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Chapter

Double Burden of Poverty and Cardiovascular Disease Risk among Low-Resource Communities in South Africa

Wilna Oldewage-Theron and Christa Grobler

Abstract

Limited studies evaluating the prevalence of cardiovascular risk (CVR) in resource-poor black communities in South Africa (SA), exist. The objective of this chapter is to evaluate the prevalence of CVR in a cross-sectional studies in randomly selected low income children, adults and elderly in Gauteng, Free State and Eastern Cape, SA. The test panel of CVR markers included: anthropometry, lipid profile, blood pressure, fibrinogen, high sensitive–C–reactive protein (HS–CRP), homocysteine, vitamin B12, folate, glucose and dietary intakes. The main findings indicated high CVR with prevalence of overweight/obesity, Hypertension, hyperhomocysteinaemia, increased fibrinogen and HS-CRP, as well as low intakes of dietary fibre, vitamins B6 and B12, folate and polyunsaturated- and monounsaturated fatty acids, and high intakes of dietary sodium, saturated and trans fatty acids, and added sugars. Multiple CVR factors are present among all the communities. It can thus be concluded that a double burden of poverty and risk of CVD exists across the different age groups and geographical locations in these resource-poor communities.

Keywords: cardiovascular risk, poverty, South Africa, children, adults, elderly

1. Introduction

South Africa (SA) is a middle-income country that is characterised by contrasting living conditions ranging from wealthy urban suburbs to lower-income, underdeveloped areas. [1] SA has faced many socio-economic challenges such as high levels of poverty, inequality and unemployment [1, 2] despite having the second largest economy on the African continent. Since the country's transition to democracy in 1994, progress has been made, but unemployment rates and poverty levels remain high. [1] Poverty is the main underlying factor contributing to food insecurity. [3, 4] The food insecure often use strategies to cope with the inability to access food. One of these include reducing the quality and quantity of food consumed, thus consuming poor diversity diets which can have detrimental consequences such as hunger, malnutrition [5, 6] and increased prevalence of metabolic and cardiovascular diseases (CVDs) [7] due to it hindering individuals' ability to choose the most appropriate foods and beverages for an adequate diet. [8] A disadvantage of food insecurity is thus monotonous diets with consumption of more affordable energy-dense staples and foods that may have detrimental health outcomes such as obesity and its chronic disease comorbidities. [9] Food insecurity thus does not only cause under-nutrition, but also in over-nutrition such as obesity and its comorbidities, especially in low-income communities. [10] SA is a country in health transition and suffers from a quadruple burden of (a) poverty and nutrition-related chronic diseases of lifestyle [CDL], (b) communicable diseases, (c) peri-natal, maternal and injury-related disorders, [11] and (d) a nutrition transition. A recent study has found that this quadruple burden of disease is predominantly present in the black African population. [1] Urbanisation and westernisation of the Black African population of SA is marked not only by demographic transition, but also by increased animal protein, total dietary fat and added sugar intakes [11] and a health transition resulting in an increased prevalence of obesity [6] and CDL such as CVD. [11, 12]

2. Double burden of poverty and cardiovascular disease among black south Africans

The South African population of approximately 59 million people consists of 81% black Africans. [13] In 2017, it was reported that 56% of the SA population lived in poverty [14] with 28% living in extreme poverty, thus not having enough money to purchase enough food to consume around 2,100 calories per day for a month (food poverty). The most vulnerable to food poverty are women, children (66.8%), those with low education (79.2%) and people from the black population group (64.2%). [15, 16]

CVD incidence is increasing rapidly among all population groups in SA. [11] CDLs contribute 51% to the mortality rate, with CVD and diabetes accounting for 19% and 8% of the total deaths. Many people in SA have poor living conditions and limited resources to maintain health and well-being. [15] In spite of cultural background, people that has been subjected to urbanisation, has adopted a more Western lifestyle with lower dietary fibre and higher dietary fat and added sugar intakes, as well as lower physical activity levels. These dietary changes have led to higher prevalence of CDL, [17] specifically an increased risk and susceptibility of CVD among the black population, [18] and not only in adults, but also among children. [19] The face of CVD has thus changed in recent years. Initially it was a disease of the white population group, the affluent and older generations, but since the 2000s, it was also observed that the prevalence of CVD risk factors, such as dyslipidaemia and obesity, has increased among black Africans [20] as well as children and adolescents. [21–24]

The aim of this chapter was thus to investigate the prevalence of the various cardiovascular risk factors, specifically those that are irreversible, among children (6–18 years old) in peri-urban Free State (FS), [25] rural Eastern Cape (EC), [24, 26–28] peri-urban [29] and urban [30–33] Gauteng; adults (19–59 years old) in urban Gauteng [30, 31, 34–37] and peri-urban FS; [38–40] and elderly (≥60 years) in urban Gauteng, [41–43] including both genders, living in poverty in SA. Gauteng was chosen as the authors both resided in Gauteng and it was the focus of the university for funding. No data had been available for the cardiovascular risk factors in the above-mentioned communities and a valuable research opportunity was created to address the paucity of information in these communities. For this reason, the FS and EC provinces were chosen because of funding opportunities and gap in the knowledge base on the areas included in these studies.

3. Methodology

A search of electronic databases focusing on poverty, food insecurity and cardiovascular risk factors was carried out between 2010 and 2020. Databases used included: MEDLINE (PubMed), Web of Science, ScienceDirect, Scopus, EBSCOHost, Springer Link, and Sabinet. The keywords used included: "poverty", "food security", "nutrition security", "food and nutrition security", "cardiovascular disease", "CVD", "cardiovascular risk", "CVR", "cholesterol", "triglycerides", "HDL", "LDL", "C-reactive protein", "CRP", "fibrinogen", "homocysteiene", "vitamin B6", "vitamin B9", "folate", "folic acid", "vitamin B12", "glucose", "insulin", "obesity", "overweight", "nutritional status", "hypertension", "high blood pressure", "dietary diversity", "dietary intake", "children", "adults", "elderly", "older people", "aged", "double burden", and "South Africa".

The data used for this chapter included all the databases and articles published for the various studies undertaken by the authors between 2000 and 2020 among black children in the EC, FS and Gauteng, [24–28, 30–32, 36] adults in Gauteng and the FS [25, 30, 35, 37, 40] and the elderly in Gauteng [37, 41, 43] in various urban, peri-urban and rural areas of SA. For the purpose of this book chapter, urban areas include cities and towns that are developed, thus having a density of human structures such as houses, commercial buildings, roads, and public transport. Peri-urban areas are underdeveloped areas on the outskirts of the towns and cities where people live, but no public transportation or commercial buildings are present. Rural areas refer to areas with low population density and large areas of undeveloped land where people mainly live far apart from their neighbours.

Comparative tables were drawn up using the published articles and, where data were not published, descriptive statistical analyses (frequencies) were calculated using IBM SPSS Statistics, version 26, from the study databases that had not been destroyed. The ethical and scientific procedures for the sampling strategy and data collection methods were the same for the published and unpublished data.

4. Poverty and food insecurity

Poverty and food insecurity were observed in all seven study communities. A large majority of the adults (75.7%–78.0%) [35, 44] and child caregivers (53.0%–94.0%) [27, 29, 30, 44] were unemployed, had either no or only primary education (39.9%–78.8%), [27, 29, 30, 34, 36, 43, 44] and lived in poverty (67.7–100%). [27, 29, 35, 36, 44] The poverty rates of all the communities were more than double the 25.2% national food poverty rate. [15] This may have been due to the high unemployment rate and low education levels found among the adults in all the communities. A chronic money shortage to buy food was also reported in large percentages of the study population.

5. Cardiovascular risk factors

Many risk factors for CVD have been identified in the scientific literature and can be reversible or irreversible (**Table 1**). In 2016, 20% of the South African adults (15+ years) were smoking. [45] Risk factors present in the South African adult (18+ years) population are obesity (68% women; 31% men) hypertension (46% in women and 44% in men), [46] physical inactivity (37%), high blood pressure (24%) and hyperglycaemia (10%). [45] There is a paucity of national data for other CVD risk factors in adults, and very little CVD national data are available for children, except for the prevalence of overweight and obesity.

Irreversible	Gender (male)
	Ageing
	Genetically inherited factors
Potentially reversible factors	Cigarette smoking
	Obesity
	Hypertension Physical activity
	Hyperglycaemia, diabetes
	Increased haemostatic factors, decreased fibrinolysis, increased platelet aggregration
	Increased levels of homocysteine
	Increased inflammatory response (HS-CRP)
	Dyslipidaemia (increased cholestrol, LDL, Triglyseride, decreased LDL)
	Diet and dietary diversity
Psyschosocial	Low socio-economic class
	Stressful environment
	Personality types
Geographic	Climate and season (cold weather increased risk)
	Soft drinking water
	Environmental pollution

Table 1.
Reversible and irreversible cardiovascular risk factors.

5.1 Socio-demographic risk factors

The history of CVD of an individual is directly proportional to the risk of CVD (the earlier the age of onset and the more family members affected the greater is the risk of CVD). [47] It is known that men are at greater risk of developing CVD than women [47, 48] maybe because oestrogen has an inhibiting effect on low density lipoprotein-cholesterol (LDL-C) oxidation and increasing the production of large very low-density lipoproteins (VLDL) and therefore has a protective effect against atherogenesis. [50] Low levels of education in middle-income countries like SA had a significantly higher risk of major CVD events compared to those with high incomes. [49] The majority (>70%) of our communities showed low education (no or primary school education), [29, 31, 34, 35, 43] except for the peri-urban adults in the FS (44.2%); [44] and caregivers of the peri-urban children in Gauteng (39.9%), [29] however, these percentages are still high. High unemployment rates (53.0–94.0%) [29–31, 35, 44] for the majority of all the communities were also observed. The low education and high unemployment rates of the communities could be some of the main reasons for the high poverty rates in the study communities (67.7–100%). [26, 35, 36, 44] Research has found that people with low education may not have access to health care that may prevent detecting and treating disease and thus compromise their health even further. [50]

5.2 Cigarette smoking

Cigarette smoking doubles the risk of coronary artery disease and contributes seven-fold to the increase in risk for peripheral arterial disease. [51] Cigarette smoking and increases blood pressure and increases the heart's workload. It deprives the heart muscle of oxygen and damages the platelets that increase coagulation and clot formation. Toxins in cigarettes may also damage the blood vessels and increase atherosclerosis. [48, 52] In SA, the proportion of adult (15+ years) women that smoke (37%) daily is higher than in men (8%). [46] Smoking patterns among children were not measured in our studies, but we previously reported 11.7%, 15.2% and 23.6% smoking among urban elderly, [43] peri-urban adults in Gauteng [31] and rural adults in the FS. [37]

5.3 Obesity

Obesity is considered a multi-factorial condition [20, 53, 54] associated with an increased risk for comorbidities such as type 2 diabetes, insulin resistance, cancer, stroke, [53] hypertension, dyslipidaemia, [53, 55] and hypertriglyceridaemia. [55] Obesity is also considered an independent risk factor for CVD. [40] For every 1% increase above ideal body mass index (BMI), the cardiovascular risk (CVR) increases by 3.3% for females and 3.6% for males. [56] In our studies, the majority of the adults and elderly were overweight/obese. [44, 57] Although we did not report gender differences in this chapter, previous published results confirmed a higher prevalence among women in rural FS [37] and urban elderly [41] than in men. Our results further showed that the urban women in Gauteng had the highest prevalence (82.3%) of overweight/obesity, but cannot be compared to the peri-urban adults and urban elderly that included both men and women. However, the overweight/obesity prevalence among the urban elderly in Gauteng [57] and the peri-urban adults in the FS [44] was consistent with the national prevalence.

There is usually a higher prevalence of overweight/obesity in urban than rural. [20] We did not have any rural adult communities to compare our results, but the urban elderly in Gauteng (61.0%) [57] had lower prevalence of overweight/obesity than the peri-urban adults in the FS (67.9%). [44] This was inconsistent with research from sub-Saharan Africa (SSA) [54] and SA where it was found that age is positively correlated with overweight and obesity. [58, 59] In all three the adult communities, the prevalence of obesity was higher than the prevalence of overweight. (**Table 2**). The increasing prevalence of childhood overweight/obesity in SA [11] is presenting a major public health problem. Childhood overweight/obesity is associated with early onset of hypertension and hyperglycaemia, both risk factors for CVD, [71] as well as adult obesity, [54] premature death and disability. [54] Similar to adults, a higher prevalence of overweight/obesity among children is found in urban areas. [54, 72, 73] (**Table 3**) However, our results showed higher prevalence among the rural children (4.3%) [24] compared to the urban children (1.0%). [32] In addition, the rural [28] and urban [32] children had the lowest prevalence of overweight and no obesity prevalence. Both peri-urban areas showed a prevalence of 21.0% in the FS [25] and 18.3% in Gauteng. [32, 33] This was higher than the national prevalence. In our studies among resource-poor communities, the prevalence of obesity was much lower than the prevalence of overweight. Our studies have found significantly higher prevalence of overweight/obesity in girls when compared to the boys. [24, 26] These results were consistent with national data [77] and for SSA, [54] but inconsistent with a recent systematic review and meta-analysis investigating overweight/obesity among 5–19 year old children in 15 countries in Africa where the boys and girls were equally affected by overweight/obesity. [71].

To summarise, overweight/obesity is common among the poor-resource adults and elderly in our study population. The high prevalence observed among the adults, specifically women, and elderly may be due to poor nutrition (**Table 2**). Although the prevalence of obesity is not yet high among the children in our study

Variable	Reference values	Urban women Gauteng (n = 628) %	Peri-urban adults Free State (n = 271) %	Urban elderly Gauteng (n = 170) %
Overweight	BMI ≥ 25 < 30 [60]	39.3 [37]	26.0 [44]	29.5 [57]
Obese	BMI ≥ 30 [60]	43.0 [37]	41.9 [44]	31.5 [57]
High serum TC levels	≥6.2 mmol/L [61]	0.5 [37]	16.7	22.3 [57]
Low HDL-C levels	<1 mmol/L (adult men) <1.3 mmol/L (adult women) [61, 62]	43.0 [37]	62.7 [39]	76.2 [57]
High LDL-C levels	>4.1 mmol/L [60, 63]	0.5 [37]	16.7	14.6 [57]
Hypertriglyceridaemia (High TRG levels)	≥2.3 mmol/L [60, 63]	24.7 [37]	12.7 [39]	13.8 [57]
High normal BP	130–139 mm Hg/85–89 mm Hg (systolic/diastolic blood pressure) [64]	11.6 [37]	12.7	10.8 [57]
Hypertensive	≥140/≥90 mm Hg (systolic/diastolic blood pressure) [64]	36.4 [37]	53.2 [39]	68.0 [57]
Hyperhomocysteienemia	>15 umol/L [61] (serum homocysteiene)	—	—	66.4 [57]
Fibrinogen	>3.5 g/L [65]	—	—	68.0 [57]
Inflammation (HS-CRP)	≥3 mg/dL [62]	—	56.9	68.3 [57]
Hyperglycaemia (serum glucose)	>5.5 mmol/L [66]	—	16.0 [39]	38.5 [57]
Serum vitamin B6	<8.6 mcg/L [67]	—	—	98.0 [57]
Serum vitamin B12	<156 pmol/L [68, 69]	—	—	4.8 [57]
Serum folate	<5.9 nmol/dL [70]	—	—	9.6 [57]

Table 2.
Cardiovascular risk factors in adults and elderly.

communities, the results highlight the increasing burden of overweight among children (**Table 3**). The high prevalence of overweight and obesity in our study communities is a concern as the comorbidities associated with overweight/obesity have negative effects on health across the life cycle. [71]

5.4 Hypertension

Hypertension (blood pressure ≥ 140/90 mm Hg) [64] is considered one of the most important risk factors for developing CVD [50, 78] due to organ injury to the heart and kidneys. [79] Sharp increases in childhood hypertension have been reported in SA recently. [11] In childhood, hypertension treatment does not reverse the target organ injury and although hypertension treatment will significantly reduce event rates, the burden of CVD event rates will remain high though adulthood. [79] SA has a high hypertension burden with 44% and 41% of adult (≥15 years) black African women and men respectively. [46] In our adult populations the urban women in Gauteng had lower prevalence of 36.4% compared to the peri-urban adults in the FS (53.2%). [39] The elderly in urban Gauteng had the highest prevalence (68.%). [57] (**Table 2**) This was consistent with the national prevalence (84% among both genders aged ≥65 years), indicating that

Variable	Reference values	Rural children Eastern Cape (n = 232) %	Peri-urban children Free State (n = 98) %	Peri-urban children Gauteng (n = 203) %	Urban children Gauteng (n = 152) %
Overweight	BMI:A ≥ 2 < 3 [74]	4.3 [24]	17.0 [25]	15.8 [29]	1.0 [32]
Obese	BMI:A ≥ 3 [74]	0.0 [24]	4.0 [25]	2.5 [29]	0.0 [32]
High serum TC levels	≥5.18 mmol/L [75]	1.3 [24]	19.4	3.0	10.2 [32]
Low HDL-C levels	<1.04 mmol/L [75]	42.5 [24]	30.6	19.2	95.9 [32]
High LDL-C levels	≤3.37 mmol/L [75]	2.12 [24]	12.2	2.5	28.6 [32]
Hypertriglyceridaemia (High TRG levels)	≥1.12 mmol/L (0–9 years old) ≥1.47 mmol/L (10–19 years old) [75]	12.4 [24]	35.7	4.4	1.0 [32]
Hyperhomocysteienaemia	>15 umol/L [61]	1.6	—	—	—
Fibrinogen	>3.5 g/L [65]	14.8	—	—	—
Inflammation (HS-CRP)	≥3 mg/dL [62]	19.0 [24]	7.8	—	—
Hyperglycaemia (serum glucose)	>6.1 mmol/L [76]	10.3[24]	6.5	6.9	—
Serum vitamin B12	<156 pmol/L [69]	7.6	—	—	—
Serum folate	<5.9 nmol/dL [70]	4.6	—	—	—

Table 3.
Cardiovascular risk factors of children.

the hypertension burden increases with age. [46, 80] A recent national survey has found an overall prevalence of 43%, of which 58% were unaware of the condition and thus did not receive treatment. [80] Similar results were observed where only 36.8% of the hypertensive urban elderly in Gauteng used hypertensive medication. [43] No hypertension data were available for the children.

In summary, our results showed high levels of hypertension in adults and the elderly in both urban and peri-urban areas. A recent national survey has found older age, obesity and lower education levels as the main risk factors for hypertension in SA. [80] High prevalence of obesity and poor education levels have been identified in all our adult communities.

5.5 Hyperglycaemia, diabetes and metabolic syndrome

Diabetes mellitus is the most common, but also the most complex CDL. [81, 82] Hyperglycaemia affects multiple organs and can lead to arterial hypertension. [83] It is estimated that the cause of death in 80% of individuals suffering from type 2 diabetes will be due to thrombotic complications of which 75% will result from a cardiovascular event. [84] Data on the incident rates of children with diabetes are available for only 6% of African countries and may be due to lack of screening tests available in the poor and low income communities. [84] Results in **Tables 2** and **3** indicated that 38.5% urban elderly (Gauteng), [57] 16.0% peri-urban adults (FS), [39] 10.3% rural children

(EC), [24] 6.5% peri-urban children (FS), and 6.9% peri-urban children (Gauteng) had high serum glucose levels. An increased prevalence of diabetes was reported for developing countries, [85] and it can be concluded that the prevalence of hyperglycaemia in all age groups in urban, peri-urban and rural areas in SA is concerning.

5.6 Haemostasis

The development of coronary artery disease and myocardial infarction has both atheromatous and thrombotic components. Haemostasis is a finely balanced system of clot formation and fibrinolysis. [86–88] Fibrinogen is recognised as an independent risk marker of CVD. Fibrinogen, because of its mass, also has a direct effect on the blood viscosity and a physical functional effect on platelet aggregation. [65, 89] Studies have indicated an increased level of plasma fibrinogen in black South Africans. [12, 57, 90] An increase of one gram per litre in plasma fibrinogen doubles the risk of CVD. [89] The fibrinogen levels were measured in two of the communities. High fibrinogen levels were observed in 68.0% of the elderly [57] (**Table 2**) and 14.8% of the rural children (**Table 3**), indicating an increased risk for CVD.

5.7 Homocysteine metabolism

5.7.1 Homocysteine

Several mechanisms have been proposed to clarify the link between homocysteine and pro-thrombotic state. The oxidative damage to the endothelium, combined with inhibition of the vasculo-protective function of nitric oxide, enhances thrombogenecity. [91] Homocysteine is metabolised by (a) the trans-sulphuration pathway which results in the production of cystathionine - a process that requires vitamin B6 and the main route of metabolism is via a methionine-conserving pathway - a process that requires methyltetrahydrofolate (from folic acid) and vitamin B12 as co-factor or alternatively (b) by the remethylation pathway taking place in the kidney and liver (where betaine is utilised instead of folate). [92–95] An association between elevated plasma homocysteine and the development of atherosclerosis has been confirmed. [96] Studies in animal models have shown that elevated homocysteine promoted atherosclerosis by increased oxidative stress impaired endothelial function and increased thrombogenecity. [92, 93, 95–99] Epidemiological retrospective and prospective clinical studies established homocysteine as a potent independent risk factor for atherothrombotic vascular disease. [91, 92, 100] Additionally, homocysteine increase superoxide (O_2^-) levels resulting in increased oxidative stress, causing an inflammatory state and increased atherosclerosis and ischemia reperfusion. Oxidative stress in return inhibits the cobalamine metabolism and enhances the cycle. [101, 102] The frequency of hyperhomocysteienaemia as an independent risk factor for atherothrombotic vascular disease [91, 92, 100] was found in 66.4% and 1.6% of the urban elderly [57] and rural children respectively. Thus, although homocysteine measurement did not form part of the objectives in all our communities, prevalence of hyperhomocysteienaemia in the urban elderly (Gauteng) (**Table 2**) and the rural children (EC) (**Table 3**) is an additional confirmation of an increased risk for CVD in the low income South African population.

5.7.2 Serum vitamin B6 levels

Vitamin B6 acts as coenzyme in the irreversible trans-sulfuration of homocysteine to cysteine. Higher vitamin B6 level are associated with lower homocysteine levels. Fat metabolism requires carnitine, obtained either directly [103] through diet or via synthesis requiring lysine and vitamin B6. Vitamin B6 deficiency was also found to be associated with decreased plasma PUFAs (n-6 and n-3) which may be associated with elevated cardiovascular risk and a contributing factor to the anti-inflammatory response. [104, 105] Low circulating vitamin B6 levels have been found inversely related to inflammatory markers (HS-CRP, fibrinogen, IL-6 and TNF-α) and are related to the incidence of inflammatory diseases (rheumatoid arthritis, CVD, and diabetes). [106, 107] Vitamin B6 levels were only available for the urban elderly and 98% of the respondents had low serum vitamin B6 levels (**Table 2**). Vitamin B6 levels were not available for any of the children, but pre-school children in Zambia indicated a suboptimal vitamin B6 in the studied group. [108] It would, therefore, be beneficial to include vitamin B6 serum levels in their analytical profile in future.

5.7.3 Serum folate levels

Low serum folate levels is a cardiovascular risk marker independently from homocysteine level. [109] Folate, as a donor of one-carbon units, is essential for methylation and affects numerous metabolisms involved in CVD [110] and accurate replication of deoxyribonucleic acid (DNA) and its repair. If DNA repair capacity of the cell is exceeded by the rate of damage to the genome, serious defects in cellular and tissue physiology occur, resulting in degenerative diseases including CVD. [111] The four mechanisms by which folate is involved in reducing atherosclerosis are: (1) Optimising methylation cycle and thereby directly reducing the homocysteine levels; (2) Acting directly as an antioxidant; (3) Interacting with enzyme endothelial nitric oxide synthase; (4) Affecting cofactor bioavailability of nitric oxide. Apart from being an independent cardiovascular risk marker, decreased serum folate levels also Indicate a decreased cell regeneration. [112] The serum folate levels were only available for two of the communities and 4.8% and 7.6% had low folate levels in the elderly [57] (**Table 2**) and rural children (EC) (**Table 3**) respectively. Study communities included in this study are therefore at risk for CVD and the general effect of ineffective cell recovery.

5.7.4 Serum vitamin B12 levels

The cofactor cobalamin is required for the optimal function of the enzymes methionine synthase and L-methylmalonyl-CoA. [113, 114] During methionine synthase, homocysteine is converted to methionine, when the methyl group is transferred from 5-methylene tetrahydrofolate to cobalamin to form methylcobalamin and tetrahydrofolate while methylcobalamin donates its methyl group that binds to homocysteine to form methionin (required for the synthesis of S-adenosylmethionine [SAM]). [87, 115] SAM is required in many cellular methylation reactions, including the methylation ribonucleic acid (RNA) and DNA. [116, 117] Reduced synthesis of methionine as a result of insufficient cobalamine results in increased homocysteine levels. [104] Vitamin B12 is also the coenzyme required to remove the methyl group from folate, thereby activating folate. [117, 118] Serum vitamin B12 was only available for the elderly in Gauteng (**Table 2**) and the rural children (EC) (**Table 3**) and 4.8% [57] and 7.6% had low folate levels respectively, thus at risk of impaired homocysteine metabolism and CVD.

5.8 Inflammation

An inflammatory response is initiated by damage to the vascular cell lining resulting in a series of mechanisms (acute-phase response) including haemodynamic (vasodilatation) activation of endothelial cells (increased adhesion molecule expression), increased permeability (enhanced protein movement) and an increase in acute-phase proteins. [119, 120] Vessel injury can also be caused by high LDL-C, hypertension, cigarette toxins and elevated homocysteine levels. During the inflammatory response that aims to repair the damage to the artery wall, LDL-C becomes trapped in the lesion that is engulfed by the macrophages and the free radicals oxidise the LDL trapped in the macrophage and eventually become plaque. [48] CRP is a β-globulin which is bound strongly to phospholipids and increases twentyfold to thirtyfold during an infectious or inflammatory response and is, therefore, considered a credible marker for systemic inflammation. [47] The prevalence of systemic inflammation was found in 56.9% of the adult respondents (peri-urban FS) and in 68.3% of the elderly, [57] (**Table 2**) as well as 19% and 7.8% of the rural (EC) [26] and peri-urban children (FS) respectively. (**Table 3**) Elevated CRP is a strong independent predictor of risk of future cardiovascular events. [121, 122] Thus, the results from our studies indicate an increased risk for CVD.

5.9 Dyslipidaemia

The prevalence of dyslipidaemia varies across the regions in SSA due to increased urbanisation and change of lifestyle factors (epidemiological transition). [123] A similar variation was observed in SA where a significant difference in the prevalence of dyslipidaemia occurs in different ethnic groups. [124] Although, studies indicated that people from an African decent showed an athero-protective lipid profile (lower total cholesterol) compared to their white European or Indian fellow countrymen, widespread low High density Lipoprotein (HDL-C) was present. [125] The use of antiretroviral therapy (ARV) also leads to an increase in dyslipidaemia. With the high prevalence of HIV/AIDS in SA [45, 46], is ARV treatment (the largest health programme internationally) is considered as a contributing factor to dyslipidaemia in SA. [126]. Previous studies indicated that prevalence of dyslipidaemia among black South Africans (independent of rural or urban) varies between 30% and 63%. [125, 127, 128]

The high protein component of high-density lipoprotein-cholesterol (HDL-C) accounts for its metabolic function of removing cholesterol from tissue back to the liver, and is considered as an important anti-atherogenic pathway modulating inflammation. The inverse correlation between serum HDL-C and cardiovascular risk (CVR) is well known and widely accepted. [129] Studies showed that improving poor lifestyle habits to have a positive effect on the HDL-C levels. [130]

With reference to the reported results in **Tables 2** and **3**, the prevalence of increased total serum cholesterol (TC) with the lowest in the urban adult women in Gauteng where 0.5% of participants had an increased TC. The highest prevalence was observed among the urban elderly population of Gauteng, where 22.3% of participants had an increased TC. The prevalence of low serum HDL-C levels was significantly decreased in all the study communities with the lowest prevalence in the peri-urban children where 19.2% had a HDL-C of less than 130 mg/dl. The highest prevalence was in the urban children where 95.6% had a decreased HDL-C level. The percentage of participants with the highest prevalence of abnormal LDL-C levels was found in the urban children in Gauteng (28.6%) and the lowest prevalence was found in the urban women of Gauteng (0.5%). In contrast, the lowest prevalence of participants with increased serum triglyceride levels were found in the urban children of Gauteng and the highest prevalence was in the urban (Gauteng) women (24.7%). Results obtained from our studies are in line with results obtained from other studies in SA [125–128], confirming that prevalence of dyslipidaemia (mainly decreased HDL-C) is becoming an increasing concern that needs to be consciously addressed in planning for Health care interventions.

Dyslipidaemia is regarded as an independent CVR marker. [124] As indicated in **Figure 1**, a total of 4.1% Peri-urban children from the FS had four elevated lipid

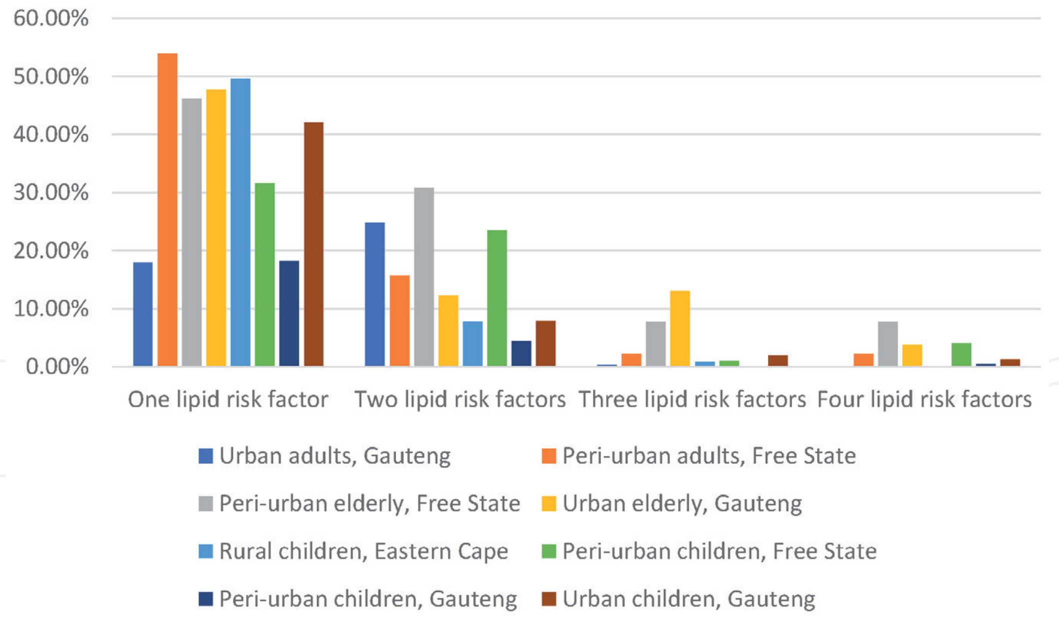

Figure 1.
Dyslipidaemic factors present in study groups.

risk factors, additionally, of the urban elderly from Gauteng 3.8% had four, 13.1% had three, 12.3% had two and 47.7% had one elevated lipid parameter. Interestingly, more than one lipid risk factor were present in almost all the communities (>10% of adults and elderly), even in the children (>5%).

5.10 Dietary intake factors

Dietary diversity has a significant positive association with health. [34] An inverse relationship between dietary diversity and CVD risk factors, namely hypertension, hypercholesterolaemia and high HDL-C has been observed. [131] Although we did not measure dietary diversity in all the communities, poor to moderate dietary diversity were observed in all of the communities. [26, 29, 33, 35, 38, 57]. This may have been due to their socio-economic status and food insecurity and may be a risk factor for CVD.

5.10.1 Added sugar intakes

An association between higher dietary sugar intakes and overweight/obesity and CDLs such as CVD exists. Increased dietary glycaemic load, caused by high sugar consumption, results in increased hepatic lipogenesis, dyslipidaemia,[132] and CVD. [133] Childhood overweight/obesity risk and morbidity were associated with consumption of sugar-sweetened beverages (SSBs) and highly processed foods and snacks. [54] The World Health Organisation recommends the intake of added sugar to be <10% of total energy intake. [134] More than 20% of the adults, elderly [57] and children in rural EC had high added sugar intakes whereas the children in peri-urban FS and urban Gauteng [33] had no added sugar intakes. Although SSB consumption has not been investigated in our studies, during the past 50 years, SBB consumption has increased [132] and SA is in the top 10 countries with the highest consumption of SSBs globally. [135]

5.10.2 Dietary fibre

Vegetables, legumes, whole grains and fruit all contribute to dietary fibre intake. Dietary fibre is differentiated as soluble (dissolves in water and forms a gel) and insoluble fibres. Good sources of soluble fibre are oats, citrus fruit, barley and legumes. It lowers LDL-C and glucose levels and, therefore, has a protective effect against CVD. [136] Lowering of cholesterol is achieved by the binding of fibre to bile acids, thereby escalating its excretion. This inhibits the production of cholesterol by the liver, resulting in lower blood cholesterol. [137] Food sources of insoluble dietary fibre include whole grains and vegetables. It cannot be fermented and promotes bowel movement and alleviates constipation. [138] A large majority (0–100%) of the children and adults in all our communities had low dietary fibre intakes. [24, 26, 29, 33–35, 38, 43, 44, 57] This may be due to the mainly refined carbohydrate-rich diet consumed by all these communities.

5.10.3 Dietary fats and fatty acids

Dietary fats consist mainly of cholesterol and fatty acids. Total dietary fat (% of total energy [TE]) intakes were higher than recommended for all the communities, ranging from 13.7% to 32.7% in urban Gauteng women and elderly respectively. [24, 26, 29, 32, 35, 36, 38, 39, 42–44, 57] High-fat diets cause an increase in postprandial triglyceride levels that are associated with risk of coronary heart disease (CHD). [139, 140] Fatty acids can be either protective against the development of CVD or can be risk factors for CVD. Saturated fatty acids (SFAs) and trans fatty acids (TFAs) have the greatest adverse effect on atherogenic cholesterol levels and are both associated with risk of CVD. [136, 141] Increased SFA intakes increase LDL-C levels. [142] TFAs have a HDL-C lowering effect and also increase LDL-C levels and, therefore, increase the risk of CVD.[47]. The contribution of TFA to CVD is a multiple pathway mechanism affecting lipid metabolism, increased inflammatory response and adiposity, and decreased endothelial function and insulin sensitivity. [143]

Dietary SFA intakes of <10% and TFAs of <1% of total energy intakes are recommended. [144] High TFA intakes were observed in less than 10% of our communities, except for the children in rural EC where the proportion of respondents with high intakes of TFAs was 36.7%. The proportion of the respondents that had high SFA intakes ranged from 18.6% to 42.9%. [24, 26, 32, 34, 37, 38, 42] The elderly (40.0%) [57] and peri-urban children (41.6% in Gauteng and 42.9% in the FS) [25, 29] had the highest prevalence of high TFA intakes (40.0%). Low-cost processed meats such as polony and Russians as well as chicken feet and heads were frequently consumed by our communities and may have contributed to the large intakes. Although there has been controversy about SFA intake and CVD risk, sufficient evidence exists that high SFA intakes cause increased LDL-C level by downregulating LDL receptors. [136]

PUFAs have a protective effect against CVD, specifically omega-6 PUFAs that significantly reduces total cholesterol and LDL-C levels as well as inflammatory markers. [145] High intakes of omega-3 PUFAs lowers the risk for myocardial infarction, CHD and CVD mortality and CVD events. [136] In addition, a diet rich in PUFA reduces the TC:HDL-C ratio and CHD incidence. [146] Linolenic acid (omega-3 fatty acid) and linoleic acid (omega-6 fatty acid) are essential fatty acids that cannot be physiologically produced and, therefore, need to be supplied by food sources. [147] Omega-3 decreases the risk of CVD by preventing thrombus formation, lowering blood pressure and protecting against irregular heart beat. [142] Replacing dietary carbohydrates and SFAs by an increased intake of omega-6 PUFAs lower LDL-C and increase HDL-C levels [148]. A large proportion of all of our communities had low PUFA intakes (33.0–100%), particularly for both omega-3 (93.1–100%) and omega-6 (2.4–29.7%) fatty acids. MUFA intakes were low in a large proportion of the participants (29.0–77.6%), except for the peri-urban children in Gauteng where only 4.8% of the children had low MUFA intakes. The majority of these children also showed high dietary cholesterol intakes (57.6%) whereas the rest of the study communities had relatively low prevalence (<20%) of high dietary cholesterol intakes. Because most of our communities live in poverty, it is questionable if they can afford oily fish, olive oil and the other MUFA and PUFA dietary sources, however, they do consume mostly sunflower oil, but in small quantities. [26, 29, 33, 34, 38, 57]

5.10.4 Dietary vitamin B6, B12 and folate intakes

Dietary sources of vitamin B6 include meat, fish, potatoes and bananas which are good sources. However, it is also present in nuts, whole grain, fortified cereal and leafy vegetables, chicken, legumes, non-citrus fruit, liver and soy products. [149–152] The bioavailability differs according to food type, with pyridoxine glycoside as the least bioavailable. Vitamin B6 (5–75%) obtained from plant sources is in the form of glycosylated pyridoxine. [153, 154] Owing to the abundance of vitamin B6 in a variety of food sources, deficiency is not very common, however, in our communities, large proportions of the adults (79.1% in peri-urban FS Province and 85.7% urban women in Gauteng) and elderly (91.0%) [57] had low vitamin B6 intakes. Among the children, 36.7% of the rural and 24.8% of the peri-urban children in Gauteng showed low intakes of vitamin B6. Vitamin B6 deficiency often occurs in conjunction with other nutritional disorders and is associated with an increased risk of CVD. [155] Vitamin B6 not only has a homocysteine lowering effect, but is also needed for the metabolism of omega-3 PUFAs. [96]

Folate is the major determinant of homocysteiene [96] and thus has homocysteiene lowering effect. A recent meta-analysis showed that folic acid supplementation resulted in a 4% reduced risk for CVD events and the benefit was even greater among participants without pre-existing CVD or low folate levels. [156] Because folate cannot be physiologically synthesised, concentration depends on consumption. [65] All of our communities showed large proportions of participants (>40.0% ≤ 95.0%) with low dietary folate intakes. Green leafy vegetables, citrus fruit, legumes, yeast, liver and organ meats contain the highest concentration of folate. [155] Low intakes of these food items have been found in our studies. [25, 26, 29–31, 33, 35, 38, 43, 44, 57] Folate is omnipresent in nature, but heat and oxidation during food preparation and storage have a destructive effect and can destroy up to 50% of the original concentration. [157]

Vitamin B12, together with folate, plays a key role for the enzyme methionine synthase needed for the re-methylation of homocysteine to methionine. [96] Dietary sources of vitamin B12 are animal products (meat, fish, chicken, milk and cheese) and rarely found in plants or yeast. [158] Vitamin B12 is stored in large quantities in the liver and a deficiency is developed over years. [65] The majority of our communities showed large proportions of participants (≥60% ≤ 95.2%) with low intakes of vitamin B12, except for the peri-urban children in Gauteng where 14.4% of the participants had low vitamin B12 intakes. This may be mainly due to the mainly carbohydrate-based diet with low meat and cheese intakes.

5.10.5 Dietary sodium intakes

Sodium is an essential nutrient that is required for many physiological functions. [146] The daily physiological requirement for sodium is estimated at 0.1–1.0 gram. [159] High sodium intakes have been established as the major cause of hypertension in many epidemiological, experimental, controlled clinical and population trials. [160, 161] Sodium is mainly consumed as (a) salt (sodium-chloride) which is added during food preparation and cooking or at meal time, and (b) from sodium used in processed foods in SA. [162] Unfortunately we did not measure dietary sodium intakes in all our communities. Bread was identified as the largest contributor to salt intakes and that 41.0% of the South African population has a high salt intake. [162] Bread also consistently appeared in the top 20 most commonly consumed foods among our study communities [26, 29–31, 33, 34, 38, 43, 44, 57]. Another contributor to sodium intake in SA is sodium glutamate that is used as a condiment, [163] as well as salt in soup, gravy and spice mixes and powders, margarine and atchar, a spicy condiment, [163] biscuits/cookies, and breakfast cereals [164]. Stock cubes are regularly used for flavouring meat and vegetable dishes in SA [165, 166]. High stock cube consumption has also been observed in these communities by the authors.

6. Conclusions

In the studies reported among various communities, low education and employment status were observed as well as poverty in a large majority of the respondents. The scientific literature shows a strong association between poverty and CVD [163]. Poverty is an underlying factor of food insecurity that often results in poor dietary intakes that were observed in our communities. Many of the dietary CVD risk factors were present in large proportions of the communities. The literature is clear

Figure 2.
Cardiovascular risk factors prevalent among children, adults and the elderly.

that these dietary factors may be associated with some of the risk factors for CVD, such as obesity, hypertension and the biochemical risk factors for CVD. Irreversible and potentially reversible and physiological (low income) risk markers were found to prevail. A summary of the elevated cardiovascular risk markers in our study is schematically presented in **Figure 2**. Multiple preventable CVR markers were present among the children, adults and elderly in rural, peri-urban and urban areas. It can thus be concluded that a double burden of poverty and risk of CVD exists across the different age groups and geographical locations in these resource-poor communities. Prevention of CVD can be achieved through nutrition education and awareness programs. It is recommended that policy makers give serious attention to CVR and screening should be done from an early age to identify those at risk and implement appropriate interventions.

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Conflict of interest

The authors have no conflict of interest to declare.

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