the study. I appreciate the patience she showed during the whole period and her ability to accommodate my busy work schedule. I would also like to thank my family and friends for their unwavering support and words of encouragement. I would especially like to thank my good friend Pascal for his immense support and encouragement.

The acknowledged persons bear no responsibility for the deficiencies contained herein.

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Acronyms

BMI	Body Mass Index
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CNI	Care Need Index
CT	Computed Tomography
FDI	Foreign Direct Investment
GIMD	German Index of Multiple Deprivation
GDP	Gross Domestic Product
GNI	Gross National Income
HIC	High Income Country
LMIC	Low and Middle Income Countries
MRI	Magnetic Resonance Imaging
NCDs	Non Communicable Diseases
OECD	Organization for Economic Cooperation and Development
PIMD	Provincial Index of Multiple Deprivations
PSU	Primary Sampling Unit
SALDRU	Southern Africa Labour and Development Research Unit
SAPRI	Southern African Social Policy Research Institute/Insights
SSA	Sub-Saharan Africa
StatsSA	Statistics South Africa
TI	Townsend Index
UCT	University of Cape Town
UNDP	United Nations Development Programme
WC	Waist Circumference
WHO	World Health Organisation
WHR	Waist/Hip Ratio

PART A: Protocol

1. Introduction

1.1 Statement of the Problem

1.1.1 Background

Adiposity can be defined as the accumulation of lipids (fat) at a particular site or organ (Bacon, 2013; Schwandt, 2011). Visceral, ectopic and subcutaneous adiposity refer to some of the different areas where fat can distribute itself within the body (Fenger et al., 2012). Adiposity can be accurately measured using Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). However, these methods are generally not used in large epidemiologic studies due to their high cost, complexity of operation, non-portability of equipment and need for skilled operators (Sun et al., 2010). Anthropometric measures such as body mass index (BMI), waist circumference (WC) and waist/hip ratio (WHR) are more commonly used in literature as surrogate measures of adiposity (Bosy-Westphal et al., 2010; Fleming, 1996; Neovius et al., 2004). This is due to their convenience, safety and relatively low cost.

Over the past three decades, there has been a significant increase in the prevalence of excess adiposity globally. This has been characterised by an increase of body mass index (BMI) by 0.4kg/m² (95% CI: 0.2-0.6) among men and 0.5kg/m² (95% CI: 0.3-0.7) among women per decade since 1980 (Finucane et al., 2011; Swinburn et al., 2011). Globally, an estimated 1.46 billion adults were classified as overweight (BMI> 25kg/m² or WC> 102cm for men and WC> 88cm for women) in 2008 and a further 502 million adults as obese (BMI>30kg/m²) in the same year (Finucane et al., 2011). The prevalence of obesity increased simultaneously in high income countries (HICs) in the 1970s and 1980s. Low and middle income countries (LMICs) have since joined the surge in obesity rates (Swinburn et al., 2011). The World Health Organisation (WHO) estimates that the burden of obesity would have doubled by 2030 (Micklesfield et al., 2013).

The prevalence of urban obesity increased by up to 35% in sub-Saharan Africa (SSA) between 1992 and 2005 (Ziraba et al., 2009). Most of these countries are investing in battling mortality due to diseases related to infectious agents, nutritional deficiencies, maternal and perinatal conditions which are expected to decrease by 3% over the next ten years. On the other hand, mortality as a result of non-communicable diseases (NCDs), for which excess adiposity is a major risk factor, is expected to increase by 17% over the same period (Tunstell-Pedoe, 2006).

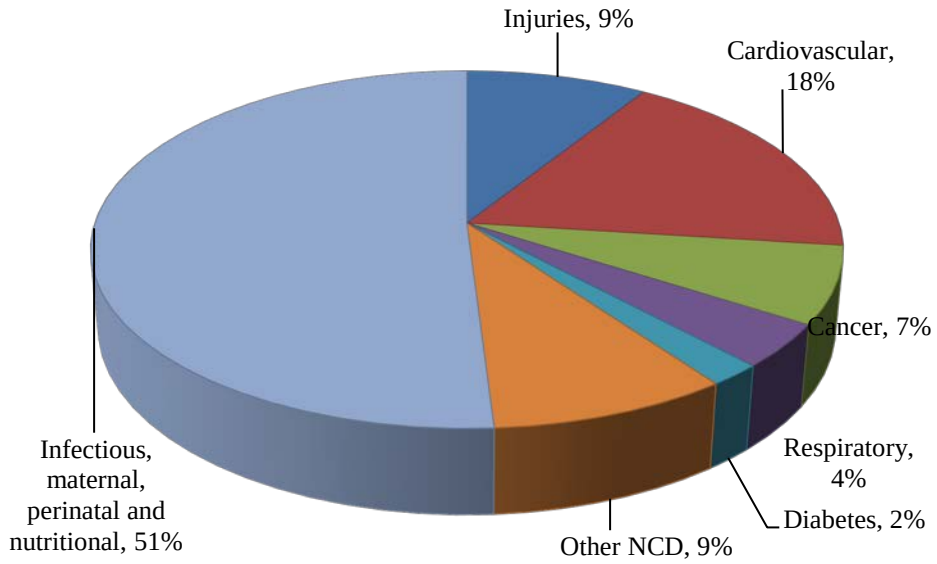
In the SSA region, South Africa has the highest prevalence of obesity (Micklesfield et al., 2013). This can be attributed to urbanisation, industrialisation and economic transition promoting the consumption of energy dense foods and a sedentary life style (National Department of Health, 2013; Yoon and Kwon, 2014). Empirical evidence from South Africa utilising the first and second Waves of the South African National Income Dynamics Survey (NIDS) shows an increase in the prevalence of obesity from 23.5% to 27.2% between 2008 and 2012 (Sartorius et al., 2015). The same study also showed a disproportionately higher burden of excess adiposity among women (37.9%) as compared to men (13.3%).

1.1.2 Impact of Excess Adiposity on Health

Obesity can be viewed as both a disease and a cause of disease. Excess adiposity is of public health concern, as it is a risk factor for most non-communicable diseases (NCDs), particularly type 2 diabetes mellitus (Sassi, 2010). Severely obese individuals (BMI>40kg/m²) have 7.37 odds of being diagnosed with diabetes than non-obese individuals (Micklesfield et al., 2013; Dalal et al., 2011; Van Itallie, 1979). Furthermore other studies have reported that obese individuals are 60 times more likely to develop diabetes than non-obese individuals (Colditz, 1999). Moreover, as adiposity increases high blood pressure and high cholesterol become common. These increase an individual's chances of suffering and possibly dying from cardiovascular diseases (CVDs) (Dalal et al., 2011; Van Itallie, 1979). Several cases of cancers have also been linked with obesity for example breast cancer and colorectal cancer (Micklesfield et al., 2013).

Prospective Studies Collaboration (2009) reported that mortality from selected NCDs was lowest among individuals with a BMI of 22.5 to 25 kg/m². Furthermore, each 5kg/m² increase in BMI was associated with a 30% increase in all-cause mortality (Whitlock et al., 2009). However, this association is not as strong beyond the age of 70 as higher mortality has been observed in those with lower BMI as compared to the obese and mildly obese, giving rise to the so called "obesity paradox" (Colditz, 1999). In South Africa, an estimated 31.9% of deaths can be attributed to NCDs (National Department of Health, 2013; Schneider et al., 2009). According to a Statistics South Africa (StatsSA) 2011 report on mortality, there was an increase in the proportion of deaths attributed to heart disease, stroke, diabetes and hypertension (Health-E News, 2014).

Figure 1: All-cause mortality rates in South Africa 2008



Source: Strategic Plan for the Prevention and Control of NCDs 2013-17

1.1.3 Economic Consequences of Excess Adiposity

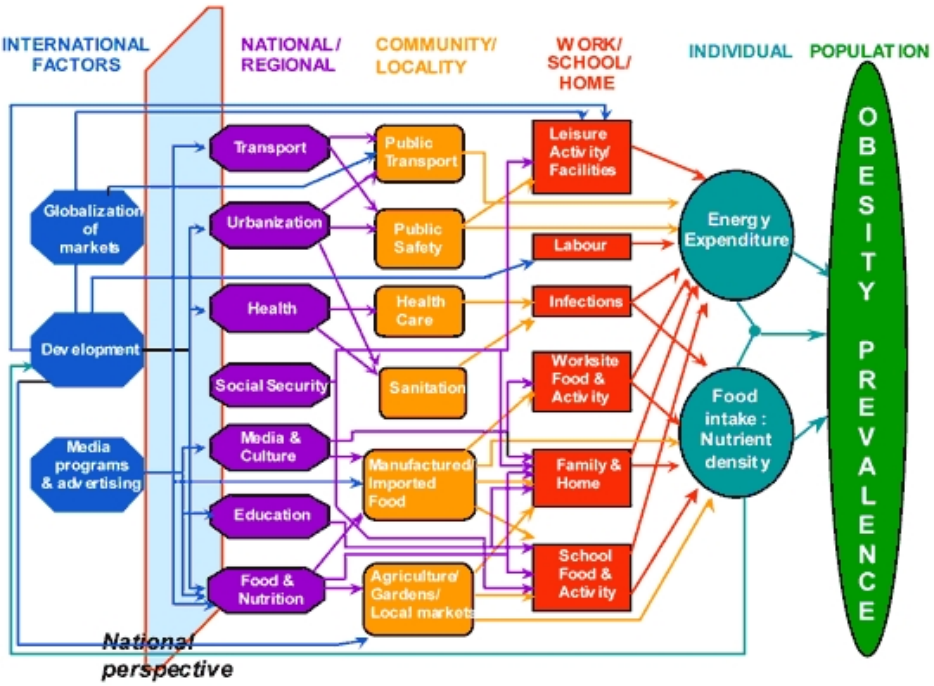
As compared to those with normal body weight, obese individuals incur higher costs in terms of health care expenditure. This is likely due to the high association between excess adiposity and non-communicable diseases (Dalal et al., 2011; Mokdad et al., 2003). The direct medical costs associated with obesity were $52 billion which accounted for about 5.7% of the national health care expenditure for USA in 1995 (Colditz, 1999). Moreover, these costs are expected to increase by $48-66 billion/year in the USA whilst in the UK cost are expected to increase by £1.9-2 billion/year if current projected obesity trends continue unabated (Pischon et al., 2008). The indirect costs as a result of disability and/or exclusion from labour force participation are much greater than the direct cost alone. In China it is estimated that 8.73% of gross national product (GNP) in 2025 may be lost to the effects of excess adiposity (Colditz, 1999).

1.1.4 Determinants of Adiposity

Adiposity is generally a result of energy imbalance where an individual consumes more energy than they expend (positive energy balance) (Yoon and Kwon, 2014). This excess energy is stored as fat in the body's adipose tissues. The key determinants of adiposity are physical activity, sedentary behaviours and the over consumption of energy dense foods (Lakerveld et al., 2012a). However, the cause of excess adiposity is not as straightforward and its

determinants are complex and multidimensional (Yoon and Kwon, 2014). Furthermore, causes of adiposity are neither an issue of individual choice nor linear cause and effect rather they are influenced by multiple levels of interacting socio-economic, cultural and physical factors at micro- and macro- levels (Swinburn, Egger, & Raza, 1999).

Figure 2: A diagrammatic representation of the micro- and macro- determinants of Adiposity



Source: Huang et al., 2009, A systems-oriented multilevel framework for addressing obesity in the 21st century

As illustrated in figure 2, the determinants of obesity operate at micro- and macro- levels of society. At the micro level we can consider individual attributes, home, work or school environment. The macro level community, national and international factors may directly or indirectly influence adiposity. At the individual level, biology seems to play an important role in predicting adiposity for example through epigenetic effects an obesogenic pre-natal environment increases the likelihood of obesity in the off-spring at adulthood (Huang et al., 2009). Moreover, bodies can decrease sensitivity to metabolic signals that inhibit overeating when food supply is limited or cyclic to allow for storage of excess energy in the form of body fat. However, in the abundance of palatable energy dense foods it is this decreased sensitivity that promotes adiposity. On the other hand there is increasing recognition that effectively

tackling the obesity epidemic requires that we go beyond individual risk factors to broader environmental factors (Lakerveld et al., 2012a).

The built environment is man-made and it encompasses a range of physical and social elements that make up a society and it may influence adiposity (Papas et al., 2007). It can have direct and indirect influence on food choice and level of physical activity (Feng et al., 2010). Food choice can be influenced by the availability and accessibility of large chain grocery stores. These tend to have a wider variety of healthier and cheaper foods as compared to smaller stores (Ford and Dzewaltowski, 2011). The type of foods marketed within a locality may have an influence on food choice. Also a clustering of cheap fast food outlets within a community may promote consumption of these foods (Black and MacInko, 2010). The perceptions of neighbourhood safety and availability of parks and recreational sporting areas can influence the amount of physical activity by residents (Xu and Wang, 2015).

The social and economic environments also have an influence on adiposity. In some cultures, obesity in a child is viewed as a sign of health (Huang et al., 2009). Among South African women of African descent, a moderately overweight shape is associated with dignity, confidence, wealth, respect and beauty (Puoane et al., 2005). In addition, some scholars have suggested that in places or among groups that obesity is stigmatised we tend to find lower rates of obesity (Rundle et al., 2008). In developed countries, a high socioeconomic status (SES) is associated with a lower prevalence of obesity, whilst in developing countries the opposite is true (Van Hulst et al., 2013). An explanation to this might be that low income groups in developed countries and high income groups in developing countries have access to high energy yet poor nutrient foods (Huang et al., 2009).

2. Study Justification

Evidence from the repeated panels of the South African National Income Dynamic Survey (NIDS) indicates that there is a continued increase in the prevalence of obesity in South Africa, from 23.5% in 2008 to 27.2% in 2012 (Sartorius et al., 2015). There are both direct and indirect costs that can be averted by effectively controlling the obesity epidemic. Still this can only be achieved when there is a good understanding of its determinants. It is widely recognised that the determinants of obesity operate at both individual and community levels (Bouchard, 2007; Lee and Kolonel, 1984; Puoane et al., 2005). The societal context is particularly relevant in South Africa, whose apartheid legacy has left it with one of the most unequal societies in the

world (Budlender, 2008). It is therefore crucial to understand how differences in neighbourhood deprivation impact individual adiposity. This will help to inform obesity prevention and control strategies.

This study intends to add to the body of literature on area deprivation and adiposity particularly in a developing country context as most studies have been carried out in developed countries. In addition, we intend to utilise two indicators of adiposity: BMI and WC in order to improve the identification of obese individuals as compared to when only one of these surrogate measures is used. Moreover, the study utilises a broad measure of deprivation that captures four dimensions of deprivation, namely material, employment, education and living environment deprivation, and an income poverty measure. The deprivation measure allows for decomposition of the index in order to better understand the mechanisms with which deprivation affects adiposity. The measures of deprivation and poverty were generated from a small area (ward level) which has an advantage over larger areas (e.g. municipal) as individuals in small areas tend to be more homogenous as compared to larger areas. Moreover, the study utilises the NIDS data set which is a nationally representative sample of the South African population.

Text Box 1: Summary of study's contribution to literature

- The study focuses on the South African context, a developing country, most studies of this nature have mainly been conducted in developed countries
- The study utilises two anthropometric measures (BMI &WC) as proxies of adiposity in order to reduce misclassification of individuals
- The study utilises a nationally representative sample of the South African population allowing for wider generalisation of the study results
- The study uses both a multidimensional index of deprivation and income poverty measure which (to our best knowledge) has not been done within a African country context
- The deprivation measure is taken from the ward level which tend to be more homogenous as compared to diverse larger areas
- Use of a nationally representative sample allows for greater heterogeneity between neighbourhoods
- Each of the component domains of deprivation are regressed separately in order to better understand how area deprivation influences adiposity

3. Research Question

To what extent do social and economic environments determine adult adiposity in South Africa?

3.1 Objectives

The study seeks to address the following objectives;

1. To investigate associations between area-level deprivation indices and two measures of adult adiposity (body mass index and waist circumference)

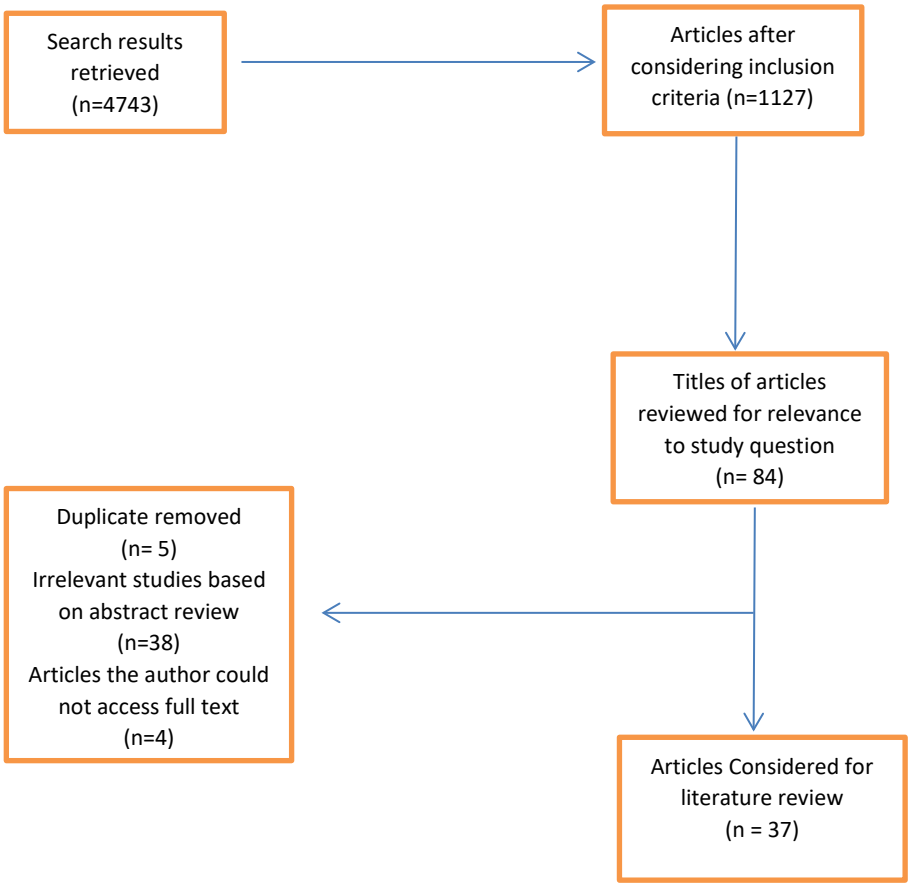
2. To examine individual and household level determinants of adiposity (body mass index and waist circumference)

4. Mini-Literature Review

4.1 Search Strategy

The following databases were searched for articles in English that were conducted among humans; Medline via PubMed; Africa-Wide Literature, Academic Search Premier, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Econlit via EBSCO host; Google scholar; Scopus and Web of Science. Search terms relevant to the study topic which included; deprivation, poverty, indigence, low-income, developing countries, underdeveloped countries [Basic Search] AND adiposity, overweight, obesity, over nutrition, body mass index, waist circumference, hip to waist ratio [MeSH] AND small area analysis, multilevel analysis, contextual, spatial analysis, built environment, hierarchical [MeSH] were used. The search was restricted to the title and abstract of full text articles. The retrieved articles were screened by reviewing their titles and articles. Titles that were not relevant to the study objectives were excluded. The literature was further screened by going by reading through the abstracts of the identified articles.

Figure 3: Diagrammatic representation of the search process



4.2 Theoretical Overview

4.2.1 Understanding Poverty and Deprivation

4.2.1.1 Background on Poverty and Deprivation

One of the central themes of economic and social policy is poverty alleviation/eradication. Yet there is no consensus on the meaning of the term and how it should be measured (Nolan and Whelan, 1996). There are generally two schools of thought relating to the measurement of human welfare, one relates to the use of income level (insufficient incomes or consumption) whilst the other advocates for the use of a broader multidimensional measure (Klasen, 2000; McIntyre, 2002). Income poverty has been assessed using either expenditure levels or income threshold i.e. less than US$2/day, whilst broader measures seek to measure access to resources and/or assets, living patterns and concrete indicators of deprivation (Iceland, 2005).

4.2.1.2 Income Poverty

People can be defined as poor if they *lack of resources to obtain the types of diet, participate in the activities and have the living conditions and amenities which are customary or at least widely encouraged or approved in the societies to which they belong (Townsend,1979:31 referenced in Noble et al., 2006).* Sen in explaining impoverishment purports that it is the lack of financial resources or means of production to access food (Sen, 1981). Proponents of the income poverty measurement school of thought argue that income can be used to measure welfare as all welfare relevant goods can be purchased on the competitive market (Klasen, 2000). This is supported by classical utilitarianism and social welfare assumptions, which assume that utility can be quantified and added across different individuals (Nolan and Whelan, 1996).

Expenditure level have been shown to be strongly correlated with deprivation in South Africa (Budlender, 2008). Hence the use of access to financial resources as a proxy measure for deprivation. However, there are some theoretical and empirical issues relating to the measurement of financial resources as a proxy for deprivation. Key issues relate to adjustment for under reporting of income/expenditure, child cost economies, household economies of scale and failure to account for the 'social wage'[1] (Meth and Rosa, 2010). Furthermore other scholars have criticised the aspect of quantifying and adding up of individual utilities arguing that (1) there is inter personal variation in translating income into utility (2) it is difficult to make inter personal comparisons of utility (Iceland, 2005; Klasen, 2000; Sen, 1981). The assumption of

[1] The social wage includes social grants, tax relief and the provision of free basic services.

complete markets is unrealistic as market for most welfare relevant goods, for example health care, is incomplete and awash with increasing returns and externalities (Budlender, 2008). Klasen (2000) reports that in South Africa, the expenditure measure fails to identify about 30% of the most deprived who would be otherwise identified by a broader measure.

4.2.1.3 Multidimensional Deprivation

Townsend (1987) defines deprivation as a *lack of types of diets, clothing, housing, household facilities, fuel, environmental, educational, working and social conditions, activities and facilities which are customary (Townsend,1987:131&140 referenced in Noble et al., 2006).* Thus the concept of deprivation looks beyond access to financial resources, rather on the material and social conditions that individual experience relative to the norm in their communities (McIntyre, 2002). This concept of deprivation is similar to Sen's human capabilities approach which defines deprivation as *the inability of individuals to acquire the minimum capabilities required to function (such as inability to be healthy, sheltered, well-clothed e.tc.)* as accustomed in their societies (Klasen, 2000).

This approach to welfare measurement concentrates directly on achievements avoiding some of the challenges inherent in financial resource based approaches. These include heterogeneity of people (differentials in translation of consumption to welfare), impact of public goods and the 'social wage' on welfare (Klasen, 2000). Furthermore, directly measuring human welfare is important within the South African context due to its apartheid past which promoted differential access to resources by race and whose legacy persists in today's society (McIntyre and Gilson, 2002). Under the apartheid regime, a black[2] family could have access to wealth in monetary terms but would be prevented from residing in an area with basic services such as electricity, clean water, refuse collection and so forth (Budlender, 2008).

The measurement of capabilities approach also has its shortcomings. There is a wide debate on the capabilities to include, the cardinal interpretation of the value of each component and the relative weight assigned to each component (Klasen, 2000). However, the author feels that it is superior to the financial resources approach. Multidimensional measurements of poverty can be decomposed in terms of dimension of deprivation and social-economic attribute (Whelan et al., 2014). This allows policy makers to target the causes of deprivation within their constituencies. Moreover, due to the nature of poverty and inequality in LMICs (including South Africa) a focus on multidimensional deprivation is of relevance (McIntyre, 2002). The

[2] Black in this instance refers to people of African descent, Asians and Coloureds.

Southern African Social Policy Institute produced the multiple deprivation and Income poverty at small area level report in South Africa in 2011. The report gives both income poverty measures and a multidimensional deprivation measure as such this study will utilise both measures (Noble et al., 2013).

4.2.2 Measuring Adiposity

Anthropometric measures such as body mass index (BMI), waist circumference (WC) and waist/hip ratio are used in these studies as surrogate measures of adiposity in preference to computed tomography (CT) and magnetic resonance imaging (MRI) (Bosy-Westphal et al., 2010; Fleming, 1996; Neovius et al., 2004). This is due to their convenience, safety and comparative low cost. BMI though widely used in epidemiologic studies is not flawless as it fails to distinguish between lean mass and fat mass (Romero-Corral et al., 2008).

BMI as an indirect surrogate measure of adiposity is considered imprecise (Fleming, 1996). It fails to account for the fact that men lose less muscle with age as compared to women (Shah and Braverman, 2012). In women greater muscle loss leading to sarcopenic obesity[3] is positively associated with age (Romero-Corral et al., 2008). Moreover, BMI does not account for the inverse relationship between mortality and muscular strength in men. Furthermore BMI misclassifies 25% and 48% of men and women respectively (Shah and Braverman, 2012). As a result, this inaccurate measurement of obesity potentially underestimates the epidemic and can contribute to failed treatment.

Waist circumference has been shown to predict health and mortality risks beyond that predicted by BMI (Ardern et al., 2003; Janssen et al., 2002). Though not well established, this can be attributed in part to the ability of WC to identify those with high levels of total abdominal fat (Wei et al., 1997). Some cross sectional studies have reported that within each weight category, men and women with high WC were at higher health risk as compared to those with normal WC (Janssen et al., 2002; Wei et al., 1997). Nevertheless, BMI and WC have shown to independently contribute to the prediction of visceral, abdominal sub cutaneous and non-abdominal fat in both males and females (Janssen et al., 2002). Furthermore, evidence suggests that WC together with BMI predicts health risks better than BMI alone (Wei et al., 1997). As

[3] Sarcopenic obesity is a scenario where an individual gains fat mass whilst simultaneously losing lean muscle mass.

such we intend to explore the impact of area level deprivation on BMI and WC as surrogates of adiposity in this study.

4.2.3 Multilevel Analysis

There is an increasing recognition of the existence of social influences on health and one of their key operating mechanisms is the areas or neighbourhoods within which individuals reside (Diez Roux, 2001; Duncan et al., 1998). Multilevel analysis explains variations in the dependent variable at one level as function of independent variables at defined various levels and interactions between and within the levels (Diez-Roux, 2000). Evidence suggests that some neighbourhood contexts may influence health independently of individual level attributes (Diez Roux, 2002). Hence the use of multilevel modelling which allows for simultaneous examination of the effect of both individual level variables and area level variables on individual outcomes (Merlo, 2005). This allows us to control for the potential confounding or mediatory effect of individual level attributes on the association between group level variables and individual level outcomes being investigated (Pickett, 2001).

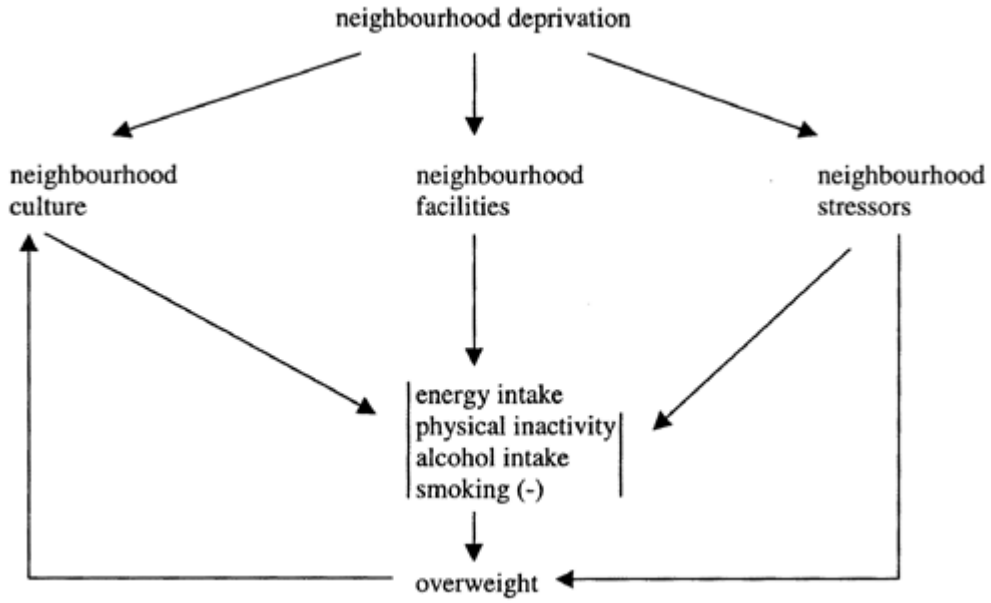
Multilevel modelling is generally applied to nested data, it can be individuals nested within households which are nested in neighbourhoods and so forth. It can even be applied to patients within a medical institution, health facilities within districts and workers in an organization (Duncan et al., 1998). This type of modelling has been utilised in literature to investigate the social determinants of health (Merlo, 2005). Diez Roux, (2001) utilising multilevel modelling to investigate the determinants of health whilst Santana, Santos, & Nogueira, (2009) have utilised it to investigate the influence of the neighbourhood environment on individual level health. This method is intended to be utilised to access the influence of neighbourhood level deprivation on individual level adiposity.

4.2.4 Area level deprivation and Adiposity

Human interaction with the neighbourhood environment is complex, as such several pathways with which area level deprivation influences adiposity exist (Laraia et al., 2014). However, before we examine the pathways from area level deprivation to adiposity, it is important to understand that the association could be a result of self-selection. Some scholars note that individuals with similar lifestyles and social norms tend to live in the same neighbourhoods (van Lenthe and Mackenbach, 2002). Rundle et al. (2008) contends that health conscious people may be attracted by the better resources for health often found in more affluent neighbourhoods. On the other hand, there are sound theoretical discussions on both biologic

and non-biologic mechanisms from neighbourhood deprivation to individual level weight gain as shown in Figure 4 (Coogan et al., 2009; Do et al., 2007; Maier et al., 2014; Santana et al., 2009; Sundquist et al., 1999).

Figure 4: Conceptual model explaining neighbourhood deprivation impact on adiposity



Source: Neighbourhood deprivation and over weight: The Globe Study

Deprived areas tend to have a higher number of stressors as compared to affluent areas (King et al., 2006). These stressors may be a result of higher crime rates, poor perception of safety (Smith et al., 1998), physical incivilities[4] (Laraia et al., 2014) or greater overcrowding and noise levels (Coogan et al., 2009). Biologically stress can result in neuroendocrine autonomic dysregulation which influences the accumulation of fat in the body (Coogan et al., 2009; Yoon and Kwon, 2014). Moreover, stress has been linked to non-homeostatic eating[5] and the ingestion of energy high foods (Grundmann et al., 2014; Janssen et al., 2006; Laraia et al., 2014).

A paucity of resources in deprived areas has been linked to limited access to healthy foods and fewer opportunities for physical activities (Black and MacInko, 2010; Laraia et al., 2014; Wen and Maloney, 2011). Neighbourhood resources have an impact on the availability of facilities within neighbourhoods such as large chain supermarkets (Ford and Dzewaltowski, 2011), safe

[4] Physical incivilities are manifestation of neighbourhood deprivation through littering, uncollected garbage, unkempt property and dishevelled public spaces (Laraia et al., 2014)
[5] Non-homeostatic eating is the consumption of food other than for caloric need (Laraia et al., 2014)

recreation spaces (Sundquist et al., 1999), fast food outlets (Robert and Reither, 2004) and transport networks (Matheson et al., 2008). A high number of fast food outlets versus a limited number of supermarkets may produce an unhealthy food environment (Robert and Reither, 2004). Supermarkets tend to have a wide variety of healthier foods such as fruits and vegetables at affordable prices as compared to smaller grocery shops (Santana et al., 2009). This is particularly important within the South African context where there is a higher concentration of small "spaza" shops in deprived areas than affluent areas. Opportunities for physical activities may be limited by unavailability of safe recreation spaces such as parks (Shi et al., 2015).

The amount of resources available to an area also has an impact on the neighbourhood culture as it may provide cues that support particular social norms (Laraia et al., 2014, 2012). Social norms and cultural beliefs are another mechanism by which neighbourhood deprivation may influence personal behaviours (Dragano et al., 2007). Environments in which obesity is stigmatised may encourage inhabitants to eat healthier and exercise more (Rundle et al., 2008). On the other hand in some societies, for example, black South African women find a moderate overweight shape to be more appealing (Puoane et al., 2005).

Table 1: Summary of High Income Country studies assessing association between area level deprivation and adiposity

Study Description						Explanatory Variables		Outcome variables (Measure(s) of adiposity status)		Association between Adiposity & Area Level Deprivation
#	Reference	Country	Study Population	Study Design	Area level metric	Area-Deprivation Measure/Indices	Control Variables	Measurement	Adiposity measure	
1	Grundmann et al., (2014)	Germany	National cross sectional survey (n=39,908[6])	Multilevel Logistic Regression Analysis	Municipality	German Index of Multiple Deprivation composing of Income, Employment, Education, Municipal Revenue, Social Capital, Environment & Security	•Physical Activity •Income	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Positive *(for both men and women)*
2	Keita et al., (2014)	USA	Cross sectional survey of 48 States (n=19,079)	Logistic regression analysis (Individual Level)	Census block group level	Deprivation Index composing of Income, Median value of housing units, Education, Employment	•Race •Sex •Income	Measured	Binary Variable: Obese = BMI ≥ 30 kg/m² OR WC: men > 102cm, women > 88cm	Positive *(for both white and black adults)*
3	Yoon & Kwon, (2014)	Korea	Cross sectional national health survey (n=337,136)	Multilevel Logistic Regression Analysis	Community	Education Level	•Age •Household Income •Occupation •Marital Status	Self-reported	Binary Variable: Obese = BMI ≥ 25 kg/m²	Positive *(for women)* No Association *(for men)*

[6] Study population included in the analysis

							•Physical Activity •Stress			
4	Wen & Maloney, (2011)	USA	Cross sectional data for Whites and Hispanics living in the State of Utah (n=735,975)	Multilevel Logistic Regression Analysis	Census tract level	Deprivation Index composing of Income, Education & Home Ownership	•Ethnicity •Sex Age	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Positive *(for both men and women)*
5	Cubbin et al., (2006)	Sweden	Cross sectional nationally representative survey (n= 18,081)	Logistic Regression Analysis (Individual Level)	Small Area Market Statistics (SAMS)	Care Need Index composed of elderly living alone, foreign-born, unemployment, single parents, residents who moved residences during the past year, education, children under age five	•Age •Sex •Marital Status •Immigration Status •Urbanisation Socio-economic Status	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
6	Ford & Dzewaltowski, (2011)	USA	Cross sectional survey of Kansas *mothers* enrolled in a nutrition program (n=21,166)	Multilevel Linear Regression Analysis	Census tract level	Deprivation Index composing of Employment, Income, Housing, Female headed HH, Car Ownership	•Race •Ethnicity •Education Income	Self-reported	Continuous Variable: BMI	Positive *(for Metropoilitan areas)* Non-linear *(for Micropolitan areas*) No association *(for Rural areas)*

7	Santana et al., (2009)	Portugal	National Health Survey of adults above 18 years (n=7,669)	Multilevel Logistic Regression Analysis	Neighbourhood (mean population = 12,420)	Deprivation Index composing of Local resources, Social Capital &Public Health Services	•Age •Sex •Marital Status •Economic Activity •Education Level •Occupational Class •Income •Physical Activity •Smoking •Healthy diet	Self-reported	Binary Variable: Overweight = BMI ≥ 25 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
8	King et al., (2006)	Australia	Cross sectional Survey of Melbourne residents (n=2564, 2349)	Multilevel Linear Regression Analysis	Census Collector Districts	Deprivation Index composing of Education, Occupation & Income	•Age •Income •Occupation •Education	Self-reported	Continuous Variable: BMI	Positive *(for women)* No association *(for men)*
9	van Lenthe & Mackenbach, (2002)	Netherlands	Prospective cohort study of adults residing in the S/East of	Multilevel Logistic Regression Analysis	Neighbourhood	Deprivation Index composing of Education, Occupation & Employment	•Educational Level •Age •Sex	Self-reported	Binary Variable: Overweight = BMI ≥ 25 kg/m²	Positive *(for women)* No association *(for men)*

			Netherland (n=10,450)							
10	Black & MacInko, (2010)	USA	Repeated Cross sectional surveys of New York City (n=44,730)	Multilevel Logistic Regression Analysis	Zip Code	Area income	•Sex •Race/Ethnicity •Marital Status •US birthplace (or not) •Education Level •Employment Status	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Positive *(for women)* No association *(for men)*
11	Maier et al., (2014)	Germany	Cross sectional data from German Health Update survey (n=33,690)	Multilevel Logistic Regression Analysis	Districts	German Index of Multiple Deprivation composing of Income, Employment, Education, Municipal Revenue, Social Capital, Environment & Security	• Age •Smoking Status •Sport Activity •Living with a partner •Educational Level	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Positive *(for both men and women)*
12	Do et al., (2007)	USA	Nationally representative cross sectional survey (n=14,152)	Multilevel Linear Regression Analysis	Census tract level, County level	Deprivation Index composing of Education, Income, Female headed HH, Employment:	•Age •Employment Status •Education Level •Nativity •Marital Status	Measured	Continuous Variable: BMI	Positive *(for White and Mexican American women and men)* No association *(for Black*

										women and men)
13	Matheson et al., (2008)	Canada	Nationally representative cross sectional survey (n=64,277)	Multilevel Linear Regression Analysis	Urban Census Tracts	Deprivation Index composing of Education, Income, Female headed HH, Employment, Living Conditions	•Sex •Marital Status •Education Level •Visible Minority Status •Age •Self-perceived stress •Sense of belonging to local community •Fruit and Vegetable consumption •Smoking •Physical activity	Self-reported	Continuous Variable: BMI	Positive *(for women)* Negative *(for men)*
14	Robert & Reither, (2004)	USA	Cross sectional survey (n=3,617)	Multilevel Linear Regression Analysis	Census Tract Level	Deprivation Index composing of Income and Unemployment	•Physical Activity •Smoking •Social support •Stress •Age	Self-reported	Continuous Variable: BMI	Positive *(for women)* No association *(for men)*
15	Sundquist et al., (1999)	Sweden	Nationally representative cross sectional	Multilevel Logistic Regression Analysis	Small Area Market Statistics (SAMS)	Care Need Index (CNI) Townsend Index (TI)	•Sex •Age		Binary Variable: Obese= BMI: men≥ 30kg/m²;	Positive *(for CNI)* No association *(for TI)*

			survey (n=9240)						women ≥ 28.6kg/m²	
16	Mujahid et al., (2005)	USA	Prospective cohort study in 4 US communities (n=13,167)	Multilevel Linear Regression Analysis	Census block group level	Deprivation Index composing of Income, Education & Occupation	•Age •Sex •Income •Education •Self-reported health	Measured	Continuous Variable: BMI	Positive *(for women)* No association *(for men)*
17	Smith et al., (1998)	UK	Cross sectional analysis of Renfrew and Paisley (n=14,952)	Logistic Regression Analysis (Individual Level)	Postcode sectors	Deprivation Index composing of Male unemployment, Occupation, Overcrowding & Car Ownership		Measured	Binary Variable: BMI cut-offs not reported	Positive *(for women)* No association *(for men)*
18	Coogan et al., (2009)	USA	Cross sectional study of African-American *women* (n=48,359)	Linear Regression Analysis (Individual Level)	Census block group level	Deprivation Index composing of Income, Housing Value, Education, Occupation & Female headed HH	•Age •Smoking •Physical Activity •Energy Intake •Education •Income •Household size	Measured	Obese = BMI ≥ 30 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
19	Dragano et al., (2007)	Germany and Czech republic	Cross sectional survey in urban populations (Germany:	Multilevel Logistic Regression Analysis	Neighbourhoods based on country specific boundaries	Unemployment Rate & Over Crowding were used individually	•Age •Sex •Education •Social isolation •Economic activity	Measured	Binary variable: Obese = BMI ≥ 30 kg/m²	Positive *(in Germany)* No association *(in the Czech Republic)*

			n=4032; Czech Republic: n=7522)				•Physical Activity •Smoking			
20	Rundle et al., (2008)	USA	Cross sectional survey of New York City adults (n=13,102)	Multilevel Linear Regression Analysis	Zip Code	Income Poverty Line	•Race/Ethnicity •Income •Education	NOT REPOTERD	Continuous Variable: BMI	Positive *(for both men and women)*
21	Laraia et al., (2012)	USA	Cohort study of diabetic patients from California (n=19,804)	Multilevel Linear Regression Analysis	Census block group level	Deprivation Index composing of Income-Poverty, Housing, Education, Employment & Occupation	•Age •Sex •Race/ethnicity •Marital status •Nativity •Time lived in USA •Education •Income •Social Status	Measured	Continuous Variable: BMI	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
22	Stafford et al., (2010)	UK	Longitudinal survey of British civil servants (n=14,524)	Multilevel Linear Regression Analysis	Census-Ward level	Townsend Index	•Age •Civil Service employment grade •Smoking •Alcohol consumption	Measured	Continuous Variable: BMI	Positive *(for women)* No association *(for men)*

							•Physical Activity			
23	Zhang et al., (2015)	USA	Cross sectional survey of people in the San Francisco Bay area (n= 16,634)	G-Computation	Census track (neighbourhood)	A composite deprivation index of income, poverty, housing, education, employment, and occupation	•Healthy food vendor density •Smoking •Physical Activity •Diet adherence •Age •Sex •Race/ethnicity •Marital Status •Nativity •Household size •Employment •Value of Assets •Income	Measured	Binary Variable: Obese = BMI ≥ 30 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
24	Xu et al., (2014)	USA	Cross sectional survey of Utah residents (n=21,961)	Multilevel Logistic Regression Analysis	County/Zip code level	Proportion living below the income poverty line *(Ø)*	•Age •Sex •Race •Marital Status •Education •Employment •Smoking	Self-reported	Binary variable: for both, Overweight = BMI ≥ 25 kg/m² Obese = BMI ≥ 30 kg/m²	No association *(analysis not stratified by any demographic or socioeconomic characteristics)*
25	Van Hulst et al (2013a)	Canada	Cross sectional Survey of	Multilevel Logistic	Neighbourhood	Mean neighbourhood income		Measured	Binary variable:	Positive *(for children and all when*

			Quebec families (n =417)	Regression Analysis		% residents with a university degree			Obese = BMI ≥ 30 kg/m²	*education is used a deprivation measure)* No association *(for parents)*
26	Stoddard et al., (2013)	USA	Cross sectional survey of Northern California residents (n= 18529)	Multilevel Linear Regression Analysis & Multilevel Multinomial Regression Analysis	Neighbourhood	Neighbourhood deprivation index of Education, Employment, Housing, Occupation, Poverty, Racial Composition and Residential Stability	•Age •Sex •Race •Marital Status •Education •Employment •Nativity •Income	Measured	Continuous and Categorical BMI used BMI CUT OFFS NOT REPORTED	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
27	Powell-Wiley et al., (2014)	USA	Longitudinal survey of Dallas residents (n=939)	Multilevel Linear Regression Analysis	Block level	Neighbourhood deprivation index of Education, Employment, Housing, Occupation, Poverty, Racial Composition and Residential Stability	•Age •Sex •Race/Ethnicity •Education •Employment •Income •Physical Activity	Measured	Continuous Variable: BMI	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*

							•Perception of neighbourhood environment			
28	Gregson, (2011)	USA	Cross sectional survey of California residents (n= 14,205)	Multilevel Linear Regression Analysis	County Level	% living below Federal Poverty Line	•Age •Sex •Race •Income		Continuous Variable: Obese = BMI ≥ 30 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*
29	Prince et al., (2012)	Canada	Cross sectional survey of Ottawa residents (n=4,727)	Multilevel Logistic Regression Analysis	Neighbourhood level	A deprivation index composed of Income, Unemployment, Education and % of single parents	•Age •Education •Smoking •Income •Season of data collection	Self-reported	Binary Variable: Obese BMI≤30 kg/m²	No association *(for both men and women)*
30	Koh et al., (2015)	USA	Cross sectional survey of metropolitan Detroit (n= 3146)	Deterministic Spatial Microsimulation Method	Census track	Average Neighbourhood Income	•Age •Sex •Race •Education	NOT REPORTED	Continuous Variable: Obese BMI≤30 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*

Table 2: Summary of Low and Middle Income Country studies assessing association between area level deprivation and adiposity

Study Description						Explanatory Variables		Outcome Variables (Measure(s) of adiposity status)		Association between Adiposity & Area Level Deprivation
#	Reference	Country	Study Population	Study Design	Area level metric	Area-Deprivation Measure/Indices	Control Variables	Measurement	Adiposity measure	
1	Jones-Smith et al., (2011)	Multi Country (37 Low and Middle Income Countries)	Repeated nationally representative cross-sectional surveys of women (DHS) n=405,550	Ecological	Country	Gross Domestic Product adjusted for purchasing power parity	•Age	Measured	Overweight = BMI ≥ 25 kg/m²	Negative *(analysis not stratified by any demographic or socioeconomic characteristics)*
2	Nandi et al., (2014)	Multi Country (40 Low and Middle Income Countries)	Nationally representative cross-sectional surveys (n=200,796)	Multilevel Logistic Regression Analysis	Country	Foreign Direct Investment (FDI)	•Sex •Age •Marital Status	Self-reported	Categorical Variable: Overweight = BMI ≥ 25 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*

							• Socio-Economic Status • Area of Residence			
3	Subramanian et al., (2011)	Multi Country (54 Low and Middle Income Countries)	Nationally representative cross-sectional surveys (n=538,140)	Multilevel Linear Regression Analysis	PSU and Country level	per capita Gross Domestic Product	• Age • Household Wealth • Education • Place of Residence	Measured	Continuous Variable: Overweight = BMI ≥ 25 kg/m²	Negative *(analysis not stratified by any demographic or socioeconomic characteristics)*
4	Monteiro et al., (2004)	Multi Country (37 Low and Middle Income Countries)	Nationally representative cross-sectional surveys of non-pregnant women (n=148,579)	Multilevel Logistic Regression Analysis	Country Level	Gross National Product per capita	• Age • Socio-Economic Status	Measured	Binary Variable: Obese = BMI ≥ 30 kg/m²	Negative *(for Low Income Countries)* Positive *(for Upper Middle Income Countries)*
5	Dai et al., (2013)	China	Cross sectional survey of selected Chinese provinces (n= 7831)	Multilevel Logistic Regression Analysis	Provincial Level	Gross Domestic Product & Proportion illiterate	• Sex • Age • Marital Status • Education • Employment • Income	NOT REPORTED	Binary Variable: Obese = BMI ≥ 28 kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*

6	Zhang., (2012)	China	Repeated panel survey of rural and urban Chinese neighbourhoods (n= 9,586)	Multilevel Linear Regression Analysis	Community	Community Mean Education *(+)* Urbanicity index *(-)*	•Sex •Age •Marital Status •Education •Occupation •Income	NOT REPORTED	Continuous Variable: Obese= BMI ≥ 25kg/m²	Positive *(using education deprivation measure)* Negative *(using the urbanicity index)*
7	Chen et al., (2009)	Taiwan	Cross Sectional Survey of Taiwanese households (n= 29,312)	Multilevel Logistic Regression Analysis	Township	Average per capita income	•Education •Employment •Income •Age •Marital Status •Smoking •Physical Activity	NOT REPORTED	Binary Variable: Obese= BMI ≥ 27kg/m²	Positive *(analysis not stratified by any demographic or socioeconomic characteristics)*

4.3 Methodological Overview

In the reviewed literature, 31 out of 37 studies utilised multilevel analysis. The use of multilevel or hierarchical analysis in these kind of study questions is important as it allows for the simultaneous consideration of both individual and area level determinants (Pickett, 2001). Keita et al., (2014) and Smith et al., (1998) conduct the analysis at the individual level failing to account for the nested structure of the data which could result in erroneous associations being observed. In multilevel analysis, the size of the area matric being considered also has an influence on the outcome of interest. In the case of adiposity and deprivation, a small area metric could best describe the influence of the latter on the former.

A few of the studies considered deprivation at an area level metric small enough to be able to elicit the influence of deprivation at that level on adiposity. However, most studies used very large areas such as countries, (Jones-Smith et al., 2011; Monteiro et al., 2004; Nandi et al., 2014; Subramanian et al., 2011; Xu et al., 2014), provinces (Dai et al., 2013) and districts (Maier et al., 2014). Small areas allow for the easy of identification of priority areas for policy makers to focus on.

A multidimensional index of deprivation captures the poor better than the use of an income measure as a proxy for deprivation (Klasen, 2000). A number of the reviewed articles utilised multidimensional deprivation indices such as the Care Need Index (Sundquist et al., 1999), Townsend Index (Stafford et al., 2010; Sundquist et al., 1999), Neighbourhood Deprivation Index (Powell-Wiley et al., 2014; Stoddard et al., 2013) and the German Index of Multiple Deprivation (Grundmann et al., 2014; Maier et al., 2014). Yoon & Kwon, (2014) utilise high area education rate as a proxy for deprivation in their study. Use of education alone fails to account for other dimensions of deprivation which may influence adiposity such as the living environment. Furthermore, several studies used proxy measures of deprivation that were solely based on income (Black and MacInko, 2010; Gregson, 2011; Rundle et al., 2008; Van Hulst et al., 2013; Xu and Wang, 2015)..

The use of self-reported measures of height and weight might introduce systematic bias (Cubbin et al., 2006; Sundquist et al., 1999; Wen and Maloney, 2011). However, 14 out of 37[7] of the studies used BMI that was calculated from self-reported height and weight. There is a tendency of over estimation of height with increasing BMI, reduced education levels and lower

[7] Two studies did not report their data source for height and weight measures

status occupations (King et al., 2006). The prevalence of obesity may thus be underestimated in lower socio-economic status groups with the net effect of underestimating the effects of area deprivation on adiposity (Yoon and Kwon, 2014). However, high socio-economic status individuals whom may find obesity socially undesirable may underestimate their weight (Matheson et al., 2008). As discussed earlier the use of BMI alone as a surrogate measure for adiposity misclassifies some individuals particularly in the intermediate ranges (Shah and Braverman, 2012). All the studies reviewed in this study except for Keita et al., (2014), who utilised both BMI and WC, used BMI only. Keita et al., (2014) on the other hand does not account for the hierarchal structure of the data by conducting the analysis at the individual level rather than a multilevel analysis. A cross sectional analysis of the data was done for all of the studies reviewed except Zhang et al., (2015). As a result of the nature of the analysis all the studies could not infer causality (Janssen et al., 2006; Stafford et al., 2010; Sundquist et al., 1999; Yoon and Kwon, 2014).

4.4 Empirical Overview

Much of the studies reviewed were conducted in high income Organization for Economic Cooperation and Development (OECD) countries (30 out of 37 reviewed studies). There is evidence to suggest that at an individual level SES has a differential influence on adiposity by country income level. In developed countries a high individual SES has been found to be protective from adiposity whilst in developing countries a high SES is positively associated with adiposity (Subramanian et al., 2011, 2007; Tunstell-Pedoe, 2006). As indicated in Tables 1 and 2 most of the studies reviewed showed a positive association between area level deprivation and adiposity. Yoon & Kwon, (2014) utilise an area measure of education as a proxy for area level deprivation and report a positive association between deprivation and adiposity among women. It can be hypothesised that the educated are more knowledgeable on the adverse effects of being overweight than the less educated. Also, educated individuals are better able to understand and implement health promotion messages than the less educated.

Studies using income as a proxy measure for adiposity also reported a positive association between deprivation and adiposity (Black and MacInko, 2010; Gregson, 2011; Rundle et al., 2008; Van Hulst et al., 2013; Xu et al., 2014). Dragano et al., (2007) also reported a positive association with between area level deprivation and adiposity, utilising employment as a proxy for deprivation. Income and employment both may have influence on the resource that one may

have access to, for them to engage in healthy behaviours such as eating healthy foods and exercising.

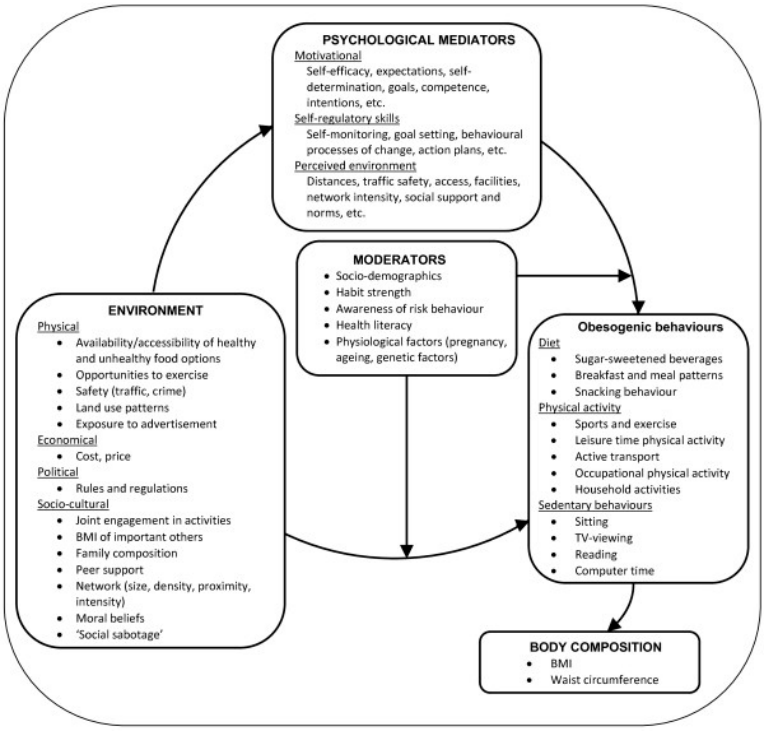
Several studies observed a stronger association of a composite index of neighbourhood deprivation with adiposity among women than men (Maier et al., 2014; Rundle et al., 2008), with some studies not showing any association among men at all (King et al., 2006; Smith et al., 1998; van Lenthe and Mackenbach, 2002; Yoon and Kwon, 2014). This has been attributed to the fact that most women may be unemployed and tend to spend more time in their living environments than men (Laraia et al., 2012). However, there is a need to further investigate the causes for the differential influences of area level deprivation on men and women. Smith et al., (1998) examined the association among civil servants and stratified their analysis by gender. They found a positive association between a multidimensional index of deprivation and obesity among women and no association among men.

Some of the studies conducted in LMICs showed a negative association with deprivation. The analysis was however done at country level utilising measures such as Gross National Product (GDP), Gross National Income (GNI) and Foreign Direct Investment (FDI) as proxies of deprivation. When considering the developing country context an increase in GDP, GNI or FDI might be coupled with greater rural to urban migration (Jones-Smith et al., 2011). Urbanisation often results in more sedentary lifestyles and increased access to energy dense foods (Nandi et al., 2014). It is however important that more studies are conducted in LMICs, for us to fully understand how neighbourhood deprivation influences adiposity in these countries.

5. Conceptual Framework

As a result of the literature reviewed, the adopted framework recognises that the pathway to adiposity is neither linear nor is it simply a result of individual choice. Adiposity is a result of interacting determinants at individual and environmental levels (Lakerveld, Brug, Bot, Teixeira, et al., 2012). This study, therefore, takes a multilevel approach to examining the association between area level deprivation and adiposity. This considers the mediatory and moderating role that individual level attributes may have the influence of the environment on obesogenic behaviours. We posit that the physical, economic, political and socio-cultural environments are influenced by the level of area deprivation and vice versa. Age, sex, race, education level, occupation, employment status, household income, marital status and physical exercise will be considered as individual level attributes that may influence adiposity and the association of area level deprivation and adiposity.

Figure 5: A conceptual frame work to understand the interaction between the environment and individual on the influence of adiposity



Source: Lakerveld et al., (2012), Sustainable prevention of obesity through integrated strategies: The SPOTLIGHT project's conceptual framework and design.

6. Methodology

6.1 Model Specification

This study aims to investigate the impact of neighbourhood level deprivation on individual level adiposity. It recognises that individuals are nested within these neighbourhoods and therefore utilises multilevel modelling to examine influence of neighbourhood (ward level) deprivation on adiposity. Multilevel modelling has advantages in that it is able to (1) distinguish between contextual and compositional effects on adiposity (2) consider both intergroup and inter-individual variations (3) account for the non-independence of observations between groups is (Diez-Roux, 2000).

The model can be conceptualised as a two-stage system of equations. The first stage is the individual variation within each group which is explained by equation 1 (Diez-Roux, 2000).

$$\boldsymbol{Ad_{ij} = \beta_{0j} + \beta_{1j}Age_{ij} + \beta_{2j}Sex_{ij} + \beta_{3j}Race_{ij} + \beta_{4j}Edu_{ij} + \beta_{5j}Occ_{ij} + \beta_{6j}Emp_{ij} + \beta_{7j}HI_{ij} + \beta_{8j}MS_{ij} + \beta_{9j}PE_{ij} + \varepsilon_{ij}\ ,\quad \varepsilon_{ij} \sim N(0, \sigma^2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{Equation\ 1}$$

where Ad_{ij}= Waist Circumference or Body Mass Index for the i^{th} individual in the j^{th}ward, Age_{ij} is the age of the i^{th}individual in the j^{th}ward, Sex_{ij} is the sex/gender of the i^{th} individual in the j^{th}ward, $Race_{ij}$is the race of the i^{th} individual in the j^{th}ward, Edu_{ij} is the highest education level attained by the i^{th} individual in the j^{th} ward, Occ_{ij} is the occupation of the i^{th} individual in the j^{th} ward, Emp_{ij} is the employment status of the i^{th} individual in the j^{th} ward, HI_{ij} is the household income within the household which the i^{th} individual in the j^{th} ward resides, MS_{ij} is the marital status of the i^{th} individual in the j^{th} ward and PE_{ij} is the physical exercise/activity carried out by the i^{th} individual in the j^{th} ward. ε_{ij} denotes individual errors within each group which are assumed to be independent and normally distributed with a mean of 0 and a variance of σ^2 (Duncan et al., 1998).

The second stage explains the variations across groups of group specific regression coefficients (β_{0j},β_{1j},...) defined in equation 1 (Diez-Roux, 2000). They are modelled as a function of the group level variables in question (in this case ward level deprivation and its domains) as shown in equations 2 and 3 (Pickett, 2001). At this stage the unit of analysis ward level.

$$\beta_{0j} = \gamma_{00} + \gamma_{01} SAIMD_j + U_{0j}, \qquad U_{0j} \sim N(0, \tau_{00}); \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{Equation 2}$$

$$\beta_{1j} = \gamma_{10}\,; \beta_{2j} = \gamma_{20}; \beta_{3j} = \gamma_{30}$$

$$\mathbf{cov}(U_{0j}, U_{1j}) = \tau_{10},$$

where $SAIMD_j$ is the ward level deprivation score for the j^{th} ward. U_{0j} and U_{1j} are the group/area level error terms which are assumed to be normally distributed with a mean of 0 and variances of τ_{00} and τ_{11} respectively (Diez Roux, 2002). They are also assumed to be independent across groups and independent of individual errors (ε_{ij}). The inclusion of an error term at group level allows for sampling variability in area specific coefficients and that the area level variables are not deterministic (Diez-Roux, 2000). Equations 2 and 3 can then be substituted into equation to give the overall contextual effects model (equation 4). We intend to examine the influence of area level income poverty and the individual component domains of SAIMD on adiposity as such similar equations will be utilised for them.

$$Ad_{ij} = \gamma_{0j} + \gamma_{1j} Age_{ij} + \gamma_{2j} Sex_{ij} + \gamma_{3j} Race_{ij} + \gamma_{4j} Edu_{ij} + \gamma_{5j} Occ_{ij} + \gamma_{6j} Emp_{ij} + \gamma_{7j} HI_{ij} + \gamma_{8j} MS_{ij} + \gamma_{9j} PE_{ij} + \cdots \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{Equation 4}$$

This multilevel linear regression function will then be interpreted in terms of the change in BMI or WC in relation to the β coefficient of the variable of interest holding other variables constant.

6.2 Sources of Data

The study will utilise Wave 3 of the South African National Income Dynamic Survey (NIDS) 2012, the ward level South African Index of Multiple Deprivation 2011 (SAIMD 2011) and the ward level income poverty measures, produced by Southern Africa Labour and Development Research Unit (SALDRU) and the Southern African Social Policy Research Institute/Insights (SASPRI) respectively.

The NIDS is a panel survey commissioned by the South African Presidency in 2006 to closely follow up 28,000 individuals across all age groups over a period of years. The Southern Africa Labour and Development Research Unit (SALDRU) are tasked to implement this survey. They sought ethical approval from the University of Cape Town's Senate Ethics Committee through the Commerce Faculty Ethics Committee. The NIDS data sets are also open source and are available to the public for download on the website http://www.nids.uct.ac.za/. The key

objectives are to elicit the dynamic structure of the South African people's lives whilst also measuring changes in income, expenditure, assets, access to services, education, health and other domains of well-being (Leibbrandt et al., 2009).

In the first wave of NIDS a nationally representative sample was drawn using stratified two stage cluster sampling. Initially 400 Primary Sampling Units (PSU) were randomly selected from Stats SA's 2003 Master Sample of 3000 PSUs (Leibbrandt et al., 2009). These were then followed up in subsequent waves of the NIDS wave 2 and wave 3 in 2011 and 2012 respectively. To ensure reliability of the responses elicited the questionnaires were pre-tested prior to the survey and appropriate adjustments made. Adult questionnaires were administered to participants 15 years and above (population of interest in this study).

The South African Index of Multidimensional Poverty (SAIMD 2011) and Income Poverty were produced by the SAPRI to facilitate the analysis of poverty and deprivation at sub-municipal level in South Africa. The SAIMD 2011 was developed using census data as a follow up to the original 2001 South African study on SAIMD (Noble et al., 2013). The rationale behind the measurement of multiple dimensions of deprivation is that individuals experience accumulation of different dimensions of deprivation (Townsend,1987 referenced in Noble et al., 2006). The domains used to generate the SAIMD 2011 were material deprivation, employment deprivation, education deprivation and living environment deprivation. This is in contrast to the SAIMD 2001 which included a health deprivation domain and a combined income and deprivation domain (Noble et al., 2006). The exclusion of income from the SAIMD 2011 is more consistent with our definition of deprivation which relates to a lack of necessities for a standard of living rather than access to resource to acquire these necessities (McIntyre, 2002; Noble et al., 2013). The health deprivation domain in the SAIMD 2001 was derived from mortality data as such its inclusion would not have had significant impact on this study (Noble et al., 2006). This is because, intuitively, death does not lie along the causal pathway to increase in adiposity. Therefore, its inclusion would not help elucidate the determinants of adiposity as is the goal of this study.

6.3 Measurement of Variables

6.3.1 Outcome Measurements

6.3.1.1 Measuring Body Mass Index (BMI)

BMI is used in this study as one of the surrogate measures for adiposity. During the NIDS survey enumerators were required to take two height measures and a third one if the first two had a difference of a centimetre or greater. Similarly, a third weight measurement was taken if the first two weight readings had a difference of a kilogram or greater (De Villiers et al., 2013). BMI is calculated using the formula below;

$$BMI = \frac{weight\ in\ kilograms}{(height\ in\ metres)^2}$$

An average of the first two measurements for height and weight were used to calculate BMI. In the event that the first two reading had a difference greater than 1 cm or 1 kg the third reading was used if available (De Villiers et al., 2013).

6.3.1.2 Measuring Waist Circumference (WC)

Waist circumference was measured by the NIDS interviewers. They took two measures of WC per respondent. An average of the two measurements was used as the waist circumference measure. If the two measures differed by 2 cm or more a third measurement was taken and used as the waist circumference measure.

6.3.2 Assessing Area Level Deprivation and Income Poverty

6.3.2.1 Area Level Deprivation

The SAIMD 2011 which will be used in this study is a weighted average of four domains or dimensions of deprivation. These are material deprivation, employment deprivation, education deprivation and living environment deprivation. They were developed to describe deprivation at sub-municipal level using census data (CENSUS 2011). The domains of deprivation were combined with equal weight to produce the overall SAIMD 2011. The selection of domains for inclusion in the SAIMD 2011 was influenced by those included in the SAIMD 2001, these were selected after a wide stakeholder consultation (Noble et al., 2006). However, unlike the SAIMD 2001, the SAIMD 2011 was constructed from published data as such it was not possible to construct a health deprivation domain. The indicators used to construct each of the domains were informed by an earlier piece of research which solicited the views of South Africans about basic necessities adequate for a standard of living (Noble et al., 2013).

Material Deprivation Domain: This domain seeks to capture the proportion of households in a ward experiencing material deprivation. The following indicators were selected for inclusion into the domain;

- Number of households with no refrigerator (basic asset for storage of food)
- Number of households with neither a landline phone nor a cell phone (access to the labour market for the working age and a lifeline to relatives, social and health services for the old)
- Number of households with neither a television nor a radio (communication with the outside world and a means of obtaining information critical to one's life and livelihood)

The indicators were combined to make one domain by calculating the proportion of household s experiencing at least one of the deprivations.

Employment Deprivation Domain: This domain seeks to measure the proportion of unemployed individuals within an area. It measures unemployment in terms of the "expanded definition" which includes discouraged workers. The following indicators were used to construct the domain;

- Number of people aged 15 to 64 inclusive who are unemployed (using the official definition[8])
- Number of people aged 15 to 64 inclusive who are discouraged workers.

These indicators were combined into one domain by calculating a proportion. The numerator is the unemployed (official definition) + the discouraged workers whilst the denominator is the total labour force (employed + unemployed (official definition) + the discouraged workers).

Education Deprivation Domain: This domain seeks to measure the extent of deprivation in terms of educational qualifications among adults (18 to 64 years) in a local area. The following indicators were used to construct this domain;

- Number of 18 to 64 year, inclusive, olds with no schooling at secondary level or above.

[8] Statistics South Africa (StatsSA) gives the official definition of the unemployed as 'those people aged 15–65 years who:

- ✓ did not work during the 7 days prior to 10 October;
- ✓ want to work and are available to start work within a week of the interview; and
- ✓ have taken active steps to look for work or to start some form of self-employment in the 7 days prior to 10 October (Statistics South Africa, 2012: 78).

The domain was then calculated as a proportion of adults aged 18 to 64 years inclusive.

Living Environment Domain: The purpose of this domain is to measure the deprivation related to the poor quality of the living environment. It covers issues that may be regarded as service delivery deprivation. The following indicators were used to construct this domain;

- Number of people without an adequate water supply; or
- Number of people without access to an adequate toilet; or
- Number of people without use of electricity for lighting; or
- Number of people living in a house that is a shack.

To combine the indicators, a proportion of the number of households experiencing at least one of the deprivations was calculated.

A full report on how the SAIMD-2011 was developed is available on the SASPRI website. (http://saspri.org/SASPRI/wp-content/uploads/Docs/SAIMD_2011_ward_level_National_Report_for_Web.pdf)

6.3.2.2 Income Poverty

The income poverty measure seeks to measure the extent to which household lack the resources for a "decent" standard of living. In South Africa there is no widely agreed upon income poverty line, however the SASPRI team utilised the one extensively used in the NIDS. This is based on the work conducted by Hoogeveen and Ozler who propose to use two income bounds: a lower bound (R604[9] per capita per month) and an upper bound (R1113 per capita per month). Both the lower and upper bound poverty lines scores are presented followed by the rank. The poorest ward is ranked 1 whilst the least poor ward is ranked 4277 (Noble et al., 2013).

For a detailed methodology on the income measures were developed follow the link below; http://saspri.org/SASPRI/wp-content/uploads/Docs/Income_Poverty_at_ward_level_National_Report_for_Web.pdf

6.3.3 Measuring Individual Level Variables

The individual level variable considered in this study were based on literature and limited to those variables captured in the NIDS questionnaires (A drawback of secondary data analysis). Also household level variables will be considered as operating on the individual level in the multilevel analysis. The following determinants will be considered in the study age, sex, race,

[9] Inflated to 2011 prices

education level, occupation, employment status, household income, marital status, physical exercise.

Age: This was based on self-reported information. Participants were asked their date of birth (month and year) and their age calculated. It is coded as *w3_best_age_yrs* in the NIDS data set. To account for the curvi-linear relationship between age and adiposity increase, the age-squared will be used in the regression models (Wen and Maloney, 2011). This will be treated as a continuous variable.

Sex: This was based on self-reported information. It is coded as *w3_a_gen* in the NIDS data set. Those who refused to give their gender or gave their response as do not know and missing responses will be dropped from the study. Male will be set as the reference group in the initial multivariate model. A number of studies have reported differentials in the determinants of obesity by gender as such our analysis will be stratified according to gender (Jones-Smith et al., 2011; Keita et al., 2014; King et al., 2006).

Race/Population group: This was based on self-reported information. It is coded as *w3_a_popgrp* in the NIDS data set. This will be treated as a categorical variable, African, Coloured, Asian/Indian, White and Other. African will be set as the reference group in the multivariate model.

Education Level: The NIDS data set has a derived variable on highest level of educational attainment, coded as *w3_best_edu.* It was derived from self-reported data on educational attainment in the adult questionnaire. Education will be categorised into four categories; No education, Primary Level, Secondary Level and Tertiary Level. Those who responded as having no schooling and grade 0 as the highest level educational attainment will be classified as having "No education". Those who said their highest educational level attained was grades 1 to 7 will be classified as "Primary Level". Those who said their highest educational level attained was grades 8 to 12 will classified as "Secondary Level". Those who attained a higher educational level than grade 12 were classified as "Tertiary Level". "No education", will be set as the reference group in the multivariate model.

Occupation: This relied on self-reported information. It was coded as *w3_a_em1occ_c* in the NIDS data set. Occupation will be re-categorised into three categories, "not working", "blue collar" and "white collar", to aid in final analysis. Those who responded as do not know and never worked will be classified as "Not working". Those whose occupation falls under the

following categories; service workers and shop and market sales workers, skilled agricultural and fishery workers, craft and related trades workers, plant and machinery operators and assemblers and elementary occupations will be classified as “Blue collar”. Those whose occupation falls under the following categorises; Legislators senior officials and managers, Professionals, Technicians and associate professionals and Clerks will be classified as “White collar’. “Not working”, will be set as the reference group in the multivariate model.

Employment status: This relied on self-reported information. It was coded as *w3_a_em1* in the NIDS data set. Those with missing data and those who declined to respond to the question on employment will be excluded from the analysis. This will be treated as a binary variable Unemployed = 0 and Employed = 1.

Household Income: This variable is already calculated in the NIDS data set and is coded as *w3_hhincome*. The household income will be divided into income quintile, “Low Income”, “Middle Income” and “High Income”. “Low Income”, will be treated as the reference group in the multivariate model.

Marital Status: This relied on self-reported information. It was coded as *w3_a_marstt* in the NIDS data set. Marital status will categorised into three categories, that is, “Married/Living with a partner”, "Widow/Widower/Divorced" and “Never married”. Those who responded as either married or living with a partner will be classified as “Married/Living with a partner”. Those who responded as either widow, widower or divorced will be classified as "Widow/Widower/Divorced". Those who responded as never married will be classified as “Never married”. “Married/Living with a partner”, will be treated as the reference group in the multivariate model.

Physical Exercise: This relied on self-reported information. It was coded as *w3_a_hllfexer* in the NIDS data set. Physical exercise will be treated as a binary variable, “exercise” = 1 and “no exercise” = 0. Those who responded as never doing exercises will be classified as “no exercise”. Those who responded as doing exercises; Less than once a week, Once a week, Twice a week and Three or more times a week will categorised as “exercise’.

6.4 Analysis Plan

The statistical software Stata® 12.1 (StataCorp, TX, USA) will be used for data exploration, cleaning and analysis. We will exclude all missing data points and erroneous extreme values (negative and zero values) of WC, height and weight from the analysis. The extreme values for

height and weight considered to be biologically implausible are less than 1m and more than 2m for height and less than 25kg and more than 200kg for weight (Corsi et al., 2012). All pregnant women and those above 65 year of age will also be excluded from the analysis. A variable for BMI will be generated using height and weight. In the analysis both BMI and WC will be treated as continuous variables.

Firstly, descriptive statistics for all variables provided will be generated for the study population. These will be presented by way of frequency and percentage tabulations. A bivariate analysis will be done for all individual and household level variables to determine which variables to include in the regression analysis.

Due to the hierarchical nature of the data; individuals (level 1) and area level deprivation (level 2), we first create a baseline model using individual level variables. Then develop a multilevel generalized linear latent and mixed model accounting for both the individual level and area level deprivation variables. All analysis will be stratified by gender.

7. Ethics

The study will utilise data that is already available in the public domain. The NIDS data is available from the University of Cape Town through the Southern Africa Labour and Development Research Unit (SALDRU). Every effort was made to remove personal identifier information from the publicly available NIDS dataset (names and contact details are kept separately from the public release data) (De Villiers et al., 2013). The SAIMD and income poverty measures are available from the Southern African Social Policy Research Institute and the Southern African Social Policy Research Insights, collectively known as (SASPRI). Since the study relies on secondary data, no ethical issues are expected to arise. However, consent will be sought from the Health Research Ethics Committee (HREC) of the University of Cape Town.

8. Stakeholder Reporting and Implementation

The study findings will be published as a journal article and policy brief. The journal article will be submitted for peer review to appropriate journals. It will also be availed to the University of Cape Town's Health Economics Unit, the Southern Africa Labour and Development Research Unit, the Southern African Social Policy Research Institute and the Southern African Social Policy Research Insights.

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PART B: Literature Review

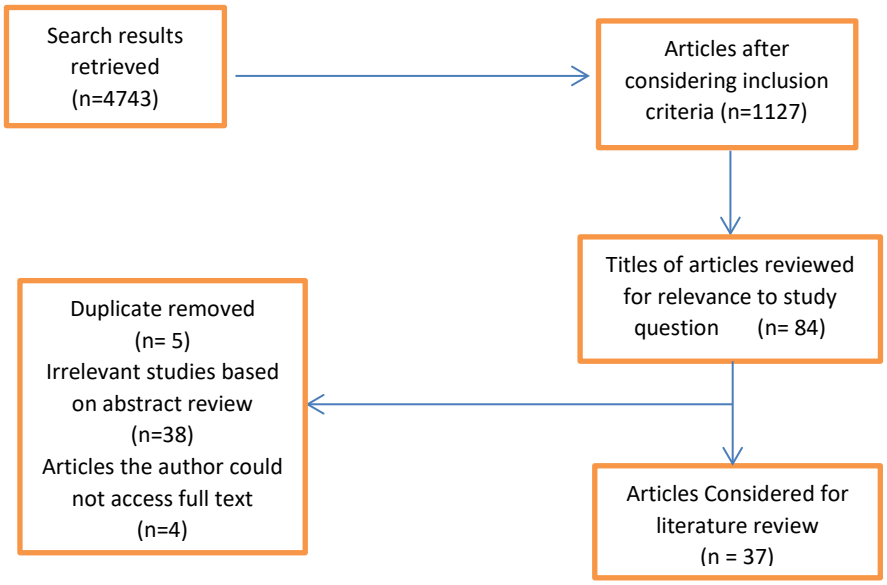
Introduction to the Literature Review

The literature review section presents a structured theoretical, methodological and empirical review associated with neighbourhood level deprivation and adiposity. Firstly, we will provide a summary of how the literature search was conducted.

Search Strategy

The following databases were searched for articles in English and conducted among humans; Medline via PubMed; Africa-Wide Literature, Academic Search Premier, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Econlit via EBSCO host; Google scholar; Scopus and Web of Science. Search terms relevant to the study topic which included; deprivation, poverty, indigence, disadvantage, low-income, developing countries, underdeveloped countries [Basic Search] AND adiposity, overweight, obesity, over nutrition, body mass index, waist circumference, hip to waist ratio [MeSH] AND small area analysis, multilevel analysis, contextual, spatial analysis, built environment, hierarchical [MeSH] were used. The search was restricted to the title and abstract of full text articles. The retrieved articles were screened by reviewing their titles and articles. Titles that were not relevant to the study objectives were excluded. The literature was further screened by reading through the abstracts of the identified articles.

Figure 6: Diagrammatic representation of the search process



1. Background

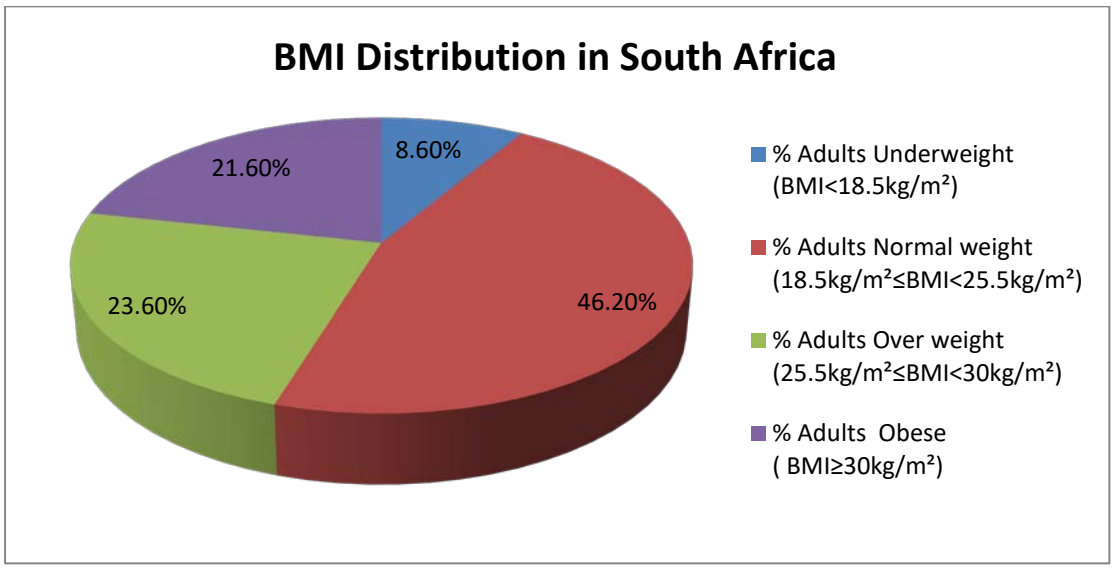
1.1 Epidemiology of Adiposity

Globally the prevalence of adiposity has been on the increase over the past three decades. There has been an increase of body mass index (BMI), an indirect measure of adiposity, by 0.4kg/m² (95% CI: 0.2-0.6) among men and 0.5kg/m² (95% CI: 0.3-0.7) among women per decade since 1980 (Finucane et al., 2011; Swinburn et al., 2011). The surge in obesity rates was first observed on high income countries in the 1970s and 1980s with low and middle income countries recently experiencing similar trends (Swinburn et al., 2011). Furthermore, the World Health Organisation (WHO) estimates that the burden of obesity will double the 2008 rates by 2030 if left unabated (WHO, 2010).

In sub-Saharan Africa the prevalence of obesity in urban settings has increased by up to 35% between 1992 and 2005 (Ziraba et al., 2009). However, most of these countries are channelling resources toward battling mortality due to diseases related to infections agents, nutritional deficiencies, maternal and perinatal conditions. These are expected to decrease by up to 3% over the next 10 years, whilst non communicable diseases (NCDs) are expected to increase by up to 17% over the same period (Tunstell-Pedoe, 2006). Excess adiposity is a major risk factor for a number of NCDs.

Among SSA countries South Africa has the highest prevalence of obesity as it is experiencing a rapid epidemiological transition (Micklesfield et al., 2013). Urbanisation, industrialisation and economic transition are the possible causes of the high prevalence in obesity as they promote a sedentary life style and consumption of energy dense foods (National Department of Health, 2013; Yoon and Kwon, 2014). Evidence from repeated panel surveys show an increase in the prevalence of obesity from 23.5% in 2008 to 27.2% in 2012 (Sartorius et al., 2015). The same study also showed a disproportionately higher burden of excess adiposity among women (37.9%) as compared to men (13.3%). The figure below shows the distribution of BMI amongst South African adults of note is that 45.2% of adults are classified as either overweight or obese.

Figure 7: WHO estimates on distribution of BMI among the South African Population



Adiposity can be measured directly or using indirect surrogate measures. Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Dual-Energy X-ray Absorptiometry (DXA) have been used to accurately measure the percentage body fat individuals (Sun et al., 2010). These are direct measures of adiposity with the ability to distinguish between lean muscle mass and fat. The use of these methods has been limited in epidemiologic studies due to their high cost, complexity of operation, non-portability of equipment and need for skilled operators (Sun et al., 2010). Indirect anthropometric surrogate measures of adiposity such as body mass index (BMI), waist circumference (WC), triceps skinfold thickness, and hip to waist ratio (HWR) are widely used instead (Bosy-Westphal et al., 2010; Fleming, 1996; Neovius et al., 2004).

1.2 Impact of adiposity

Excess adiposity is of public health concern that has health, social and economic impacts as elaborated below.

1.2.1 Impact on health

Excess adiposity is a major risk factor for non-communicable diseases, chief among them is type 2 diabetes mellitus (T2DM) (Sassi, 2010). As compared to non-obese individuals, severely obese individuals (BMI>40kg/m²) have 7.37 odds of being diagnosed with T2DM (Micklesfield et al., 2013; Dalal et al., 2011; Van Itallie, 1979). Furthermore, some literature has reported that obese individuals are 60 times more likely to develop T2DM as compared to non-obese individuals (Colditz, 1999). In addition, as adiposity increases so does the likelihood of hypertension and high cholesterol levels. These are strongly linked with cardio vascular

diseases (CVDs) morbidity and mortality (Dalal et al., 2011; Van Itallie, 1979). Moreover, a number of cancers such as colorectal and breast cancer have been linked to excess adiposity (Micklesfield et al., 2013).

Mortality from selected NCDs was observed to be the lowest among individuals with a BMI of 22.5 to 25 kg/m² from prospective studies. The same studies also noted that each 5kg/m² increase was associated with a 30% increase in all-cause mortality (Whitlock et al., 2009). However, this association was not strong beyond the age of 70 years and higher mortality was observed among those with a lower BMI. This has been referred to as the obesity paradox (Colditz, 1999). Those with a high waist circumference (WC), WC> 102cm for men and WC> 88cm for women, are at higher risk of mortality as result of metabolic syndrome related diseases as compared to those with lower WC measures (Ardern et al., 2003).

In 2013, an estimated 31.9% of deaths were attributed to NCDs in South Africa (National Department of Health, 2013; Schneider, Bradshaw, Steyn, Norman, & Laubscher, 2009). The report on Mortality and causes of death in South Africa, 2013: Findings from death notification shows that diabetes, hypertension, heart diseases and cerebrovascular conditions were among the 10 leading causes of mortality in South Africa. The same report also sighted diabetes as the second leading cause of death among South African women. Adiposity is a major risk factor for the development of NCDs even more so than smoking (Mokdad et al., 2003).

1.2.2 Economic Impact

There are direct and indirect costs associated with the burden of excess adiposity. These arise due to the chronic diseases associated with obesity that have been described. The direct costs are those linked with medical expenses of treating associated diseases and indirect costs are through labour force exclusion through disability or death (Abegunde et al., 2007). Empirical evidence from high income countries suggests that obese individuals spend more on health care as compared to those with normal weight (Dalal et al., 2011; Mokdad et al., 2003).

The direct costs associated with excess adiposity amounted to $52 billion accounting for 5.2% of expenditure on health in the United States of America (USA). If current obesity trends continue to increase unabated its direct cost are expected to increase by $48-66 billion/year in the USA whilst in the UK cost are expected to increase by £1.9-2 billion/year (Pischon et al., 2008). The burden of chronic diseases is high amongst those less able to cope with the financial impact of illness as the prevalence is disproportionately higher among the poor as compared to wealthier groups (Suhrcke et al., 2006).

When compared to individuals with normal weight obese individuals are more likely to be excluded from the labour market (Colditz, 1999). This could be attributed to the fact that obese individuals tend to be absent from work for longer periods and are less productive on the job as compared to their normal weight counter parts. They have greater access to disability aid in developed countries as such this may discourage them from seeking employment (Abegunde et al., 2007). Moreover, obese individuals may be discriminated against by potential employers due to perceptions of lower productivity as compared to non-obese individuals (Montague and O'Rahilly, 2000).

Data from OECD countries suggests that being obese is associated with higher wage penalties, of up to 18% in some countries (Colditz, 1999). Production losses and health care expenditure as a result of obesity has accounted for a fraction of a percentage loss in GDP in most OECD countries and up to a 1% loss in the USA (Montague and O'Rahilly, 2000). In China it is projected that losses to gross national product (GNP) as a result of the adverse effects of excess adiposity will be up to 8.73% in 2025 (Colditz, 1999). The effects of adiposity on health and economic welfare are therefore very substantial.

2. Theoretical Review

This section will provide the theoretical and empirical motivations underpinning the deprivation measurements. It will also provide a conceptualisation of the relationship between area level deprivation and obesity.

2.1 Deprivation and Poverty

In the history of humanity there has been no single subject that has concerned societies more than poverty. This is a subject that has been debated and researched widely and still no single definition of the phenomenon has been agreed on. It has been studied in a number of disciplines from sociology, economics to politics, with each discipline positing its own theories (Agola and Awange, 2014; Asselin and Dauphin, 2001; Clark, 2003; Sameti et al., 2012; Sen and Anand, 1997). The various theories seek to understand the causes of poverty. However, there are common factors identified across on theories influencers of poverty which are individual attributes (capabilities), neighbourhood environment (including cultural factors) and structural factors (Sameti et al., 2012).

In economics, the classical, neoclassical, neoliberal, Marxian and social capital theories attempt to explain the causes of poverty. The classical traditions view an individual as being responsible

for their own density and that it is their choice to be poor (Dhillon and Peralta, 2002). The view also argues that government intervention to alleviate poverty should focus on improving capabilities and attitudes (Agola and Awange, 2014). Neoclassical school of thought is similar to the classical but broader recognising the influence structural factors such as the economic environment on individual impoverishment (Asselin and Dauphin, 2001; Dhillon and Peralta, 2002). Neoliberal economists similar to the classical economists believe that increasing incomes is the most effective way to reduce poverty. However, they put less emphasis on the individual and more on public goods and inequality as major influencers of poverty. Unemployment is viewed as involuntary and as the main determinant of poverty (Dhillon and Peralta, 2002).

The main advantage of classical and neoclassical views of poverty is that they rely on a quantifiable monetary measure (Nolan and Whelan, 2011). These are easier to collect and analysis as compared to non-monetary measures. However, they have criticised for their focus on the individual with taking into account neighbourhood influences such as culture (Mead, 1996). In order to eradicate poverty, it is widely accepted that there is need to focus beyond monetary deprivation (Sen and Anand, 1997). The classical, neoclassical and neoliberal all focus mainly material deprivation which only one dimension of poverty.

Marxian economists, also known as radical theorists, believe that growing the economy alone is not adequate to eradicate poverty. Karl Marx coined the term “class struggle” which relates to an antagonism of socioeconomic interests between different classes in society (Dhillon and Peralta, 2002; Mead, 1996). This is the reason why Marxian economists believe that economic growth does not necessarily translate to an improvement in livelihoods for all classes in society (Austin, 2006). These theories were muted at the height of the industrial revolution which was characterised by low wages and long working hours for workers (the poor). Marxian economists highlight the exploitation of the poor worker by the rich capitalists, something that still exists in a lot of society today especially in developing countries (Mead, 1996). Furthermore, the poor are usually the most affected by the environmental pollution which is usually mostly caused by the wealthier groups. Minimum wage and anti-discrimination laws are some of the policy prescriptions that have been borne out of Marxian line of thought. This way of thinking looks at society as groups (classes) rather than individuals (Asselin and Dauphin, 2001; Clark, 2003).

The social exclusion and social capital theory recognise the influence of societal structural characteristics and the situation of certain groups (Dhillon and Peralta, 2002). This line if thought recognises the influences of poverty outside income parameters (Mead, 1996). It provides a framework to view the broader influences on poverty. This perspective is particularly relevant in the South African context were the impact of apartheid persists today (Metz and Gaie, 2010). During apartheid resources and means of production were distributed according to race with the white minority receiving the largest proportion. Individual from other racial groups who managed to amass wealth in this environment were still restricted on the neighbourhoods they could leave in and schools to send their children (Woolard, 2002). However, with this approach poverty is challenging to measure, quantify and to develop policies to address it.

2.2 Measuring Poverty and Deprivation

In his famous publication, The Wealth of Nations (1776), Adam Smith recognised that poverty can be relative. He noted variations in the commodities that are regarded as necessities in different societies (Sen and Anand, 1997). This approach defines relative to others, for example, one might classify those who are impoverished as those with less than 25% of the average income. This approach is consistent with the definitions of poverty and deprivation suggested by Townsend (1979), which we will discuss later, he defines then as a lack of resources or capabilities relative to what is regarded as the norm in society.

On the other hand, poverty can also be measured in absolute terms. This is usually defined in terms of the financial requirements for a household of a particular size to afford a defined basket of basic goods and services (Agola and Awange, 2014). In Zimbabwe and Zambia, the governments publish a Poverty Datum Line (PDL) representing the cost for a defined standard of living that an individual/household must attain not to be defined as poor (Alkire et al., 2014). These two approaches to poverty measurement have an impact on the policy prescriptions that policy makers will give to combat poverty. The absolute poverty measure will promote a focus on raising incomes whilst the relative measure will promote a focus on reducing income inequality (Sameti et al., 2012).

2.3 Theoretical and Empirical Motivations for Multidimensional Deprivation Measures

Townsend (1987) defines deprivation as a *lack of types of diets, clothing, housing, household facilities, fuel, environmental, educational, working and social conditions, activities and facilities which are customary (Townsend,1987:131&140 referenced in Noble et al., 2006).* Thus the concept of deprivation looks beyond access to financial resources but rather on the material and social conditions that individual experience relative to the norm in their communities (McIntyre, 2002). This concept of deprivation is similar to Sen's human capabilities approach which defines deprivation as *the inability of individuals to acquire the minimum capabilities required to function (such as inability to be healthy, sheltered, well-clothed e.tc.)* as accustomed in their societies (Klasen, 2000). As shown by these definitions and quotes summarised in Table 1, it follows that poverty measures must reflect the multifaceted nature of poverty.

The multidimensional approach to measurement of deprivation concentrates directly on functions and capabilities that people enjoy (Sen, 2000, 1981). This inherently avoids some of the challenges in financial resource based approaches. These include heterogeneity of people (differentials in translation of consumption to welfare), impact of public goods and the 'social wage' on welfare (Klasen, 2000). Intuitively, differences understanding of health behaviours may mean that people endowed with the same amount of financial will invest differently on their health. The social wage includes social grants, tax relief and free basic services for the poor (Meth and Rosa, 2010). When using income approaches to measure welfare the impact of their impact is not captured. In South Africa, the government provides access to free basic services such as health and education for the poor and social grants for the unemployed (Budlender, 2008). Failure to capture this with income measures would make people seem worse off than they really are.

Directly measuring human welfare is important within the South African context due to its apartheid past which promoted differential access to resources by race and whose legacy persists in today's society (McIntyre and Gilson, 2002). Under the apartheid regime a black[10] family could have access to wealth in monetary terms but would be prevented from residing in an area with basic services such as electricity, clean water, refuse collection and so forth (Budlender, 2008). This had major impacts on wellbeing and opportunities for different race

[10] Black in this instance refers to people of African descent, Asians and Coloureds.

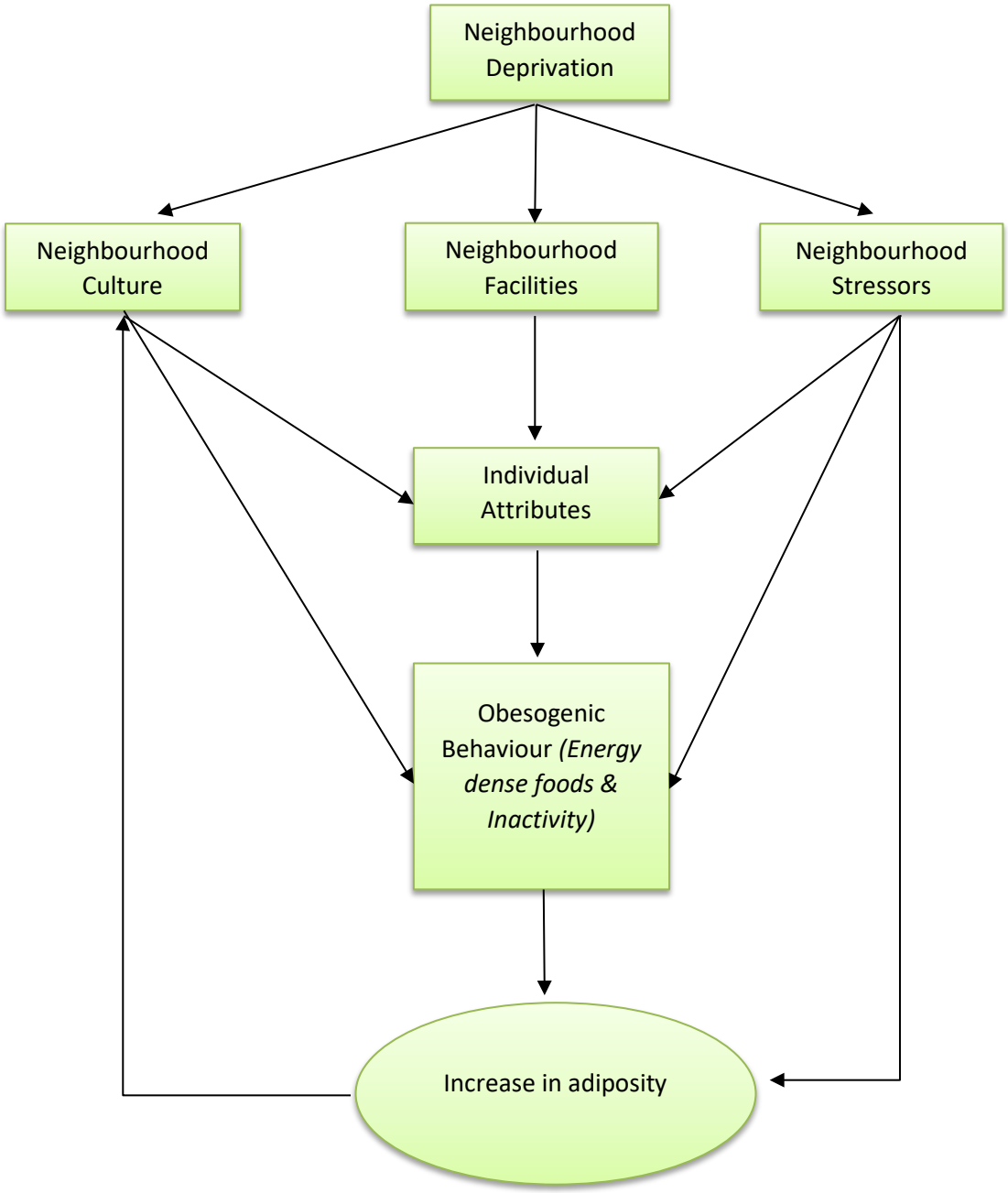
groups. Moreover, if poverty is understood as a shortfall of wellbeing it therefore cannot be measured without considering some measure of wellbeing (Alkire et al., 2015).

The multidimensional approach to measurement of deprivation however has its shortcomings. There is a wide debate on the domains/dimensions to include, the cardinal interpretation of the value of each component and the relative weight assigned to each component (Klasen, 2000). This study is of the view that a pragmatic approach to should be taken when deciding on which poverty measures to utilise. Multidimensional measurements of poverty can be decomposed in terms of dimension of deprivation and social-economic attribute (Whelan et al., 2014). This allows policy makers to target the causes of deprivation within their constituencies. Moreover, due to the nature of poverty and inequality in low and middle income countries (LMICs) (including South Africa) a focus on multidimensional deprivation is of relevance (McIntyre, 2002). The Southern African Social Policy Institute produced the multiple deprivation and Income poverty at small area level report in South Africa in 2011. The report gives both income poverty measures and a multidimensional deprivation measure as such this study will utilise both measures (Noble et al., 2013).

2.4 Conceptual Framework

In the reviewed literature the impact of derivation on adiposity has largely been assessed as one of its many determinants. As a result, most studies have employed the socio-ecologic model and ecological theories to explain the influencers of adiposity (Gregson, 2011; Hey, 2004; Koh et al., 2015; Stafford et al., 2010; Stoddard et al., 2013). These models recognise that the environment that individuals live in has an influence on their health status net of individual attributes and behaviours (Wen and Maloney, 2011; Yoon and Kwon, 2014). The study adopted and modified the conceptual framework utilised in the Globe Study which recognises the influence of neighbourhood deprivation on neighbourhood culture, stressors and facilities (van Lenthe and Mackenbach, 2002). The framework was modified in view of the Renfrew and Paisley findings; that the association between area deprivation and adiposity is modified by individual attributes (Smith et al., 1998). The figure below represents the conceptual framework explain the association between area level deprivation and adiposity.

Figure 8: Conceptual framework explaining the influence of area level deprivation on Adiposity



Source: Van Lenthe and Mackenbach, (2002) Neighbourhood deprivation and over weight: The Globe Study, modified conceptual framework

2.4.1 Individual Attributes

Biology to plays an important role in predicting adiposity for example through epigenetic effects an obesogenic pre-natal environment increases the likelihood of adult obesity in the off-spring (Huang et al., 2009). Furthermore, genetics have been shown to increase some individuals susceptibility to obesity (Hey, 2004). Moreover, bodies can decrease sensitivity to metabolic signals that inhibit overeating when food supply is limited or cyclic to allow for storage of excess energy in the form of body fat. However, in the abundance of palatable energy dense foods it is this decreased sensitivity that promotes adiposity (Swinburn et al., 1999). Santana, Santos, & Nogueira (2009) argue that the gene pool has remained unchanged in the past few decades when obesity trends have surged globally. Therefore, the key drivers of the obesity epidemic are not strongly linked with genetics.

A number of studies have shown a difference in the prevalence of adiposity among men and women and this is particularly true in South Africa (Laraia et al., 2014; Sartorius et al., 2015; Yoon and Kwon, 2014). Evidence suggests that the influence of the neighbourhood on obesity rates is stronger in women as compared to men (Wen and Maloney, 2011). Unemployment rates are higher in women and housekeeping duties usually burden women more than men as a result they tend to spend longer times in the home environment as compared to their male counterparts (King et al., 2006; Smith et al., 1998; van Lenthe and Mackenbach, 2002; Yoon and Kwon, 2014). Also with age women tend to lose more lean muscle mass as compared to men (Romero-Corral et al., 2008). As result they may have a lower metabolism rate than a male of similar body mass and size. A lower metabolism rate would result in faster rate of accumulation of body fat, with other conditions remaining the same.

In developed countries a high socioeconomic status (SES) is associated with a lower prevalence of obesity whilst in developing countries the opposite is true (Van Hulst et al., 2013). An explanation to this might be that low income groups in developed countries and high income groups in developing countries have access to high energy yet poor nutrient foods (Huang et al., 2009). Furthermore, a high SES, particularly in developed countries, might reflect a high level of education implying a better understanding of the deleterious effects of obesity as compared to their lower SES counterparts (Wen et al., 2003).

On the other hand, there is increasing recognition that effectively tackling the obesity epidemic requires that we go beyond individual risk factors to broader environmental factors (Lakerveld et al., 2012a). Environmental factors, such as neighbourhood culture, facilities and stressors,

mediate the effects of genetics and ultimately influence the development of obesity (Hey, 2004).

2.4.1 Neighbourhood Culture

The amount of resources available to an area also has an impact on the neighbourhood culture as it may provide cues that support particular social norms (Laraia et al., 2014, 2012). Social norms and cultural beliefs are another mechanism by which neighbourhood deprivation may influence personal behaviours (Dragano et al., 2007). Environments in which obesity is stigmatised may encourage inhabitants to eat healthier and exercise more (Rundle et al., 2008). On the other hand in some societies, for example, among black South African women being moderately overweight is associated with dignity, confidence, wealth, respect and beauty (Puoane et al., 2005). In addition, some cultures particularly in African view child obesity as sign of good health (Huang et al., 2009).

2.4.2 Neighbourhood facilities/built environment

The built environment is man-made and it encompasses a range of physical and social elements that make up a society and may influence adiposity (Papas et al., 2007). It can have direct and indirect influence on food choice and level of physical activity (Feng et al., 2010). The perceptions of neighbourhood safety and availability of parks and recreational sporting areas can influence on the amount of physical activity neighbourhood residents have (Xu and Wang, 2015).

Neighbourhood resources have an impact on the availability of facilities within neighbourhoods such as large chain supermarkets (Ford and Dzewaltowski, 2011), safe recreation spaces (Sundquist et al., 1999), fast food outlets (Robert and Reither, 2004) and transport networks (Matheson et al., 2008). A high number of fast food outlets versus a limited number of supermarkets may produce an unhealthy food environment (Robert and Reither, 2004). Supermarkets tend to have a wide variety of healthier foods such as fruits and vegetables at affordable prices as compared to smaller grocery shops (Santana et al., 2009). This is particularly important within the South African context where there is a higher concentration of small “spaza” shops in deprived areas than affluent areas.

2.4.3 Neighbourhood Stressors

Deprived areas tend to have a higher number of stressors as compared to affluent areas (King et al., 2006). These stressors may be a result of higher crime rates, poor perception of safety

(Smith et al., 1998), physical incivilities[11] (Laraia et al., 2014) or greater overcrowding and noise levels (Coogan et al., 2009). Biologically stress can result in neuroendocrine autonomic dysregulation which influences the accumulation of fat in the body (Coogan et al., 2009; Yoon and Kwon, 2014). Moreover, stress has been linked to non-homeostatic eating[12] and the ingestion of energy high foods (Grundmann et al., 2014; Janssen et al., 2006; Laraia et al., 2014).

[11] Physical incivilities are manifestation of neighbourhood deprivation through littering, uncollected garbage, unkempt property and dishevelled public spaces (Laraia et al., 2014)
[12] Non-homeostatic eating is the consumption of food other than for caloric need (Laraia et al., 2014)

Table 3: Summary of High Income Country studies assessing association between area level deprivation and adiposity

Author (year)	Country	Study Population	Study Design	Area level metric	Study Objectives	Contextual Variables (Area-Deprivation Measure/Indices)	Individual Level Variables	Measurement	Adiposity measure	Results
Grundmann et al., (2014)	Germany	National cross sectional survey (n=39,908 [13])	Multilevel Logistic Regression Analysis	Municipality	*Hypothesis* The prevalence of obesity and T2D both increase with increasing area deprivation, even after controlling for individual level SES using multilevel modelling	German Index of Multiple Deprivation composing of Income, Employment, Education, Municipal Revenue, Social Capital, Environment & Security	•Physical Activity •Income	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	1. A positive association of area deprivation with T2D and obesity 2. The association was relatively similar for both men and women
Keita et al., (2014)	USA	Cross sectional survey of 48 States (n=19,079)	Logistic regression analysis (Individual Level)	Census block group level	1. To assess the associations of socioeconomic status on metabolic syndrome [14] components beyond individual level socioeconomic status 2. To examine whether neighbourhood	Deprivation Index composing of Income, Median value of housing units, Education, Employment	•Race •Sex •Income	Measured	Binary Variable: Obese = BMI ≥ 30 kg/m² OR WC: men > 102cm, women > 88cm	1. Among black adults residing in the most deprived area was associated with increased odds of obesity and other metabolic syndrome markers

[13] Study population included in the analysis

[14] Keita et al., (2014) defined metabolic syndrome using the modified ATP III which includes (1) Triglycerides ≥150 mg/dL (2) HDL Cholesterol for men <40 mg/dL and for women <50 mg/dL or any lipid lowering medication (3) Blood Pressure ≥130/85 mm Hg or antihypertensive medication use (4) Fasting glucose ≥100 mg/dL or antidiabetic medication use (5) Waist Circumference for men >102 cm (>40 in) and for women >88 cm (>35 in)

					socioeconomic deprivation is associated with biological markers of metabolic syndrome					2. Among white adults residing in the most deprived areas was associated with an increased odds higher waist circumference and other markers of metabolic syndrome
Yoon & Kwon, (2014)	Korea	Cross sectional national health survey (n=337,136)	Multilevel Logistic Regression Analysis	Community	1. To explore multidimensional factors related to obesity by dividing them into individual and environmental factors 2. To examine the influence of the community environment on obesity by applying multilevel analysis	Education Level	•Age •Household Income •Occupation •Marital Status •Physical Activity •Stress	Self-reported	Binary Variable: Obese = BMI ≥ 25 kg/m²	Lower risks of obesity were associated with living in areas with high SES, high satisfaction with safety and public transportation and high accessibility to sports facilities
Wen & Maloney, (2011)	USA	Cross sectional data for Whites and Hispanics living in the State of Utah	Multilevel Logistic Regression Analysis	Census tract level	1. To examine the association between contextual residential isolation and individual risks for obesity 2.To assess whether neighbourhood context plays	Deprivation Index composing of Income, Education & Home Ownership	•Ethnicity •Sex Age	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	In both men and women, a high neighbourhood SES was associated with lower risks of obesity

		(n=735,975)			a mediatory role in observed obesity disparities					
Cubbin et al., (2006)	Sweden	Cross sectional nationally representative survey (n= 18,081)	Logistic Regression Analysis (Individual Level)	Small Area Market Statistics (SAMS)	To determine whether neighbourhood deprivation is independently associated with CVD risk factors[15]	Care Need Index composed of elderly living alone, foreign-born, unemployment, single parents, residents who moved residences during the past year, education, children under age five	•Age •Sex •Marital Status •Immigration Status •Urbanisation Socio-economic Status	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Living in a neighbourhood with high levels of deprivation was associated with higher odds of obesity *(analysis not stratified by any demographic or socioeconomic characteristics)*
Ford & Dzewaltowski, (2011)	USA	Cross sectional survey of Kansas *mothers* enrolled in a nutrition program (n=21,166)	Multilevel Linear Regression Analysis	Census tract level	*Hypothesis* 1. Track deprivation is associated with increased BMI independent of individual level covariates 2. The association between track and BMI varies along the rural- urban continuum 3. The association between track deprivation and BMI is mediated by the number of supermarkets in the track	Deprivation Index composing of Employment, Income, Housing, Female headed HH, Car Ownership	•Race •Ethnicity •Education •Income	Self-reported	Continuous Variable: BMI	1. In Metropolitan areas high deprivation was associated with increase BMI 2. In Micropolitan areas the association between BMI and track deprivation was non linear 3. In rural areas no association between track deprivation and BMI was found

[15] Cubbin et al., (2006) considered the following as CVD risk factors/behaviours (1) smoking (2) physical inactivity (3) obesity and (4) suffering from either diabetes or hypertension or both.

										4. Presence of supermarkets, grocery and convenient store did not mediate the association between track deprivation and BMI in any of the areas
Santana et al., (2009)	Portugal	National Health Survey of adults above 18 years (n=7,669)	Multilevel Logistic Regression Analysis	Neighbourhood (mean population = 12,420)	To evaluate the impact of the neighbourhood environment and weight gain in Lisbon Metropolitan Areas	Deprivation Index composing of Local resources, Social Capital &Public Health Services	•Age •Sex •Marital Status •Economic Activity •Education Level •Occupational Class •Income •Physical Activity •Smoking •Healthy diet	Self-reported	Binary Variable: Overweight = BMI ≥ 25 kg/m²	The higher the area disadvantage the higher the individual BMI *(analysis not stratified by any demographic or socioeconomic characteristics)*
King et al., (2006)	Australia	Cross sectional Survey of Melbourne	Multilevel Linear Regression Analysis	Census Collector Districts	To assess the importance of area level socioeconomic disadvantage in predicting BMI	Deprivation Index composing of Education,	•Age •Income •Occupation •Education	Self-reported	Continuous Variable: BMI	1. Significant variations in BMI by census collector district were noted

		residents (n=2564, 2349)				Occupation & Income				2. An increase in area level deprivation was associated with increased BMI
van Lenthe & Mackenbach, (2002)	Netherlands	Prospective cohort study of adults residing in the S/East of Netherland (n=10,450)	Multilevel Logistic Regression Analysis	Neighbourhood	*Research Questions* 1. Is there a relationship between neighbourhood deprivation and overweight after adjusting for SEP[16], age and sex? 2. Is the association between neighbourhood deprivation and overweight modified by SEP, age and sex?	Deprivation Index composing of Education, Occupation & Employment	•Educational Level •Age •Sex	Self-reported	Binary Variable: Overweight = BMI ≥ 25 kg/m²	1. The odds of overweight increased significantly with increasing neighbourhood deprivation. 2. Stratified analysis showed a stronger association in females than male and older (>49years) than younger individuals
Black & MacInko, (2010)	USA	Repeated Cross sectional surveys of New York City (n=44,730)	Multilevel Logistic Regression Analysis	Zip Code	To assess the change in prevalence of obesity and its individual and contextual determinants changed in New York City, New York between 2003 and 2007	Area income	•Sex •Race/Ethnicity •Marital Status •US birthplace (or not) •Education Level	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	Increased area level income was associated with reduced obesity among women but no association was observed in men

[16] SEP stands for Socioeconomic Position

							•Employment Status			
Maier et al., (2014)	Germany	Cross sectional data from German Health Update survey (n=33,690)	Multilevel Logistic Regression Analysis	Districts	1. To assess whether area level deprivation is associated with T2D and obesity in Germany and a national level independent of individual risk factors 2. To explore sex specific differences with association between area level deprivation, T2D and obesity	German Index of Multiple Deprivation composing of Income, Employment, Education, Municipal Revenue, Social Capital, Environment & Security	• Age •Smoking Status •Sport Activity •Living with a partner •Educational Level	Self-reported	Binary Variable: Obese = BMI ≥ 30 kg/m²	As positive association between area level deprivation and obesity was found in both men and women
Do et al., (2007)	USA	Nationally representative cross sectional survey (n=14,152)	Multilevel Linear Regression Analysis	Census tract level, County level	1. To investigate the extent to which neighbourhood context plays a role in generating racial disparities in BMI 2. To examine whether and to what extent the effects of neighbourhood context vary by race	Deprivation Index composing of Education, Income, Female headed HH, Employment:	•Age •Employment Status •Education Level •Nativity •Marital Status	Measured	Continuous Variable: BMI	*Females* 1. Living in a disadvantaged neighbourhood was strongly associated with higher BMI for whites and Mexican-Americans 2. No association was observed among black women *Males* 1. A strong association between neighbourhood deprivation and

										obesity among Mexican Americans 2. A weak association and no association were observed in Blacks and Whites respectively
Matheson et al., (2008)	Canada	Nationally representative cross sectional survey (n=64,277)	Multilevel Linear Regression Analysis	Urban Census Tracts	*Hypotheses* 1. Neighbourhood deprivation is associated with BMI 2. The association between BMI and material deprivation differs by gender 3. The gender difference in the impact of neighbourhood deprivation on BMI will remain after controlling for individual level risk factors and lifestyle behaviours	Deprivation Index composing of Education, Income, Female headed HH, Employment, Living Conditions	•Sex •Marital Status •Education Level •Visible Minority Status •Age •Self-perceived stress •Sense of belonging to local community •Fruit and Vegetable consumption •Smoking •Physical activity	Self-reported	Continuous Variable: BMI	1. Neighbourhood deprivation is positively associated with BMI 2. The average difference in BMI between males and females depends on the extent of deprivation, with high material deprivation associated with higher BMI among women 3. The association between material deprivation and BMI remained significant even after the

										inclusion of individual level and lifestyle factors
Robert & Reither, (2004)	USA	Cross sectional survey (n=3,617)	Multilevel Linear Regression Analysis	Census Tract Level	*Hypotheses* 1. Age-adjusted BMI will be higher among black women than non-black women 2. Measures of individual SES will reduce but not eliminate the black disadvantage in BMI 3. Measures of community disadvantage will further reduce but not eliminate black disadvantage in BMI 4. Measures of health behaviours, stress and social support will (a) reduce black disadvantage in BMI (b) medicate the association between BMI and both individual SES and community disadvantage	Deprivation Index composing of Income and Unemployment	•Physical Activity •Smoking •Social support •Stress •Age	Self-reported	Continuous Variable: BMI	1. Black women, on average, have a BMI scare higher than non-black women 2. The association between BMI and race are reduced after controlling for individual SES 3. Communities with higher SES disadvantage were associated with higher BMI. The association was stronger on women than men 4. Measures of health behaviours, stress and social support were unable to explain higher BMI in black women
Sundquist et al., (1999)	Sweden	Nationally representati	Multilevel Logistic	Small Area Market	To examine whether CVD risk factors, including	Care Need Index (CNI)	•Sex •Age		Binary Variable:	1. The proportion of obese individual

		ve cross sectional survey (n=9240)	Regression Analysis	Statistics (SAMS)	obesity, vary by neighbourhoods controlling for sex and age	Townsend Index (TI)			Obese= BMI: men≥ 30kg/m²; women ≥ 28.6kg/m²	increases significantly with increases deprivation measured by the CNI 2. No significant relationship was observed when deprivation was measured by TI
Mujahid et al., (2005)	USA	Prospective cohort study in 4 US communities (n=13,167)	Multilevel Linear Regression Analysis	Census block group level	*Hypotheses* 1. BMI is inversely associated with SES in cross sectional analysis 2. Increases in BMI overtime would be greater in person of low SES and those living in deprived neighbourhoods	Deprivation Index composing of Income, Education & Occupation	•Age •Sex •Income •Education •Self-reported health	Measured	Continuous Variable: BMI	1. BMI was inversely associated with SES in white men, white women and black women 2. Among black men BMI was positively associated with SES 3. BMI increased with increasing neighbourhood deprivation for white and black women
Smith et al., (1998)	UK	Cross sectional analysis of Renfrew and Paisley (n=14,952)	Logistic Regression Analysis (Individual Level)	Postcode sectors	To investigate the independent contributions of occupational social class and neighbourhood deprivation to cardiovascular disease risk factors and mortality	Deprivation Index composing of Male unemployment, Occupation, Overcrowding & Car Ownership		Measured	Binary Variable: BMI cut-offs not reported	1. A positive association was observed between deprivation and BMI among women only

										2.No association was observed for men
Coogan et al., (2009)	USA	Cross sectional study of African-American *women* (n=48,359)	Linear Regression Analysis (Individual Level)	Census block group level	To assess the influence of neighbourhood SES on weight change and incidence of obesity among African-American women	Neighbourhood SES score composing of Income, Housing Value, Education, Occupation & Female headed HH	•Age •Smoking •Physical Activity •Energy Intake •Education •Income •Household size	Measured	Obese = BMI ≥ 30 kg/m²	Weight gain was inversely proportional to the neighbourhood SES score. *(analysis not stratified by any demographic or socioeconomic characteristics)*
Dragano et al., (2007)	Germany and Czech Republic	Cross sectional survey in urban populations (Germany: n=4032; Czech Republic: n=7522)	Multilevel Logistic Regression Analysis	Neighbourhoods based on country specific boundaries	To examine the association between CVD risk factors and neighbourhood characteristics	Unemployment Rate & Over Crowding were used individually	•Age •Sex •Education •Social isolation •Economic activity •Physical Activity •Smoking	Measured	Binary variable: Obese = BMI ≥ 30 kg/m²	1. Using both unemployment and overcrowding a positive association between obesity and deprivation was observed in Germany 2. No association in the Czech Republic was observed
Rundle et al., (2008)	USA	Cross sectional survey of New York City adults (n=13,102)	Multilevel Linear Regression Analysis	Zip Code	To assess the associations between BMI and individual and neighbourhood level SES in New York City	Income Poverty Line	•Race/Ethnicity •Income •Education	NOT REPOTERD	Continuous Variable: BMI	1. A positive association between poverty rate and BMI was observed among women 2. No association was observed for men

Laraia et al., (2012)	USA	Cohort study of diabetic patients from California (n=19,804)	Multilevel Linear Regression Analysis	Census block group level	To estimate the association neighbourhood deprivation and cardio metabolic[17] risk factors (including BMI) independent of individual level demographic and socioeconomic characteristics	Deprivation Index composing of Income-Poverty, Housing, Education, Employment & Occupation	•Age •Sex •Race/ethnicity •Marital status •Nativity •Time lived in USA •Education •Income •Social Status	Measured	Continuous Variable: BMI	1. A strong positive association between neighbourhood deprivation and obesity was observed *(analysis not stratified by any demographic or socioeconomic characteristics)*
Stafford et al., (2010)	UK	Longitudinal survey of British civil servants (n=14,524)	Multilevel Linear Regression Analysis	Census-Ward level	1. To utilise longitudinal data to describe BMI trajectories over a 13-year period 2. To examine whether these trajectories differ in men and women in more and less deprived areas	Townsend Index	•Age •Civil Service employment grade •Smoking •Alcohol consumption •Physical Activity	Measured	Continuous Variable: BMI	Positive *(for women)* No association *(for men)*
Zhang et al., (2015)	USA	Cross sectional survey of people in the San Francisco Bay area	G-Computation	Census track (neighbourhood)	To examine whether the interactions between primarily English speaking and community level measures are associated with physical inactivity and obesity	A composite deprivation index of income, poverty, housing, education, employment, and occupation	•Healthy food vendor density •Smoking •Physical Activity	Measured	Binary Variable: Obese = BMI ≥ 30 kg/m²	The interacting between community mean income and primarily English speaking at home was associated with lower likelihood of

[17] Laraia et al., (2012) considered the following as cardio metabolic risk factors (1) severe obesity (BMI≥35 kg/m2), (2) glycosylated haemoglobin (A1c ≥9%), (3) low density lipoproteins (LDL≥130 mg/dL) and (4) systolic blood pressure (SBP≥140 mmHg)

		(n= 16,634)					•Diet adherence •Age •Sex •Race/ethnicity •Marital Status •Nativity •Household size •Employment •Value of Assets •Income			physical inactivity and obesity *(analysis not stratified by any demographic or socioeconomic characteristics)*
Xu et al., (2014)	USA	Cross sectional survey of Utah residents (n=21,961)	Multilevel Logistic Regression Analysis	County/Zip code level	To examine neighbourhood effects, at both ZIP code and county levels, on association of several built environment factors with overweight and obesity	Proportion living below the income poverty line *(Ø)*	•Age •Sex •Race •Marital Status •Education •Employment •Smoking	Self-reported	Binary variable: for both, Overweight = BMI ≥ 25 kg/m² Obese = BMI ≥ 30 kg/m²	1.At the ZIP code level, poverty is positively associated with obesity 2. At the county level, no association was observed between poverty and obesity
Van Hulst et al (2013a)	Canada	Cross sectional Survey of Quebec families (n =417)	Multilevel Logistic Regression Analysis	Neighbourhood	1. To examine the associations between neighbourhood built and social environments with excess weight	Mean neighbourhood income % residents with a university degree		Measured	Binary variable: Obese = BMI ≥ 30 kg/m²	No association was observed between neighbourhood poverty and excess weight

					2. To examine whether these associations differ within family triads (father, mother and child)					
Stoddard et al., (2013)	USA	Cross sectional survey of Northern California residents (n= 18529)	Multilevel Linear Regression Analysis & Multilevel Multinomial Regression Analysis	Neighbourhood	To examine the associations of neighbourhood deprivation and measures of BMI change among adults with T2D	Neighbourhood deprivation index of Education, Employment, Housing, Occupation, Poverty, Racial Composition and Residential Stability	•Age •Sex •Race •Marital Status •Education •Employment •Nativity •Income	Measured	Continuous and Categorical BMI used BMI CUT OFFS NOT REPORTED	1. The was a positive association between neighbourhood deprivation and BMI change 2. Those in the most deprived areas were more likely to experience substantial BMI loss or gain
Powell-Wiley et al., (2014)	USA	Longitudinal survey of Dallas residents (n=939)	Multilevel Linear Regression Analysis	Block level	To examine the associations of neighbourhood deprivation and measures of BMI change within a multi-ethnic cohort in Dallas, Texas	Neighbourhood deprivation index of Education, Employment, Housing, Occupation, Poverty, Racial Composition and Residential Stability	•Age •Sex •Race/Ethnicity •Education •Employment •Income •Physical Activity	Measured	Continuous Variable: BMI	Neighbourhood deprivation was positively associated with obesity even after adjusting for individual level determinants

							• Perception of neighbourhood environment			
Gregson, (2011)	USA	Cross sectional survey of California residents (n= 14,205)	Multilevel Linear Regression Analysis	County Level	To examine how structural poverty explains BMI index among individuals	% living below Federal Poverty Line	• Age • Sex • Race • Income		Continuous Variable: Obese = BMI ≥ 30 kg/m²	County poverty exhibited a negative association with BMI *(analysis not stratified by any demographic or socioeconomic characteristics)*
Prince et al., (2012)	Canada	Cross sectional survey of Ottawa residents (n=4,727)	Multilevel Logistic Regression Analysis	Neighbourhood level	To assess the built and social environmental factors and their relationships with physical activity and overweight or obesity	Socioeconomic status index composed of Income, Unemployment, Education and % of single parents	• Age • Education • Smoking • Income • Season of data collection	Self-reported	Binary Variable: Obese BMI≤30 kg/m²	No association was observed for both men and women between neighbourhood socioeconomic status and either obesity or physical activity
Koh et al., (2015)	USA	Cross sectional survey of metropolitan Detroit (n= 3146)	Deterministic Spatial Microsimulation Method	Census track	1. To estimate local obesity prevalence rates in Detroit 2. To assess the spatial patterns of local obesity prevalence in relation to obesogenic environment	Average Neighbourhood Income	• Age • Sex • Race • Education	NOT REPORTED	Continuous Variable: Obese BMI≤30 kg/m²	High obesity prevalence rates overlapped with low income tracks – implying that low income is a strong indicator of high obesity at the local level

										(analysis not stratified by any demographic or socioeconomic characteristics)

Table 4: Summary of Low and Middle Income Country studies assessing association between area level deprivation and adiposity

Reference	Country	Study Population	Study Design	Area level metric	Study Objectives	Area-Deprivation Measure/Indices	Control Variables	Measurement	Adiposity measure	Results
Jones-Smith et al., (2011)	Multi Country (37 Low and Middle Income Countries)	Repeated nationally representative cross-sectional surveys of women (DHS) n=405,550	Ecological	Country	*Hypotheses* Higher rates of GDP would be associated with higher rates of overweight prevalence in increases in lower SES individuals compared to higher SES individuals	Gross Domestic Product (GDP) adjusted for purchasing power parity	•Age	Measured	Overweight = BMI ≥ 25 kg/m²	Higher GDP was associated with a higher increase in obesity among lower SES groups Negative
Nandi et al., (2014)	Multi Country (40 Low and Middle Income Countries)	Nationally representative cross-sectional surveys (n=200,796)	Multilevel Logistic Regression Analysis	Country	To examine the association between macro level economic characteristics and the probability of individual underweight or overweight	Foreign Direct Investment (FDI)	•Sex •Age •Marital Status •Socio-Economic Status	Self-reported	Categorical Variable: Overweight = BMI ≥ 25 kg/m²	Economic development and higher FDI were associated with a higher probability of overweight *(analysis not stratified by any demographic or*

							•Area of Residence			*socioeconomic characteristics)*
Subramanian et al., (2011)	Multi Country (54 Low and Middle Income Countries)	Nationally representative cross-sectional surveys (n=538,140)	Multilevel Linear Regression Analysis	PSU and Country level	To assess impact of country level development indicators on obesity and overweight	per capita Gross Domestic Product (pcGDP)	•Age •Household Wealth •Education •Place of Residence	Measured	Continuous Variable: Overweight = BMI ≥ 25 kg/m²	An increase pcGDP was associated with an increase in BMI and higher odds of overweight *(analysis not stratified by any demographic or socioeconomic characteristics)*
Monteiro et al., (2004)	Multi Country (37 Low and Middle Income Countries)	Nationally representative cross-sectional surveys of non-pregnant women (n=148,579)	Multilevel Logistic Regression Analysis	Country Level	To identify the level of economic development in which obesity starts fuelling inequalities in health among women	per capita Gross National Product (pcGNP)	•Age •Socio-Economic Status	Measured	Binary Variable: Obese = BMI ≥ 30 kg/m²	1. Belonging to a low SES group protects against obesity in low income countries, but fuels obesity in upper middle income countries 2. Obesity begins to fuel health inequities in the developing countries when pcGNP reaches a value of about USD2500
Dai et al., (2013)	China	Cross sectional survey of selected	Multilevel Logistic Regression Analysis	Provincial Level	1. To identify risk factors for obesity both the individual and regional levels	Gross Domestic Product & Proportion illiterate	•Sex •Age •Marital Status •Education	NOT REPORTED	Binary Variable: Obese =	A decrease in provincial level GDP and an increase in proportion illiterate

		Chinese provinces (n= 7831)			2. To evaluate the whether the relationship between obesity and area level SES can be explained by individual level factors		•Employment •Income		BMI ≥ 28 kg/m²	were associated with an increased odds of obesity net of individual level factors *(analysis not stratified by any demographic or socioeconomic characteristics)*
Zhang., (2012)	China	Repeated panel survey of rural and urban Chinese neighbourhoods (n= 9,586)	Multilevel Linear Regression Analysis	Community	To examine the impact of individual- and area-level measure of SES on Obesity in China	Community Mean Education *(+)* Urbanicity[18] index *(-)*	•Sex •Age •Marital Status •Education •Occupation •Income	NOT REPORTED	Continuous Variable: Obese= BMI ≥ 25kg/m²	As the community mean education increased the likelihood of obesity decreased. Ubarnicity was associated with increased odds of obesity
Chen et al., (2009)	Taiwan	Cross Sectional Survey of Taiwanese households (n= 29,312)	Multilevel Logistic Regression Analysis	Township	To investigate the relative effects of individual level SES, household resources and neighbourhood SES on obesity amongst in Taiwan adult population	Average per capita income	•Education •Employment •Income •Age •Marital Status •Smoking •Physical Activity	NOT REPORTED	Binary Variable: Obese= BMI ≥ 27kg/m²	Individuals living in low income neighbourhoods had a higher likelihood of being obese as compared to individuals in middle income neighbourhoods

[18] The urbanicity index is used to characterise the level of urbanisation for a given community. Zhang., (2012) utilised the following components in developing the index population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communications, housing, education, diversity, health infrastructure and social services.

3. Methodological Overview

Study Design: Cross sectional survey data was utilised for most of the literature reviewed except for Black & MacInko (2010); Laraia et al., (2012); Mujahid et al., (2005); Powell-Wiley et al., (2014); Stafford et al., (2010); van Lenthe & Mackenbach (2002) and L. Zhang (2012). However, among the studies that used longitudinal data from repeated surveys and prospective cohorts it was only to assess weight change over specified periods. As a result, they did not consider the change in area deprivation over the specified periods meaning none of the reviewed articles could infer causality. In cross sectional analysis we cannot determine temporality as such we cannot not infer causality (Janssen et al., 2006; Stafford et al., 2010; Sundquist et al., 1999; Yoon and Kwon, 2014).

Studied Samples: The studied samples were drawn from varying area matrices as countries, (Jones-Smith et al., 2011; Monteiro et al., 2004; Nandi et al., 2014; Subramanian et al., 2011; Xu et al., 2014), provinces (Dai et al., 2013), districts (Maier et al., 2014), census block, ZIP code and township levels (Coogan et al., 2009; Dragano et al., 2007; Powell-Wiley et al., 2014; Smith et al., 1998; Stoddard et al., 2013; Van Hulst et al., 2013; Xu et al., 2014). The choice of area matric to examine the determinants of adiposity should reflect people's actual activity spaces (Xu et al., 2014). Smaller area such as census block in USA, neighbourhoods in Canada and Germany and townships in China tend to reflect people's activity spaces better than larger areas. Furthermore, smaller areas help in the identification of context specific risk factors that policy makers can focus on.

Adiposity Measurement: The use of self-reported measures of height and weight might introduce systematic bias (Cubbin et al., 2006; Sundquist et al., 1999; Wen and Maloney, 2011). However, 14 out of 37[19] of the studies used BMI that was calculated from self-reported height and weight. There is a tendency of over estimation of height with increasing BMI, reduced education levels and lower status occupations (King et al., 2006). The prevalence of obesity may thus be underestimated in lower socio-economic status groups with the net effect of underestimating the effects of area deprivation on adiposity (Yoon and Kwon, 2014). Moreover, some scholars have reported that high socio-economic status individuals underestimate their weight as they may perceive overweight to be socially undesirable (Matheson et al., 2008).

[19] Two studies did not report on how height and weight measures were obtained

As discussed earlier the use of BMI alone as a surrogate measure for adiposity misclassifies some individuals particularly in the intermediate ranges (Shah and Braverman, 2012). All of the studies reviewed in this study expect for Keita et al., (2014), who utilised both BMI and WC, used BMI only. Keita et al., (2014) on the other hand does not account for the hierarchal structure of the data by conducting the analysis at the individual level rather than a multilevel analysis.

Covariates: The majority of the studies reviewed controlled for individual and household level characteristics so as to elicit the impact of area level derivation on adiposity net of these characteristics. The individual and household level characteristics that were considered in most could be broadly classified as demographic, socioeconomic status and behavioural. The demographic characteristics considered were race, sex, age, marital status, ethnicity, immigration status, US birth place (or not) and visible minority status. The socioeconomic status characteristics controlled for were household income, individual income, occupation, education level, employment status, stress, sense of community belonging, social support, self-reported health, household size, civil service grade (Stafford et al., 2010) and value of assets. The behavioural characteristics considered were physical activity/inactivity, smoking, diet, sport activity and energy intake.

Deprivation Measures: As described earlier a multidimensional measure of deprivation captures the poor better than the use of an income or unidimensional measure alone (Klasen, 2000). A number of the reviewed articles (22 out of 37) utilised multidimensional deprivation indices such as the Care Need Index (Cubbin et al., 2006; Sundquist et al., 1999), Townsend Index (Stafford et al., 2010; Sundquist et al., 1999), Neighbourhood Deprivation Index (Do et al., 2007; Ford and Dzewaltowski, 2011; Keita et al., 2014; King et al., 2006; Laraia et al., 2014; Powell-Wiley et al., 2014; Prince et al., 2012) and the German Index of Multiple Deprivation (Grundmann et al., 2014; Maier et al., 2014). Yoon & Kwon, (2014) utilise a unidimensional measure of deprivation (education), these have been shown to fail to adequately capture all who are poor within an area (Alkire et al., 2014).

The use of a dashboard of deprivation measures fails to account for those who experience multiple deprivations. Dragano et al., (2007), Van Hulst et al., (2013a) and L. Zhang (2012) utilise deprivation measures individually. Whilst Black & MacInko (2010), Gregson (2011), Koh et al., (2015), Rundle et al., (2008) and Xu et al., (2014) utilise an income measure as a proxy for deprivation which as described earlier does not fully reflect the disadvantages faced by people in society.

Data Analysis: The studies reviewed were quantitative by design and used mainly multilevel regression analysis to explore the relationship between area level deprivation and adiposity. Y. T. Zhang et al., (2015) and Koh et al., (2015) utilise G-Computation and deterministic microsimulation respectively in their analysis. G-Computation utilises maximum likelihood estimation usually on longitudinal data to make causal inferences on parameters given a set of observations (Wang and Arah, 2015). Deterministic microsimulation is a technique employed to generate synthetic datasets for small geographical areas were data maybe unavailable (Heppenstall and Smith, 2014). Coogan et al., (2009); Cubbin et al., (2006); Keita et al., (2014) and Smith et al., (1998) utilised regression analysis, however without considering the nested structure of the data.

There is an increasing recognition of the existence of social influences on health and one of their key operating mechanisms is the areas or neighbourhoods within which individuals reside (Diez Roux, 2001; Duncan et al., 1998). Multilevel analysis explains variations in the dependent variable at one level as function of independent variables at defined various levels and interactions between and within the levels (Diez-Roux, 2000). Evidence suggests that some neighbourhood contexts may influence health independently of individual level attributes (Diez Roux, 2002). Hence the use of multilevel modelling which allows for simultaneous examination of the effect of both individual level variables and area level variables on individual outcomes (Merlo, 2005). This allows us to control for the potential confounding or mediatory effect of individual level attributes on the association between group level variables and individual level outcomes being investigated (Pickett, 2001).

Multilevel modelling is generally applied to nested data, it can be individuals nested within households which are nested in neighbourhoods and so forth. It can even be applied to patients within a medical institution, health facilities within districts and workers in an organization (Duncan et al., 1998). This type of modelling has been utilised in literature to investigate the social determinants of health (Merlo, 2005). Diez Roux, (2001) utilised multilevel modelling to investigate the determinants of health whilst Santana, Santos, & Nogueira, (2009) have utilised it to investigate the influence of the neighbourhood environment on individual level health. We intend to utilise this method to access the influence of neighbourhood level deprivation on adiposity. It is important to recognise that the contextual effects elucidated in multilevel modelling do not necessarily imply causation (Gelman, 2005).

4. Empirical Overview

The majority of the studies reviewed were conducted in high income Organization for Economic Cooperation and Development (OECD) countries (30 out of 37 reviewed studies). There are limited number of studies that have been conducted in developing countries, more so in South Africa, investigating the impact of neighbourhood deprivation on adiposity a gap this study intends to fill.

There is evidence to suggest that at an individual level SES has a differential influence on adiposity by country income level. In developed countries, a high individual SES has been found to be protective from adiposity whilst in developing countries a high SES is positively associated with adiposity (Subramanian et al., 2011, 2007; Tunstell-Pedoe, 2006). As indicated in Tables 1 and 2 the majority of the studies reviewed showed a positive association between area level deprivation and adiposity. Yoon & Kwon, (2014) utilise an area measure of education as a proxy for area level deprivation and report a positive association between deprivation and adiposity among women. It can be hypothesised that the educated are more knowledgeable on the adverse effects of being overweight than the less educated. Also, educated individuals are better able to understand and implement health promotion messages than the less educated.

Studies using income as a proxy measure for adiposity also reported a positive association between deprivation and adiposity (Black and MacInko, 2010; Gregson, 2011; Rundle et al., 2008; Van Hulst et al., 2013; Xu et al., 2014). Dragano et al., (2007) also reported a positive association with between area level deprivation and adiposity, utilising employment as a proxy for deprivation. Income and employment both may have influence on the resource that one may have access to, for them to engage in healthy behaviours such as eating healthy foods and exercising.

A number of studies observed a stronger association of a composite index of neighbourhood deprivation with adiposity among women than men (Maier et al., 2014; Rundle et al., 2008), with some studies not showing any association among men at all (King et al., 2006; Smith et al., 1998; van Lenthe and Mackenbach, 2002; Yoon and Kwon, 2014). This has been attributed to the fact that most women may be unemployed and tend to spend more time in their living environments than men (Laraia et al., 2012). However, there is a need to further investigate the causes for the differential influences of area level deprivation on men and women. Smith et al., (1998) examined the association among civil servants and stratified their analysis by gender. They found a positive association between a multidimensional index of deprivation and obesity among women and no association among men.

Some of the studies conducted in LMICs showed a negative association with deprivation. The analysis was however done at country level utilising measures such as Gross National Product (GDP), Gross National Income (GNI) and Foreign Direct Investment (FDI) as proxies of deprivation. When considering the developing country context an increase in GDP, GNI or FDI might be coupled with greater rural to urban migration (Jones-Smith et al., 2011). Urbanisation often results in more sedentary lifestyles and increased access to energy dense foods (Nandi et al., 2014). It is however important that more studies are conducted in LMICs in order for us to fully understand how neighbourhood deprivation influences adiposity in these countries.

5. References

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Part C: Journal Article

Neighbourhood deprivation and adult adiposity in South Africa

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1. Abstract

Adiposity refers to amount of body fat in an individual's body. High adiposity levels are associated with poor health. Using NIDS-2012 and SAIMD-2011 this study investigated associations between neighbourhood deprivation indices with two measures of adult adiposity; body mass index and waist circumference as well as with the combination of the two. The study used multilevel modelling due to the hierarchical nature of the data. Individuals living in districts that are in quintile 3 (OR= 0.659; 95% CI 0.461, 0.942) of the multiple deprivation score had significantly lower odds of having high adiposity. Our findings show that the neighbourhood environment has an impact on adiposity no matter how far distal. This impact is stronger among women as compared to men.

Keywords: *Adiposity, Deprivation, Neighbourhood Environment, Non-Communicable Diseases, Multilevel Modelling*

Key Findings

- ✓ Affluent neighbourhoods seem to be a buffer that promotes weight gain
- ✓ The impact of the neighbourhood environment on adiposity is disproportionately stronger for women as compared to men
- ✓ Individual level characteristics have a stronger influence on adiposity increase as compared to district level characteristics
- ✓ South African women are disproportionately affected by excess adiposity as compared to men

2. Introduction

Adiposity refers to the accumulation of lipids (fat) at a particular site or organ (Bacon, 2013; Schwandt, 2011). The global prevalence of excess adiposity among adults (18 years and above) has doubled between 1980 and 2016 (WHO, 2016). The increase has occurred simultaneously in developing and developed countries, and is expected that obesity rates will double by 2030 if it is not controlled (Micklesfield et al., 2013). In Sub Saharan Africa (SSA), the prevalence of urban obesity has increased by up to 35% between 1992 and 2005 (Ziraba et al., 2009). South Africa has the highest obesity rates among SSA countries, as the country experiences a rapid epidemiological transition. Furthermore, the burden of obesity in South Africa is disproportionately higher in women (37.9%) as compared to men (13.3%) (Sartorius et al., 2015).

Adiposity which refers to amount of body fat in an individual's body can be measured using direct or indirect methods. Direct methods (Computed Tomography, Magnetic Resonance Imaging and Dual-Energy X-ray Absorptiometry) are more accurate as compared to indirect methods. However, due to their high operational costs, need for skilled operators and non-profitability of equipment, their use in large epidemiological studies and clinical settings is limited (Sun et al., 2010). Surrogate measures of adiposity such as body mass index (BMI), waist circumference (WC), hip to waist ratio (HWR) and triceps skinfold thickness are widely used instead (Bosy-Westphal et al., 2010; Fleming, 1996; Neovius et al., 2004). The use of a single indirect measure is considered to be imprecise. The precision of identifying those with health risks associated with excess adiposity is improved by using a combination of these measures (Shah and Braverman, 2012; Wei et al., 1997). Therefore, individuals with both a high BMI and an expanded waist circumference are at a high risk of negative outcomes associated with body fat accumulation.

Excess adiposity is of public health concern as it can have adverse health, social and economic impacts. Obesity is major risk factor for a number of non-communicable diseases (NCDs) for example; type 2 Diabetes Mellitus (T2DM) and cardio vascular diseases (CVDs) (Dalal et al., 2011; Micklesfield et al., 2013; Van Itallie, 1979). Moreover, those with an expanded waist circumference (men > 88cm and women > 102cm) are at high risk of colorectal cancer and postmenopausal breast cancer (Freisling et al., 2017). Furthermore, obese individuals spend more money on health care as compared to their normal weight counterparts (Dalal et al., 2011; Mokdad et al., 2003). In addition, studies in OECD countries have shown that obese individuals are discriminated against within the labour market (Colditz, 1999). Therefore, the effects of adiposity on health and economic welfare are very substantial.

In order to tackle the obesity pandemic, it is crucial that policies focus on the multi-dimensional nature of the drivers of the pandemic (Huang et al., 2009). Neighbourhood level deprivation has been shown to be positively associated with adiposity in a number of studies from developed countries (Dragano et al., 2007; Ford and Dzewaltowski, 2011; Keita et al., 2014; Laraia et al., 2014; Maier et al., 2014; Rossen, 2014). Neighbourhood deprivation is thought to influence adiposity increase through its impact on neighbourhood culture, neighbourhood stressors and neighbourhood facilities (van Lenthe and Mackenbach, 2002).

Neighbourhood culture can either promote or reduce adiposity. In neighbourhoods were obesity is stigmatised, particularly in western societies, inhabitants may be encouraged to be more physically active and eat healthy foods (Rundle et al., 2008). In other cultures, particularly those in Africa, women who are moderately overweight are viewed as attractive, dignified, wealthy and command respect (Puoane et al., 2005). In addition, neuroendocrine autonomic dysregulation has an influence on fat accumulation and can be caused by biological stress (Coogan et al., 2009; Yoon and Kwon, 2014). Deprived neighbourhoods tend to have more neighbourhood stressors such as high crime rates, poor perception of safety (Smith et al., 1998), physical incivilities[20] (Laraia et al., 2014) or greater overcrowding and noise levels (Coogan et al., 2009) as compared to neighbourhoods that are less deprived.

Neighbourhood facilities has shown to have direct and indirect effects on the amount of exercise and the types of foods people eat (Feng et al., 2010). The availability of parks, sporting facilities and walkable areas can influence the amount physical activity neighbourhood residents do (Xu and Wang, 2015). Moreover, the food choices for residents can be influenced by the type of food outlets that are in the

[20] Physical incivilities are manifestation of neighbourhood deprivation through littering, uncollected garbage, unkempt property and dishevelled public spaces (Laraia et al., 2014)

neighbourhood. A high number of fast food outlets as compared to a small number of supermarkets may result in an unhealthy food environment (Robert and Reither, 2004). Furthermore, the association between neighbourhood deprivation and adiposity is modified by individual attributes (Smith et al., 1998).

This study seeks to investigate association between neighbourhood deprivation and adult adiposity (a combination of body mass index and waist circumference), the association of neighbourhood deprivation and body mass index and waist circumference individually and to examine individual and household level determinants of adult adiposity.

3. Method

3.1 Data Sources

The study utilised the South African National Income Dynamic Survey (NIDS) 2012 (wave 3) and the ward level South African Index of Multiple Deprivation 2011 (SAIMD 2011) produced by Southern Africa Labour and Development Research Unit (SALDRU) and the Southern African Social Policy Research Institute/Insights (SASPRI) respectively. The NIDS is a panel survey commissioned by the presidency in 2006 to closely follow up a nationally representative sample of 28,000 individuals across all age groups over a period of years (Leibbrandt et al., 2009). The sample was drawn using stratified two stage cluster sampling, 400 primary sampling units were selected randomly from 3000 primary sampling units. The NIDS wave 3 was completed in 2012 and 22,481 individuals above 15 years of age were followed up. We excluded those less than 18 years since our study focused on adults above the age of 18 and those with missing waist circumference, height and weight measurements from the analysis. We were left with sample size of 16,144 adults.

3.2 Outcome Variables

We utilised three outcome variables namely body mass index (BMI), waist circumference (WC) and adiposity (a combination of BMI and WC) that we assessed independently. Height, weight and waist circumference were measured by the survey enumerators during NIDS data collection (De Villiers et al., 2013). A variable for BMI was derived by dividing the square of the height in metres into the weight in kilograms. We developed a binary variable for BMI and considered those with a BMI $< 24kg/m^2$ as having "low BMI" and those with BMI $\geq 25kg/m^2$ as having "high BMI". WC was categorised according to risk of cardiovascular disease, for men WC $\geq$ 102cm was considered high risk for CVD whilst for women WC $\geq$ 88cm was considered high risk for CVD (Janssen et al., 2002). In order to improve identification individuals at high risk of developing cardio vascular diseases we combined BMI and WC to develop an

adiposity variable (Shah and Braverman, 2012; Wei et al., 1997). A binary adiposity was developed by considering individuals with both a BMI ≥ 25kg/m² and a WC ≥ 102cm for men and a WC ≥ 88cm as having high adiposity.

3.3 Neighbourhood Deprivation

The SAIMD 2011 was used in this study as a measure of neighbourhood deprivation. It is a weighted average of four domains or dimensions of deprivation namely; material, employment, education and living environment deprivation. They were developed to describe deprivation at sub-municipal level using census data (Noble et al., 2013). A full report on how the SAIMD-2011 was developed is available on the SASPRI website (http://saspri.org/SASPRI/wp-content/uploads/Docs/SAIMD_2011_ward_level_National_Report_for_Web.pdf). The 2011 income poverty rates were also used and the lower bound poverty line of R604 per capita per month was utilised. The district level was used as the area metric of analysis because the NIDS-2012 data person identifier information could only be defined to district level due to confidentiality reasons.

3.4 Independent Variables

The following determinants were considered in the study, age, sex, race, education level, employment status, household income, marital status, physical exercise, smoking status and alcohol use. This was as a result of an extensive literature search and we were also limited by those variables collected by NIDS questionnaires. Evidence indicates a curvi-linear relationship between age and adiposity increase, therefore an age squared term was used in the analysis (Wen and Maloney, 2011).

3.5 Data Analysis

The statistical software Stata® 12.1 (StataCorp, TX, USA) is used for data exploration, cleaning and analysis. We excluded all missing data points and erroneous extreme values (negative and zero values) of WC, height and weight from the analysis. The extreme values for height and weight that we considered to be biologically implausible were less than 1m and more than 2m for height and less than 25kg and more than 200kg for weight (Corsi et al., 2012). Multilevel logistic models were used to assess the impact of neighbourhood deprivation on BMI, WC and adiposity. This is due to the hierarchical nature of the data as multilevel model allows for the simultaneous examination of the impact of determinants that operate at different levels on individual level outcomes (Merlo, 2005). We specified three models, the null model which is an empty model, model 1 with only the individual level determinants included and subsequently model 2 which included the neighbourhood level variables for deprivation.

4. Results

The descriptive statistics of the study population are presented in table 1. Table 2 shows the distribution of neighbourhood deprivation and income poverty according to adiposity status. Table 3 shows the multilevel analysis on adiposity (combined BMI and WC) and tables 4 and 5 presents the measures independently. Furthermore, we stratified the analysis on adiposity by gender to attenuate the gender differentials in adiposity determinants and the results are shown on table 6.

Among the study population 39.7% were classified as having high adiposity, 40.7% had on expanded waist circumference and 53.7% were overweight (table 1). The average age of the study population was 39.4 years *95% CI* (39.2 - 39.7). 60.7% of the study population were females and 82.1% were African/Black. Most of the study participants were unemployed 62.4% and 53.9% were never married, 73.3% reported not doing any form of exercise and 81.1% of the participants being non-smokers. On the other hand, 86.5% of the participants were alcohol users. 32.4% of the study population reported not having any schooling or having primary level education as their highest level of educational attainment.

Adiposity was significantly associated with neighbourhood deprivation and neighbourhood income poverty. As shown in table 3, 39.8%, 37.5% and 37.7% of individuals in the deprivation quintiles 2, 3 and 4 were categorised as having high adiposity respectively and this was lower than 42.3% and 41.0% of individuals in the least and most deprived quintiles respectively. 42.5% of individuals in the poorest quintile were classified as having high adiposity whilst 39.3%, 38.9%, 39.4% and 39.1% of those in quintiles 2, 3, 4 and 5 were classified as having high adiposity respectively.

Intra-class correlation coefficient (ICC) shows how dependent observations are within clusters i.e. the smaller the variance within cluster the larger the ICC. The ICC therefore gives us the extent to which individual differences in the dependent variable of interest can be explained at the hierarchical level of interest. In the analysis of adiposity (combined BMI and WC) the null model had an ICC of 0.0483. When the individual determinant in model 1 and the neighbourhood deprivation in model 2 were included the ICC increased to 0.0611 and 0.0535 respectively.

The model coefficients are presented in odds ratio as the interpretation is more straight forward as compared to log odds. The following individual level factors were significantly associated with a higher likelihood of high adiposity (Table 3); being employed (OR= 1.45; 95%, CI 1.33, 1.57), being educated (with the strength increasing as the individual's level of educational attainment increases), those who are married or living with a partner and being in the highest household income quintile. Conversely being a male (OR= 0.139; 95%, CI 0.127, 0.153), those who smoke (OR= 0.499; 95%, CI 0.439, 0.567), drink

alcohol (OR= 0.758; 95% CI 0.663, 0.867) and exercise (OR= 0.841; 95% CI 0.765, 0.926) had significantly lower odds of having high adiposity. However, an insignificant relationship was observed between race and high adiposity.

Model 2 includes the neighbourhood level deprivation variables in addition to all the individual level predictors. There were no significant changes in the association observed between individual level factors and adiposity as compared to model 1. Individuals living in districts that are in quintile 3 (OR= 0.659; 95% CI 0.461, 0.942) of the multiple deprivation score had significantly lower odds of having high adiposity as compared to those living in the least deprived districts. Those living in districts that are in quintiles 2, 4 and 5 have lower odds of high adiposity as compared to those in the least deprived districts, however this association was not significant. Individuals living in quintiles 3, 4 and 5 of income poverty were at higher odds of having high adiposity as compared to individuals living in districts with the highest rates of income poverty, however this was not significant.

The results of the assessment of the individual level determinants of BMI were similar to those observed for adiposity as shown in table 4. Those living in districts that are in quintiles 3 (OR= 0.652; 95% 0.449, 0.945) and 4 (OR= 0.621; 95% 0.393, 0.983) of the multiple deprivation score were at significantly lower odds of having high BMI as compared to those living in the least deprived districts. As neighbourhood income poverty decreases the likelihood of having a high BMI increases, however this was not significant at 5% level of significance. In table 5 we present the result of the assessment of the determinants of WC, we observed similar associations as those for adiposity and BMI for the individual level determinants. However, unlike in the adiposity and BMI analyses being African (OR= 0.792; 95% 0.688, 0.913) was significantly associated with lowers of having an expanded waist circumference as compared to other races. Those living in districts that are in quintiles 2 (OR= 0.778; 95% 0.621, 0.975) and 3 (OR= 0.601; 95% 0.419, 0.863) of the multiple deprivation score were at significantly lower odds of having an expanded WC as compared to those living in the least deprived districts.

Table 6 presents the results of the analysis of adiposity determinants stratified by gender. The individual level predictors showed similar associations as those reported earlier for both genders. However, for males being African was significantly associated with lower odds (OR= 0.706; 95% 0.560, 0.891) of high adiposity as compared to other races and an opposite insignificant association was observed for females. In addition, alcohol use and physical exercise showed an insignificant association with adiposity among males. Among women district deprivation showed a negative association with adiposity. Women living in districts that are in quintiles 3 (OR= 0.654; 95% 0.450, 0.951) and 4 (OR= 0.624; 95% 0.394, 0.986) of

the multiple deprivation score were at lower odds of having high adiposity as compared to women living in the least deprived district. The results for men on the other hand showed no association between adiposity and district level deprivation. Decreasing district income poverty was associated with increased odds of adiposity for both men and women, however this was not significant.

5. Discussion

This study intended to explore the associations between neighbourhood level deprivation and adult adiposity (combined BMI and WC), neighbourhood deprivation and BMI and WC individually and to examine individual and household level determinants of adiposity (body mass index and waist circumference). Contrary to a number of studies that found a positive association between neighbourhood deprivation and adiposity, BMI and WC our results suggest a negative association (Cubbin et al., 2006; Grundmann et al., 2014; Keita et al., 2014; Wen and Maloney, 2011; Yoon and Kwon, 2014). This is not too surprising as these studies were mostly conducted in developed countries whose societies and neighbourhood structures are markedly different from those in South Africa.

The difference in the impact of the neighbourhood deprivation on adiposity, BMI and WC in South Africa compared to developed countries could be partly explained by impact of individual level socio-economic status (SES) on weight gain. Education, employment and household income were positively associated with adiposity, BMI and WC. This is consistent with findings from other studies where SES indicators have shown a positive association with weight gain in developing countries (Huang et al., 2009). In developed countries, the opposite is true, socio-economic status indicators are negatively associated with BMI and/or WC (Van Hulst et al., 2013; van Lenthe and Mackenbach, 2002). In developing countries, a high SES is associated with rural to urban migration which in turn means a move from an active to a sedentary lifestyle. Furthermore, a high SES in a developing country context may mean more access to energy dense yet poor nutrient foods (Huang et al., 2009).

South Africa has a history of apartheid whose legacy persists today. The apartheid system promoted differential access to resources due to one's race (McIntyre and Gilson, 2002). As result neighbourhoods in South Africa were largely differentiated by race rather than socio-economic position and lifestyle behaviours. Van Lenthe and Mackenbach, (2002) postulate that a selection mechanism in which individuals with similar lifestyle behaviour move into the same neighbourhoods to achieve homogeneity could be one of the mechanisms that drive neighbourhood inequalities in adiposity rates. Due to the

country's history this selection mechanism may therefore be not as important in creating neighbourhood disparities in obesity rates as compared to developed countries.

Neighbourhood disparities in weight gain are thought to be driven by the differential distribution of neighbour characteristics that have an influence on eating behaviour and physical activity (Prince et al., 2012; Santana et al., 2009). Neighbourhood deprivation is thought to influence a neighbourhood's culture, facilities and stressors which in turn influence (directly or indirectly) individual level adiposity (van Lenthe and Mackenbach, 2002). The built environment such as availability of parks, recreational areas and large chain supermarkets has shown to have a protective effect against obesity (Feng et al., 2010; Lovasi et al., 2009; Papas et al., 2007; Van Hulst et al., 2013). It is important for future studies to assess the impact of these on adiposity in order provide policy prescriptions that can adequately tackle the epidemic.

We observed that females had a disproportionately higher prevalence of high adiposity (53.5%) as compared to men (11.6%). Moreover, females were more likely to have high adiposity as compared to men. This is consistent with findings from reviewed literature. Sartorius et al, (2015) postulate that the observed the higher prevalence of excess weight in South African black women could be a result of socio-cultural factors were a fuller body image is deemed attractive. This could be true in our study as we have a high proportion of women compared to men and a high proportion of blacks compared to other races. In the same study the authors suggest that a poor nutritional status in childhood and a high socioeconomic status later in life also contributed to gender inequalities in obesity rates. There is an opportunity particularly in maternal and child health, breast and cervical cancer screening programmes to deliberately target women with messaging to promote healthy eating and physical exercise. However, these messages should be sensitive to the cultural views of its intended audience.

A key characteristic of this study was that we stratified the analysis with aim of assessing gender disparities in adiposity influences. We observed that among women there is negative association between neighbourhood deprivation and adiposity. However, the association between deprivation and adiposity was insignificant among males. These results were expected as this was observed in the reviewed literature (Dragano et al., 2007; Robert and Reither, 2004; van Lenthe and Mackenbach, 2002; Yoon and Kwon, 2014). Matheson et al., (2008) postulates that impact of the neighbourhood environment is stronger on women and compared to men because women spend more time in their living environment as compared to men. Women often work part-time, do more domestic work and tend to be primary care givers for the elderly and the young (Yoon and Kwon, 2014).

The age squared term used in this study showed a positive association with adiposity, BMI and WC. This means that as people grow older the impact of age on weight gain becomes stronger. This is consistent with reviewed literature which reported similar findings (Ford and Dzewaltowski, 2011; Gregson, 2011; Griffiths et al., 2013). This could be partially explained by the fact that as people grow older they tend to lose lean muscle mass which may have a net impact of lowing the individual's metabolism (Romero-Corral et al., 2008).

As compared to individuals who are married or living with a partner those who are either never married, divorced, widowed or separated was negatively associated with adiposity. However, there is generally no agreement in reviewed literature on the impact of marital status on weight gain. Robert and Reither (2004) and Yoon and Kwon (2014) report a negative association between not living with a partner and weight gain. Intuitively one would expect unmarried individuals to care more about their appearances as compared to married individuals, as a result this group may participate more in healthy behaviours than their married counterparts. On the other hand, Cubbin et al., (2006) and Stoddard et al., (2013) report a negative association between not living with a partner and weight gain. A possible explanation to this could be that single individuals tend to eat out more and may not have a structured living environment to encourage healthy eating.

Physical exercise was negatively associated with adiposity, BMI and WC. This is consistent with reviewed literature and intuitively makes sense. Physical exercise increases metabolism there by reducing the amount of fat stored as excess energy by the body (Yoon and Kwon, 2014). Contrary to reviewed literature both smoking and alcohol use were negatively associated with adiposity, BMI and WC. However, whilst smoking and alcohol use may appear protective against excess adiposity they are associated with a number of other non-communicable diseases (Dalal et al., 2011; Dragano et al., 2007; Whitlock et al., 2009).

The key strength of this study is that it is the first to assess the impact of neighbourhood level deprivation on adiposity in South Africa *(to the best of our knowledge)*. We used a multidimensional index of measuring deprivation rather than a unidimensional one which may misclassify some individuals or communities (Whelan et al., 2014). The height, weight and waist circumference measure used in this study were measured by NIDS enumerators therefore eliminating any bias associated with self-reported values. However, this study does have a few limitations firstly we used a large area level metric (district). The influence of neighbourhood characteristics on individual attributes or behaviours reduces as the spatial scale increases (Ford and Dzewaltowski, 2011). This could also explain why we got low intra class correlation coefficient suggesting that the neighbourhood environment plays a small part in influencing

adiposity increase. Secondly, this was a cross sectional study as such we cannot assign causality. Thirdly, this was a secondary data analysis as such we could only include variables that were collected during NIDS enumeration in the analysis.

6. Conclusion

Using the NIDS-2012 and the SAIMD-2011 datasets this study has shown that both individual and neighbourhood characteristics, no matter how far distal, have an impact on adiposity increase. Neighbourhood affluence seems to a buffer that promotes weight gain. Women are disproportionately affected by the neighbourhood environment as compared to men. Health promotion efforts on obesity reduction should therefore deliberately target women as they are disproportionately affected. However, more studies that utilise a smaller area matric, preferably ward level, are necessary to explore the impact of the neighbourhood of residence on adiposity. This will provide for better policy prescriptions with respect to the impact of the neighbourhood environment on adiposity.

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8. Tables

Table 1: Background characteristics of the study population

Background Characteristics (N= 16,144)	**Number**	**Proportion**
Age	*Mean* 39.4	*95% CI* (39.2 to 39.7)
Sex		
Female	9,794	60.7%
Male	6,350	39.3%
Race		
Other	2,896	17.9%
African	13,248	82.1%
Education Level		
No Education	1,909	11.8%
Primary Level	3,326	20.6%
Secondary Level	8,756	54.2%
Tertiary Level	2,153	13.4%
Employment Status		
Unemployed	10,067	62.4%
Employed	6,077	37.6%
Household Income		
Quintile 1	3,243	20.1%
Quintile 2	3,217	19.9%
Quintile 3	3,228	20.0%
Quintile 4	3,232	20.0%
Quintile 5	3,224	20.0%
Marital Status		
Married and living with a partner	5,670	35.1%
Widowed/divorced /separated	1,772	11.0%
Never married	8,702	53.9%
Physical Exercise		
No exercise	11,834	73.3%
Exercise	4,310	26.7%
Smoking Status		
Non smoker	13,095	81.1%
Smoker	3,049	18.9%
Alcohol Use		
No	13,959	86.5%
Yes	2,185	13.5%

Table 2: Distribution of adiposity status by neighbourhood deprivation

	Low Adiposity		High Adiposity			
Deprivation Dimension	**Number**	**%**	**Number**	**%**	**P-value**	**Decision**
Multiple Deprivation Score		**$\chi 2$= 26.17**			<0.001	***
Quintile 1 (Least Deprived)	2,459	57,7%	1,801	42.3%		
Quintile 2	1,521	60.2%	1,006	39.8%		
Quintile 3	1,968	62.5%	1,179	37.5%		
Quintile 4	2,217	62.3%	1,342	37.7%		
Quintile 5 (Most Deprived)	1,564	59.0%	1,087	41.0%		
Income Poverty		**$\chi 2$= 17.03**			**0.002**	**
Quintile 1 (Lowest Income)	2,099	57.5%	1,554	42.5%		
Quintile 2	1,807	60.7%	1,169	39.3%		
Quintile 3	2,221	61.9%	1,366	38.9%		
Quintile 4	1,829	60.6%	1,189	39.4%		
Quintile 5 (Highest Income)	1,773	60.9%	1,137	39.1%		

****: Statistically significant at 1% level of significance, **: Statistically significant at 5% level of significance, NS: Not statistically significant at 5% and 1% level of significance*

Table 3: Multilevel logistic regression models assessing the impact of area level deprivation on adiposity (combination of high bmi and wc)

Variable	Co-efficient (Odds ratio)		
	Model 0	**Model 1**	**Model 2**
Age Squared	-	1.000296***	1.000296***
Sex			
Female	-	Reference	Reference
Male	-	0.139***	0.139***
Race			
Other	-	Reference	Reference
African	-	0.910	0.930
Education Level			
No Education	-	Reference	Reference
Primary Level	-	1.59***	1.57***
Secondary Level	-	1.76***	1.73***
Tertiary Level	-	2.18***	2.15***
Employment Status			
Unemployed	-	Reference	Reference
Employed	-	1.45***	1.44***
Household Income			
Quintile 1	-	Reference	Reference
Quintile 2	-	0.921	0.922
Quintile 3	-	1.02	1.02
Quintile 4	-	1.13**	1.13**
Quintile 5	-	1.53***	1.53***
Marital Status			
Married and living with a partner	-	Reference	Reference
Widowed/divorced /separated	-	0.621***	0.621***
Never married	-	0.471***	0.473***
Physical Exercise			
No exercise	-	Reference	Reference
Exercise	-	0.841***	0.840***
Smoking Status			
Non smoker	-	Reference	Reference
Smoker	-	0.499***	0.496***
Alcohol Use			
No	-	Reference	Reference
Yes	-	0.758***	0.758***
Multiple Deprivation Score			
Quintile 1 (Least Deprived)	-	-	Reference
Quintile 2	-	-	0.866
Quintile 3	-	-	0.659**
Quintile 4	-	-	0.671
Quintile 5 (Most Deprived)	-	-	0.817
Income Poverty			
Quintile 1 (Lowest Income)	-	-	Reference
Quintile 2	-	-	0.992
Quintile 3	-	-	1.18
Quintile 4	-	-	1.16
Quintile 5 (Highest Income)	-	-	1.06
District Level random variation (s.e)	0.167 (0.0252)	0.214 (0.0309)	0.186 (0.0290)
Intraclass Correlation Coefficient (ICC)	0.0483	0.0611	0.0535
$\chi 2$ (p-value)	48.39 (<0.001)	60.60 (<0.001)	41.80 (<0.001)

****: Statistically significant at 1% level of significance, **: Statistically significant at 5% level of significance, NS: Not statistically significant at 5% and 1% level of significance*

Table 4: Multilevel logistic regression models assessing the impact of area level deprivation on BMI

Variable	Co-efficient (Odds Ratio)		
	Model 0	**Model 1**	**Model 2**
Age Squared	-	1.000235***	1.000234***
Sex			
Female	-	Reference	Reference
Male	-	0.301***	0.301***
Race			
Other	-	Reference	Reference
African	-	1.01	1.01
Education Level			
No Education	-	Reference	Reference
Primary Level	-	1.32***	1.31***
Secondary Level	-	1.60***	1.59***
Tertiary Level	-	2.14***	2.13***
Employment Status			
Unemployed	-	Reference	Reference
Employed	-	1.59***	1.59***
Household Income			
Quintile 1 (Lowest Income)	-	Reference	Reference
Quintile 2	-	0.923	0.925
Quintile 3	-	1.08	1.08
Quintile 4	-	1.12	1.12**
Quintile 5 (Highest Income)	-	1.58***	1.58***
Marital Status			
Married and living with a partner	-	Reference	Reference
Widowed/divorced /separated	-	0.633***	0.634***
Never married	-	0.497***	0.497***
Physical Exercise			
No exercise	-	Reference	Reference
Exercise	-	0.836***	0.834***
Smoking Status			
Non smoker	-	Reference	Reference
Smoker	-	0.458***	0.458***
Alcohol Use			
No	-	Reference	Reference
Yes	-	0.842***	0.841***
Multiple Deprivation Score			
Quintile 1 (Least Deprived)	-	-	Reference
Quintile 2	-	-	0.796
Quintile 3	-	-	0.652**
Quintile 4	-	-	0.621**
Quintile 5 (Most Deprived)	-	-	0.780
Income Poverty			
Quintile 1 (Lowest Income)	-	-	Reference
Quintile 2	-	-	1.01
Quintile 3	-	-	1.26
Quintile 4	-	-	1.25
Quintile 5 (Highest Income)	-	-	1.33
District Level random variation (s.e)	0.2085 (0.0275)	0.236 (0.0305)	0.212 (0.0284)
Intraclass Correlation Coefficient (ICC)	0.0596	0.0669	0.0605
$\chi 2$ (p-value)	91.38 (<0.001)	101.91 (<0.001)	81.66 (<0.001)

****: Statistically significant at 1% level of significance, **: Statistically significant at 5% level of significance, NS: Not statistically significant at 5% and 1% level of significance*

Table 55: Multilevel logistic regression models assessing the impact of area level deprivation on WC

Variable	Co-efficient (Odds Ratio)		
	Model 0	**Model 1**	**Model 2**
Age Squared	-	1.000377***	1.000377***
Sex			
Female	-	Reference	Reference
Male	-	0.0812***	0.0813***
Race			
Other	-	Reference	Reference
African	-	0.777***	0.792***
Education Level			
No Education	-	Reference	Reference
Primary Level	-	1.64***	1.62***
Secondary Level	-	1.79***	1.76***
Tertiary Level	-	2.19***	2.16***
Employment Status			
Unemployed	-	Reference	Reference
Employed	-	1.36***	1.36***
Household Income			
Quintile 1 (Lowest Income)	-	Reference	Reference
Quintile 2	-	0.883**	0.883**
Quintile 3	-	0.988	0.987
Quintile 4	-	1.09	1.09
Quintile 5 (Highest Income)	-	1.42***	1.42***
Marital Status			
Married and living with a partner	-	Reference	Reference
Widowed/divorced /separated	-	0.589***	0.589***
Never married	-	0.437***	0.439***
Physical Exercise			
No exercise	-	Reference	Reference
Exercise	-	0.838***	0.837***
Smoking Status			
Non smoker	-	Reference	Reference
Smoker	-	0.510***	0.508***
Alcohol Use			
No	-	Reference	Reference
Yes	-	0.844***	0.841***
Multiple Deprivation Score			
Quintile 1 (Least Deprived)	-	-	Reference
Quintile 2	-	-	0.778**
Quintile 3	-	-	0.601***
Quintile 4	-	-	0.645
Quintile 5 (Most Deprived)	-	-	0.774
Income Poverty			
Quintile 1 (Lowest Income)	-	-	Reference
Quintile 2	-	-	1.07
Quintile 3	-	-	1.31
Quintile 4	-	-	1.25
Quintile 5 (Highest Income)	-	-	1.06
District Level random variation (s.e)	0.160 (0.0244)	0.223 (0.0322)	0.184 (0.0303)
Intraclass Correlation Coefficient (ICC)	0.0463	0.0633	0.0528
$\chi 2$ (p-value)	45.98 (<0.001)	60.65 (<0.001)	33.87 (<0.001)

****: Statistically significant at 1% level of significance, **: Statistically significant at 5% level of significance, NS: Not statistically significant at 5% and 1% level of significance*

Table 6: Multilevel logistic regression models assessing the impact of area level deprivation on adiposity stratified by gender

Variable	Co-efficient (Odds Ratio)			
	Females (n= 9,794)		Male (n= 6,350)	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Age Squared	1.000279***	1.000279***	1.000319***	1.000318***
Race				
Other	Reference	Reference	Reference	Reference
African	1.041	1.06	0.683***	0.706***
Education Level				
No Education	Reference	Reference	Reference	Reference
Primary Level	1.70***	1.68***	1.24	1.23
Secondary Level	1.73***	1.70***	1.70***	1.69***
Tertiary Level	2.01***	1.97***	2.30***	2.27***
Employment Status				
Unemployed	Reference	Reference	Reference	Reference
Employed	1.43***	1.43***	1.45***	1.45***
Household Income				
Quintile 1 (Lowest Income)	Reference	Reference	Reference	Reference
Quintile 2	0.938	0.940	0.855	0.855
Quintile 3	1.06	1.07	0.929	0.928
Quintile 4	1.15**	1.15**	1.14	1.14
Quintile 5 (Highest Income)	1.41***	1.41***	1.76***	1.77***
Marital Status				
Married and living with a partner	Reference	Reference	Reference	Reference
Widowed/divorced /separated	0.656***	0.657***	0.534***	0.531***
Never married	0.491***	0.494***	0.423***	0.424***
Physical Exercise				
No exercise	Reference	Reference	Reference	Reference
Exercise	0.835***	0.833***	0.884	0.880
Smoking Status				
Non smoker	Reference	Reference	Reference	Reference
Smoker	0.543***	0.538***	0.496***	0.495***
Alcohol Use				
No	Reference	Reference	Reference	Reference
Yes	0.596***	0.592***	0.941***	0.934
Multiple Deprivation Score				
Quintile 1 (Least Deprived)	-	Reference	-	Reference
Quintile 2	-	0.813	-	1.04
Quintile 3	-	0.654**	-	0.670
Quintile 4	-	0.624**	-	0.843
Quintile 5 (Most Deprived)	-	0.774	-	1.04
Income Poverty				
Quintile 1 (Lowest Income)	-	Reference	-	Reference
Quintile 2	-	1.02	-	0.920
Quintile 3	-	1.18	-	1.18
Quintile 4	-	1.19	-	1.01
Quintile 5 (Highest Income)	-	1.08	-	0.909
District Level random variation (s.e)	0.210 (0.0336)	0.177 (0.0316)	0.291 (0.0572)	0.268 (0.0570)
Intraclass Correlation Coefficient (ICC)	0.0601	0.0509	0.0813	0.0752
$\chi 2$ (p-value)	39.86 (<0.001)	24.54 (<0.001)	19.00 (<0.001)	14.28 (0.0001)

****: Statistically significant at 1% level of significance, **: Statistically significant at 5% level of significance, NS: Not statistically significant at 5% and 1% level of significance*

PART D: Policy Brief

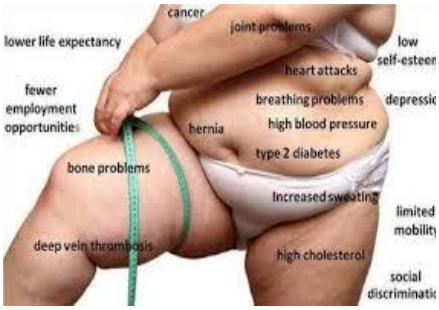
Neighbourhood deprivation and adult adiposity in South Africa

Policy Brief – 14 August 2017

Executive Summary

Adiposity refers to accumulation of fat in an individual's body. The prevalence of excess adiposity has increased in South Africa in recent decades. Excess adiposity has a negative impact on health. Furthermore, it has negative economic consequences through direct medical costs and indirect costs related to labour market exclusion. Recognizing that excess adiposity is preventable this study sought to elucidate the individual level determinants of adiposity and the impact of neighbourhood level deprivation on adiposity, body mass index (BMI) and waist circumference (WC). We observed inequalities in the prevalence of excess adiposity among women as compared to men. Moreover, a negative association between area level deprivation and adiposity was noted. This association was stronger among women as compared to men. We conclude by recommending a deliberate targeting of women with respect to adiposity prevention programmes.

ADIPOSTY IMPACT



SOURCE: *The Impact of Obesity on Life Insurance | Weight Loss Note[www.weightlossnote.com/the-impact-of-obesity-on-life-insurance].*

Introduction

The prevalence of urban obesity has sharply increased in Sub-Sahara Africa over the last few decades with South Africa having the highest prevalence (Sartorius et al., 2015). Excess adiposity is a major risk factor for a number of non-communicable diseases including type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVDs) and some forms of cancer (Lakerveld et al., 2012b). In South Africa, cardiovascular diseases were the 3rd leading cause of death among women in 2012. Obese individuals on average spend more money on health as compared to their non-obese counter parts. Furthermore, obese individuals have fewer employment opportunities as compared to those who are non-obese (Colditz, 1999). However, this increase in excess adiposity is preventable and can be reversed. In order to do so it is crucial that we understand its drivers. Literature suggests that the determinants of obesity are complex and operate at

KEY POINTS

- Affluent neighbourhoods seem to a buffer that promotes weight gain
- The impact of the neighbourhood environment on adiposity is disproportionately stronger for women as compared to men
- Individual level characteristics have a stronger influence on adiposity increase as compared to district level characteristics
- South African women are disproportionately affected by excess adiposity as compared to men

various levels (Swinburn et al., 1999). There are individual level determinants of obesity such sociodemographic characteristic, socioeconomic status and behavioural attributes. These can influence obesogenic behaviours (sedentary lifestyle and over consumption of energy dense foods). There are also contextual influencers of adiposity. These can include the neighbourhood environment characteristics such as facilities, stressors and culture (van Lenthe and Mackenbach, 2002). Neighbourhood deprivation can influence these thereby promoting obesogenic behaviours among inhabitants of these neighbourhoods. We therefore set out to determine the influence of the neighbourhood deprivation on adiposity, BMI and WC and the individual and household determinants of adiposity, BMI and WC.

Approach & Results

Data from wave 3 of the South African National Income Dynamic Study (NIDS) 20111 was used together with the ward level South African Index of Multiple Deprivation (SAIMD) 2011. A variable for adiposity was derived by combining BMI and WC circumference. Individuals considered to be at high CVD by both their BMI and WC measure were considered to have high adiposity. The SAIMD-2011 data was aggregated to district level. We used multilevel modelling to assess the impact of neighbourhood deprivation on adiposity. We observed that individuals living in neighbourhood that are in the middle quintiles of neighbourhood deprivation were less to have high adiposity as compared to individuals in the least deprived neighbourhoods. Whilst living in the most deprived neighbourhood was found to be weight neutral when compared to living the least deprived neighbourhood. Furthermore, we observed that a significantly larger proportion of women had high adiposity as compared to men. In addition, women were more strongly affected by the neighbourhood environment as compared to men. As compared to neighbourhood deprivation individual level attribute had a stronger impact on adiposity.

Recommendations

Affluent neighbourhoods to be a buffer that promotes weight gain. It is important that further research using a smaller neighbourhood metric is necessary to appropriately understand this relationship. Furthermore, we recommend that neighbourhood culture, facilities and stressors are assessed directly. As these are thought to be the mechanism through which neighbourhood deprivation affects adiposity. We observed that women are disproportionately affect by high adiposity as compared to men. There is therefore a need to develop weight loss/maintenance programmes that deliberately target women. These programmes can be integrated with other services that are already targeting women such maternal and child health, breast and cervical cancer screening programmes.

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PART E: Appendices

Appendix 1: HEALTH & PLACE – Author Information Pack

HEALTH & PLACE
An International Journal

AUTHOR INFORMATION PACK

TABLE OF CONTENTS

ISSN: 1353-8292

DESCRIPTION

The journal is an interdisciplinary journal dedicated to the study of all aspects of **health** and **health care** in which **place** or **location** matters.

Recent years have seen closer links evolving between medical geography, medical sociology, health policy, public health and epidemiology. The journal reflects these convergences, which emphasise differences in health and health care between places, the experience of health and care in specific places, the development of health care for places, and the methodologies and theories underpinning the study of these issues.

The journal brings together international contributors from geography, sociology, social policy and public health. It offers readers comparative perspectives on the difference that place makes to the incidence of ill-health, the structuring of health-related behaviour, the provision and use of health services, and the development of health policy.

At a time when health matters are the subject of ever-increasing attention, *Health & Place* provides accessible and readable papers summarizing developments and reporting the latest research findings.

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At a time when health matters are the subject of ever-increasing attention, *Health & Place* provides accessible and readable papers summarizing developments and reporting the latest research findings.

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- Have you told readers, at the outset, what they might gain by reading your paper?

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• Have you addressed the question of practicality and usefulness?

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Submission checklist

The following list will be useful during the final checking of an article prior to sending it to the journal for review. Please consult this Guide for Authors for further details of any item.

Ensure that the following items are present:

One author has been designated as the corresponding author with contact details: E-mail address Full postal address All necessary files have been uploaded, and contain: Keywords All figure captions All tables (including title, description, footnotes) Further considerations Manuscript has been 'spell-checked' and 'grammar-checked' Files submitted for review have had all identifying information removed (see review policy above), whether in the file text, the file name or the file properties. All references mentioned in the Reference list are cited in the text, and vice versa Permission has been obtained for use of copyrighted material from other sources (including the Internet)

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AFTER ACCEPTANCE

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Appendix 2: Human Research Ethics Committee approval

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: sumayah.ariefdien@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

12 May 2016

HREC REF: 288/2016

Dr O Alaba
Department of Health Economics Unit
School of Public Health & Family Medicine
FHS

Dear Dr Alaba

PROJECT TITLE: DEPRIVATION AND ADULT ADIPOSITY IN SOUTH AFRICA: A SMALL AREA STUDY (Masters candidate- Masimba Dube)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 May 2017.

Please note it is the Human Research Ethics Committee, not "Health".

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

We acknowledge that the student, Masimba Dube will also be involved in this study.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur.

Yours sincerely

TBurgess

pp **PROFESSOR M BLOCKMAN**
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.

HREC 288/2016

Institutional Review Board (IRB) number: IRB00001938
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI),and Declaration of Helsinki (2013) guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

HREC 288/2016