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Environmental Factors Drive Obesity among Rural Adolescents in Vhembe District, South Africa

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Abstract

The increased prevalence of obesity is due to a decreased level of physical activity and increased intake of fast food. Furthermore, obesity among children and adolescent is a risk factor for life-threatening conditions including cardiovascular diseases (CVD, Cardio-metabolic disorders, type 2 diabetes mellitus, hypertension, cancer and reproductive disorders. This study aims to describe the environmental factors that derive obesity among rural adolescents in Vhembe district, South Africa. A cross-sectional study was conducted on a total of 377 adolescents aged 13 to 20 years from 16 secondary schools in Thulamela Municipality, Vhembe District, South Africa. Information about socio-demographic characteristics of participants and their parents was obtained using a research-administered questionnaire. Anthropometric measurements such as weight, height and waist circumference were taken by trained field workers and body mass index (BMI), and the waist-hip ratio were determined. Biochemical measurements and clinical assessment were done by a professional nurse following standard procedures. The prevalence of obesity is 22.2% in males and 32.6% in females by abdominal obesity by (waist circumference), whilst 11.1% (males) and 28.3% (females) by waist to hip ratio (WHR). Overweight and obesity were more prevalent in females than in males in Thulamela municipality. Gender (β=0.32, p=0.018, 95%CI); age (β=1.28, p=0.015, 95%CI); source of income (β=3.25, p=0.008, 95%CI) and systolic blood pressure (β=1.04, p=0.01, 95%CI) were associated with obesity. There is a need to bring up children and adolescents in a health-promoting environment in an effort to reverse and stop the increasing trend of overweight and obesity.

Keywords: obesity; BMI; adolescents; Vhembe district

Introduction

Obesity is defined as excessive or abnormal body fat accumulation that may result in serious health problems [1]. Globally, obesity among children and adolescents is a serious public health concern [2, 3]. Children and adolescents' obesity indicates a higher risk of transition to adulthood [4-6]. Furthermore, obesity among children and adolescents is a risk factor for life-threatening conditions, including CVD, cardio-metabolic disorders, type 2 diabetes mellitus, hypertension, cancer and reproductive disorders [7-8]. According to World Health Organisation (WHO) report in 2016, an estimated 41 million deaths occurred due to noncommunicable diseases (NCDs).9 Overweight and obesity are the fifth leading cause of global death [9]. As estimated by WHO, at least 2.8 million adults die annually because of being overweight /obese [10]. In addition, 44% of diabetes, 23% of ischemic heart disease, and between 7% and 41% of certain cancer burdens are attributable to overweight and obesity [2].

The prevalence of overweight and obesity among children and adolescents aged [5–19] has escalated radically from just 4% in 1975 to over 18% in 2016 [9]. The rise has occurred similarly among both boys and girls: in 2016 18% of girls and 19% of boys were overweight.1 Around-55% of obese children go on to be obese in adolescence, around 80% of obese adolescents will still be obese in adulthood, and around 70% will be obese over age 30 [4].

Obesity can lead to physical limitations, reduced mobility, and a decreased ability to engage in physical activities, which can impact overall quality of life. People living with obesity may face stigmatization and social discrimination, which can have a negative impact on their mental health and well-being [11]. Obesity is considered a problem in developed countries however, it is currently on the rise in developing countries [6, 12, 13]. Middle-income nations, like South Africa, have seen the biggest increases in obesity rates.14 In South Africa, the prevalence of overweight and obesity has increased from 49.4% in 1980 to 57.8% in 2015 [15]. The National Department of Health [14] reported that South Africa in 2016 has 31% of male and 67% of females were either overweight or obese.

Environmental factors can have a substantial impact on obesity [16]. These factors may include the availability of unhealthy foods, sedentary work and lifestyle, easy access to high-calorie processed foods, and the absence of opportunities for physical activity [17]. The concept of self-regulatory capacity refers to an individual's ability to make healthy choices, particularly when it comes to diet and physical activity [18]. Environmental factors can impede this capacity by making unhealthy options more accessible and convenient, which can lead to poor decision-making [14]. The findings of research by Roberto et al.19 may support the idea that environmental effects play a significant role in driving obesity.19 Eating a healthy diet and engaging in regular physical activity are influenced by a multitude of factors, many of which extend beyond individual choices. The social, economic, and cultural environment, as well as issues of accessibility and affordability, and education, all play significant roles in shaping people's health behaviours [14].

In South Africa, it has been calculated that obesity costs the country R701 billion annually.14 In April 2018, the South African Government Implemented a tax on sugar-sweetened beverages (SSB) called Health Promotion Leavy (HPL) with the aim of decreasing diabetes, obesity and other related diseases. SSB taxes can help reduce the excessive intake of sugar and energy and many countries have adopted this policy as a strategy to reduce excessive sugar intake [20] WHO 21 indicates that people shift from diets based on unprocessed foods to more processed food (food high in fats, sugar, and salt), and decrease in consumption of vegetables. Foods high in salt are often high in calories and have low nutritional value. To limit the salt content of processed foods and cut the population's daily salt intake to less than 5 g, South Africa was one of the first nations to enact a mandatory law in 2016.22 Salt reduction policy may also curb excessive calorie consumption and support weight management [22].

Although cross-sectional studies have been conducted in different parts of South Africa on the prevalence of overweight and

obesity among adolescents, few studies have been conducted regarding its determinants using a case-control study design. These few studies did not consider the most important variables associated with obesity like socioeconomic factors, biochemical markers, nutrient intake, and physical activity. In addition, risk factors for overweight and/or obesity might not be the same across different regions due to differences in socioeconomic characteristics, culture, ethnicity, and geographical location. Toriola et al.23 conducted a study in the rural Capricorn district of Limpopo, indicating that 5.5% of boys and 4.4% of girls were obese. Central obesity (13.7%) was also observed in the same population.23 Therefore, the aim of this study was to investigate environmental factors that drive obesity among rural adolescents in Vhembe district in Limpopo province, SA.

Methods

A cross-sectional study was conducted among 377 adolescents residing in Thulamela municipality of Limpopo Province South Africa from February 2018 to August 2018. Stratified random sampling was used to select five learners per grade (grades: 8-12) making a total of 25 per school. Adolescents aged 13 to 20 years with variation in body composition were recruited to participate in the study from 16 secondary schools in Thulamela municipality of Limpopo province, SA. Inclusion criteria were male and female adolescents attending school at the time of data collection from grades 8-12 and free from illnesses. Pregnant adolescents were excluded from the study. The response rate was 94.25%.

Body mass index (BMI) in kg/m2 was determined and classified according to International Obesity Task Force (IOTF) cut-off points for children and adolescents.24 BMI was used as a proxy for overall obesity. Waist circumference was measured using an inelastic flexible measuring tape with learners wearing light clothing. WC was measured following standard procedures stipulated by Lee and Nieman [25]. The measurements were recorded to the nearest 0.1 cm and waist circumference for adolescents 18 years and below was classified according to age and sex [26]. For adolescents above 18 years, the WHO27 cut-off points of WC were used. Waist circumference was used as a proxy to determine android obesity. Waist and hip circumferences were measured to determine waist-to-hip ratio (WHR). WHR was calculated and the WHO27 cut-off points were used.

A phlebotomist was responsible for collecting blood samples. A Cardio-check device (model CE 0197) was used to determine total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), and glucose level. TC, LDL-C, HDL.C and TG were classified according to age and gender lipoprotein for adolescents [28]. Glucose level was classified according to laboratory standards [29].

A professional nurse was responsible for taking blood pressure readings using standard procedures [30]. BP for adolescents less than 18 years were classified according to sex, age, and height (The fourth report on the diagnosis) [31]. For adolescents ≥18 years BP was classified according to American Heart Association (AHA) for adults [32].

A quantified food frequency questionnaire (QFFQ) was used to assess the adolescents' dietary intake. The food models and the line drawing from the DAEK manual assisted the adolescents in estimating the portion sizes [33]. The data were analysed using the Food Finder computer software (version 1.1.3) to assess the dietary intake. The analysis aimed to determine the amount of nutrients and energy consumed per day. These nutrients include carbohydrates, lipids, proteins, minerals, and vitamins.

A physical activity questionnaire by Sharkey and Gaskill34 was adopted to assess the physical activity level. The following formula was used to calculate physical activity indices:

Intensity of activity X Duration of activity (in minutes) X Frequency (per week) = Score Total

The interpretation of the indices is indicated in Table 1.

Table 1: Interpretation of the physical activity indices scores

Evaluation of activity score		
Score	**Evaluation**	**Activity category**
81 to 100	Very active lifestyle	High
60 to 80	Active and healthy	Very good
40 to 59	Acceptable but could be better	Fair
20 to 39	Not good enough	Poor
Under 20	Sedentary	

Ethical Considerations

Parents or guardians provided written informed consent, and adolescents provided written assent. All procedures were approved by the Research and Ethics Committee of the University of Venda and an Ethics certificate was issued (SHS/17/NUT/03/1506). The provincial Department of Basic Education granted permission to conduct the study.

Data Analysis

Data were checked for completeness and consistency. Data were entered, cleaned, and analysed using SPSS (IBM Corporation, USA) version 26 statistical package software. Descriptive statistics like frequencies and proportions were used to summarize the data. Shapiro Wilk and Kolmogorov Smirnov test were used to test for normality. The data was homogenous. ANOVA was used to determine the differences between BMI classifications. Logistic regression was used for bivariate and multivariate analyses to calculate unadjusted and adjusted odds ratios (AOR) for determinants of obesity. Statistical significance was set at $p < 0.05$.

Results

Demographic Characteristics

The characteristics of adolescents are indicated in Table 2. The mean age of the study participants was 16.56 ± 2.10 years. Majority were of Vha-Venda ethnic group. The frequency of buying food at school was more prevalent in the overweight and obese group for both boys and girls.

Table 2: Demographic characteristics of the study participants

Variables	**Total**	**Boys**				**Girls**			
		Normal	**Overweight**	**Obese**	**P-value**	**Normal**	**Overweight**	**Obese**	**P-value**
Adolescent (mean ±SD)									
Age in years	16.56±2.10	16.89±2.08	17.14±2.27	17.00±1.66	0.945	16.25±2.16	16.68±1.79	16.32±2.03	0.639
Grade	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
Grade 8	68 (18.1%)	25 (18.8%)	1 (14.3%)	1 (11.1%)	N/A	33 (20.4%)	1 (5.3%)	7 (15.2%)	N/A
Grade 9	79 (21.0%)	28 (21.1%)	2 (28.6%)	3 (33.3%)		27 (16.7%)	6 (31.6%)	13 (28.3%)	
Grade 10	88 (23.4%)	36 (27.1%)	2 (28.6%)	3 (33.3%)		36 (22.2%)	5 (26.3%)	6 (13.0%)	

Grade 11	73 (19.4%)	21 (15.8%)	1 (14.3%)	1 (11.1%)		35 (21.6%)	5 (26.3%)	10 (21.7%)	
Grade 12	68 (18.1%)	23 (17.3%)	1 (14.3%)	1 (11.1%)		31 (19.1%)	2 (10.5%)	10 (21.7%)	
Ethnics group	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
Tsonga	5 (1.7%)	2 (1.5%)	0	0	N/A	3 (1.9%)	0	0	N/A
Venda	364 (96.8%)	130 (97.7)	7 (100%)	9 (100%)		155 (95.7%)	18 (94.7%)	45 (97.8%)	
Pedi	7 (1.9%)	1 (0.8%)	0	0		4 (2.5%)	1 (5.3%)	1 (2.2%)	
Pocket money	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
None	10 (2.7%)	4 (3.0%)	1 (14.3%)	0	N/A	5 (3.1%)	0	0	N/A
R20	1 (0.3%)	1 (0.8%)	0	0		0	0	0	
Lunch box	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
1-2 times	24 (6.4%)	6 (4.5%)	0	1 (11.1%)	N/A	14 (8.6%)	2 (10.5%)	1 (2.2%)	N/A
3-4 times	37 (9.8%)	4 (3.0%)	0	0		24 (14.8%)	2 (10.5%)	7 (15.2%)	
Everyday	30 (8.0%)	7 (5.3%)	0	0		15 (9.3%)	4 (21.1%)	4 (8.7%)	
Never	285 (75.8%)	116 (87.2%)	7 (100%)	8 (88.9%)		109 (67.3%)	11 (57.9%)	34 (73.9%)	
Buying food at school	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
1-2 times	49 (13.0%)	21 (15.8%)	0	2 (22.2%)	N/A	19 (11.7%)	3 (15.8%)	4 (8.7%)	N/A
3-4 times	105 (27.9%)	36 (27.1%)	2 (28.6%)	4 (44.4%)		44 (27.2%)	4 (21.1%)	15 (32.6%)	
Everyday	195 (51.9%)	68 (51.1%)	4 (57.1%)	2 (22.2%)		85 (52.5%)	10 (52.6%)	26 (56.5%)	
Never	27 (7.2%)	8 (6.0%)	1 (14.3%)	1 (11.1%)		14 (8.6%)	2 (10.5 %)	1 (2.2%)	
Source of income of parents	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
Salary	102 (27.1%)	36 (27.1%)	3 (42.9%)	4 (44.4%)	N/A	41 (25.3%)	3 (15.8%)	15 (32.6%)	N/A
Pension grant	68 (18.1%)	31 (23.3%)	1 (14.3%)	1 (11.1%)		24 (14.8%)	5 (26.3%)	6 (13.0%)	
Child support grant	64 (17.0 %)	21 (15.8%)	0	1 (11.1%)		31 (19.1%)	5 (26.3%)	6 (13.0%)	
Wages	137 (36.4%)	44 (15.8%)	3 (42.9%)	3 (33.3%)		63 (38.9%)	6 (31.6%)	18 (39.1%)	
Disability grant	4 (1.1%)	0	0	0		3 (1.9%)	0	1 (2.2%)	

Pension and child support grant	1 (0.3%)	1 (0.8%)	0	0		0	0	0	
Marital status of parents	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**		
Married	110 (29.3%)	38 (28.6%)	2 (28.6%)	4 (44.4%)	N/A	44 (27.2%)	5 (26.3%)	17 (37.0%)	N/A
Divorced	39 (10.4%)	14 (10.5%)	1 (14.3%)	0		17 (10.5%)	1 (5.3%)	6 (13.0%)	
Windowed	41 (10.9%)	16 (12.0%)	1 (14.3%)	1 (11.1%)		16 (9.9%)	16 (9.9%)	4 (8.7%)	
Living together	100 (26.6%)	38 (28.6%)	1 (14.3%)	2 (22.2%)		44 (27.2%)	44 (27.2%)	13 928.3%)	
Single	86 (22.9%)	27 (20.3%)	2 (28.6%)	2 (22.2%)		41 (25.3%)	41 (25.3%)	6 (13.0%)	
Highest level of education of parents	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
Never attended school	10 (2.7%)	6 (4.5%)	0	0	N/A	4 (2.5%)	0	0	N/A
Primary school	46 (12.2%)	19 (14.3%)	2 (28.6%)	2 (22.2%)		14 (8.6%)	4 (21.1%)	5 (47.4%)	
Secondary school	264 (70.2%)	87 (65.4%)	3 (42.9%)	7 (77.8%)		121 (74.7%)	9 (47.4%)	37 (80.4%)	
Tertiary	56 (14.9%)	21 (15.8%)	2 (28.6%)	0		23 (14.2%)	6 (31.6%)	4 (8.7%)	
Type of employment of parents	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
Government	53 (14.1%)	21 (15.8%)	1 (14.3%)	0	N/A	21 (13.0%)	3 (15.8%)	7 (15.2%)	N/A
Private company	136 (36.2%)	43 (32.3%)	4 957.1%)	6 (66.7%)		63 (38.9%)	3 (15.8%)	17 (37.0)	
Self employed	59 (15.7%)	23 (17.3%)	0	1 (11.1%)		24 (14.8%)	4 (21.1%)	7 (15.2%0	
Unemployed	128 (34.0%)	46 (34.6%)	2 (28.6%)	2 (22.2%)		54 (33.3%)	9 (47.4%)	15 (32.6%)	
Number of people in household (HH)	**n(%)**	**n(%)**	**n(%)**	**n(%)**		**n(%)**	**n(%)**	**n(%)**	
1-2	31 (8.2%)	14 (10.5%)	1 (14.3%)	2 (22.2%)	N/A	9 (5.6%)	2 (10.5%)	3 (6.5%)	N/A
3-4	122 (32.4%)	45 (33.8%)	2 (28.6%)	2 (22.2%)		54 (33.3%)	4 (21.1%)	15 (32.6%)	
5-6	146 (38.8%)	52 (39.1%)	2 (28.6%)	3 (33.3%)		60 (37%)	8 (42.1%)	21 (45.7%)	

7-8	63 (16.8%)	19 (14.3%)	2 (28.6%)	2 (22.2%)		29 (17.9%)	4 (21.1%)	7 (15.2%)	
9 and above	14 (3.7	3 (2.3%)	0	0		10 (6.2%)	1 (5.3%)	0	

Anthropometry, Clinical Assessment, and Biochemical Measurements of Study Participants

The prevalence of abdominal obesity among boys and girls in the obese group was 22.2% and 32.6%, respectively. The high prevalence of substantially increased WHR was seen in overweight boys and obese girls. Among those classified as obese, only 13% had hypertensive SBP (Table 3).

Table 3: Anthropometry, clinical assessment, and biochemical measurements of study participants

Variables	Total	Boys			Girls		
		Normal n(%)	Overweight n(%)	Obese n(%)	Normal n(%)	Overweight n(%)	Obese n(%)
WC							
Normal	354 (94.1%)	133 (100%)	7 (100%)	7 (77.8%	157 (96.9%)	19 (100)	31 (67.4%)
Abdominal obesity	22 (5.9%)	0	0	2 (22.2%)	5 (3.1%)	0	15 (32.6%)
WHR							
Normal	344 (91.5%)	122 (91.7%)	6 (85.7%)	8 (89.9%)	156 (96.3%)	19 (100%)	33 (71.7%)
Substantially increased	32 (8.5%)	11 (8.3%)	1 (14.3%)	1 (11.1%)	6 (3.7%)	0	13 (28.3%)
SBP							
Normal	301 (80.1%)	90 (67.7%)	6 (85.7%)	8 (88.9%)	149 (92.0%)	16 (84.2%)	36 (78.3%)
Pre-hypertensive	54 (14.4%)	35 (26.3%)	1 (14.3%)	1 (11.1%)	8 (4.9%)	2 (10.5%)	4 (8.7%)
Hypertensive	20 (5.3%)	8 (6.1%)	0	0	5 (3.1%)	1 (5.3%)	6 (13.0%)
DBP							
Normal	310 (82.4%)	118 (88.7%)	5 (71.4%)	7 (77.8%)	135 (83.3%)	15 (78.9%)	30 (65.2%)
Pre-hypertensive	37 (9.8%)	13 (9.8%)	2 (28.6%)	1 (11.1%)	14 (8.6%)	0	7 (15.2%)
Hypertensive	29 (7.7%)	2 (1.5%)	0	1 (11.1%)	13 (8.0%)	4 (21.1%)	9 (19.6%)
BGL							
Normal	366 (97.3%)	131 (98.5%)	7 (100%)	9 (100%)	155 (95.7%)	19 (100%)	45 (97.8%)
Pre-Diabetic	8 (2.1%)	2 (1.5%)	0	0	6 (3.7%)	0	0
Diabetic	2 (0.5%)	0	0	0	1 (0.6%)	0	1 (2.2%)
TC							

Normal	367 (97.6%)	133 (100%)	6 (85.7%)	9 (100%)	157 (96.9%)	18 (94.7%)	44 (95.7%)
Borderline high	8 (2.1%)	0	1 (14.3%)	0	4 (2.5%)	1 (5.3%)	2 (4.3%)
High	1 (0.3%)	0	0	0	1 (0.6%)	0	0
LDL							
Normal	370 (98.4%)	133 (100%)	7 (100%)	9 (100%)	158 (97.5%)	19 (100%)	44 (95.7%)
Above normal	5 (1.3%)	0	0	0	3 (1.9%)	0	2 (4.3%)
Borderline high	1 (0.3)	0	0	0	1 (0.6%)	0	0
HDL							
Low	160 (42.6%)	69 (51.9%)	6 (85.7%)	3 (33.3%)	52 (32.2%)	6 (31.6%)	24 (52.2%)
Normal	173 (46.0%)	56 (42.1%)	1 (33.3%)	6 (66.7%)	83 (51.2%)	7 (36.8%)	20 (43.5%)
Protective	43 (11.4%)	8 (6.0%)	0	0	27 (16.7%)	6 (31.6%)	2 (4.3%)
TRIG							
Normal	341 (90.7%)	125 (94%)	7 (100%)	6 (66.7%)	150 (92.6%)	16 (84.2%)	37 (80.4%)
Borderline high	17 (4.5%)	6 (4.5%)	0	2 (22.2%)	6 (3.7%)	0	3 (6.5%)
High	18 (4.8%)	2 (1.5%)	0	1 (11.1%)	6 (3.7%)	3 (15.8%)	6 (13.0%)

BGL=blood glucose level, DBP=diastolic blood pressure, HDL=high density lipoprotein, LDL=low density lipoprotein SBP=systolic blood pressure, TRIG=triglycerides, TC=total cholesterol, WC=waist circumference, WHR=waist hip ratio

BMI Classification of the Study Participants

The mean BMI of boys was 20.81 ± 3.45 kg/m^2 and that of girls was 23.3 ± 4.90 kg/m^2. There was a significant difference between boys and girls in terms of BMI ($p<0.005$). The results of the study population show that the prevalence of overall combined overweight/obesity is 21.5%. The prevalence of overweight and obesity was higher in girls than in boys (Figure 1).

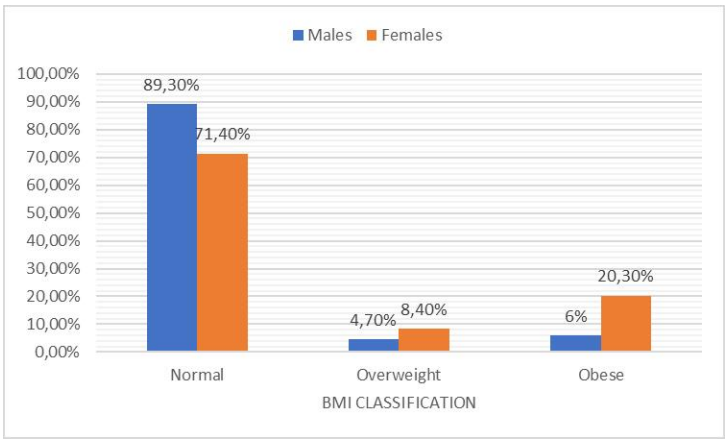

Figure 1: BMI classification

Comparison of Means of Variables

Table 4 below compares the means of variables. For WC, there was a significant difference between BMI categories in both boys and girls. Among females, there was a significant difference between BMI categories in W/HR, SBP, HDL and TCHDL.

Table 4: Comparisons of means of variables

Variables	Total (mean ± SD)(n=)	Boys (mean ± SD)				Girls (mean ± SD)			
		Normal (n=)	Overweight(n=)	Obese (n=)	p-value	Normal (n=)	Overweight (n=)	Obese (n=)	p-value
WC (cm)	71.73±10.23	67.31±5.90	77.49±7.72	89.22±9.44	0.000	68.95±6.00	76.95±5.56	88.22±13.02	0.000
W/HR	0.78±0.77	0.79±0.94	0.82±0.10	0.81±0.05	0.472	0.77±0.05	0.77±0.04	0.81±0.08	0.000
SBP (mmHg)	110.78±1341	116.02±12.92	117.29±9.49	125.06±12.90	0.125	105.24±11.26	109.02±14.73	112.16±13.40	0.002
DBP (mmHg)	71.42±9.14	69.59±8.50	74.57±3.33	71.5±8.19	0.257	71.75±9.28	70.63±12.27	75.80±8.91	0.027
BGL (mmol/L)	4.24±0.84	4.15±0.66	4.33±0.82	4.57±0.67	0.161	4.26±0.78	4.12±0.59	4.43±1.43	0.388
LDL	0.62±0.82	0.36±0.65	0.64±0.82	1.09±1.05	0.007	0.73±0.86	0.64±0.756	0.91±0.91	0.390
HDL	1.14±0.33	1.07±0.29	0.93±0.16	1.12±0.26	0.403	1.22±0.35	1.30±0.33	1.04±0.29	0.004
TCHDL	1.13±1.41	0.68±1.19	0.90±1.55	1.86±1.81	0.025	1.23±1.36	1.09±1.29	2.38±1.67	0.003

Blood Glucose Level (BGL), Diastolic Blood Pressure (DBP), High-Density Lipoprotein (HDL), Low-Density Lipoprotein (LDL), Systolic Blood Pressure (SBP), Total Cholesterol High-Density Lipoprotein Ratio (TCHDL), Waist Circumference (WC), Waist to Hip Ratio (WHR).

Nutrient Intake of Adolescents

The nutrient intakes are shown in Table 5. The result of the study shows that boys in the normal and obese groups did not meet their daily energy requirements, whereas obese girls were consuming more energy. Boys in the obese group were consuming low total fats compared to boys in the normal and overweight groups and girls in all groups who consumed more than the recommended daily total fats intake. Regarding total fibre, only obese boys did not meet the daily fibre intake. All groups were consuming more than the daily recommended intake for carbohydrates.

Table 5: Nutrients intakes of adolescents

Variables	Total (mean ±SD)	Boys (mean ±SD)					Girls (mean ±SD)				
		RDIs/AI/AMDRs	Normal (n=)	Overweight (n=)	Obese (n=)	p-value	RDIs/AI/AMDRs	Normal (n=)	Overweight (n=)	Obese (n=)	p-value
Energy (kj)	10470.05±6480.32	12552[a]	11114.66±5514.04	12594.25±4498.49	9100.02±3287.13	0.413	9205[a]	9968.92±7325.81	9290.67±3943.81	10676.59±7341.29	0.743
Total protein (g)	62.63±36.29	52[a]	66.31±32.71	74.69±2567	55.19±17.43	0.457	46[a]	60.01±40.03	57.99±24.74	62.01±40.02	0.921
Total fat (g)	49.79±28.28	20-35[c]	50.67±26.21	55.74±18.72	34.76±9.27	0.160	20-35[c]	48.74±26.27	42.89±16.42	55.43±43.48	0.245
Total trans FA (g)	1.39±1.32	-	1.31±1.41	1.54±1.65	0.98±0.67	0.700	-	1.44±1.27	1.20±0.96	1.52±1.44	0.655
Cholesterol (mg)	176.28±181.54	-	180.59±179.35	190.56±127.46	124.29±94.23	0.631	-	167.79±175.97	174.93±150.79	199.95±233.89	0.590
Total dietary fibre (g)	32.19±22.32	38[b]	35.09±18.56	43.83±20.78	30.90±12.48	0.363	26[b]	30.10±26.24	27.66±13.74	31.53±21.13	0.844
Carbohydrate, avail (g)	412.39±278.73	130[a]	442.49±230.59	501.49±205.22	373.98±151.95	0.524	130[a]	390.53±325.74	368.06±172.79	414.65±288.76	0.836
Added sugar (g)	27.09±27.23	-	24.99±26.48	39.27±35.59	10.89±7.22	0.101	-	28.62±24.72	29.66±35.54	28.06±33.91	0.978

a-Recommended Dietary Allowance (RDA), b- Adequate Intake (AI), c- Acceptable Macronutrients Distribution Range (AMDR)

Physical Activity

Majority of overweight and obese boys and girls led a sedentary lifestyle. The results show that the prevalence of a sedentary lifestyle was high in overweight and obese girls than in boys. At least a few of obese boys had a very active lifestyle as compared to girls (Figure 2).

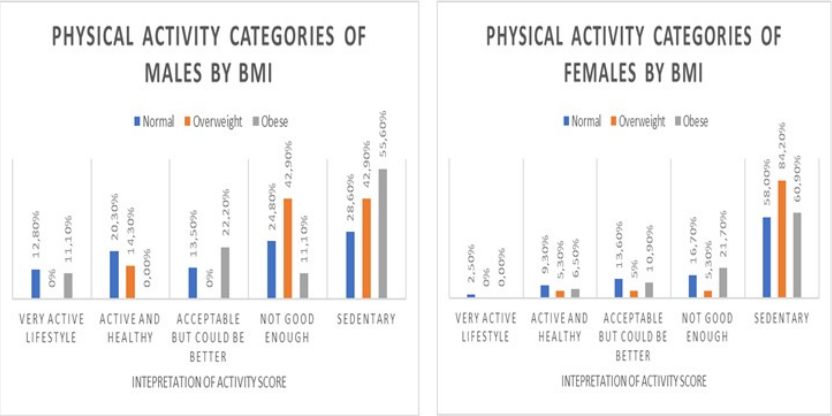

Figure 2: Physical activity categories of males and females by BMI. Physical activity

Determinants of Obesity

The determinants of obesity are shown in Table 4. Gender (female) (β=0.32, p=0.018, 95%CI); age (β=1.28, p=0.015, 95%CI); and source of income for parents who earn salary or wages (β=3.25, p=0.008, 95%CI) were associated with obesity.

Table 6: Determinants of obesity

Determinates	Unadjusted Odds ratio (OR)	Adjusted OR	95%-CI	p-value
Gender (female)	-1.145	0.32	(0.12-0.82)	0.018**
Age	0.246	1.28	(1.05-1.56)	0.015**
Source of Income (salary or wages)	1.180	3.25	(1.36-7.78)	0.008***
Moderate exercise	-0.946	0.39	(0.12-1.2)	0.107*
LDL	1.387	0.25	(0.09-0.67)	0.006***
HDL	-2.454	0.09	(0.02-0.34)	0.000***
TC/HDL	1.383	3.99	(2.17-7.31)	0.000***
Energy (KJ)	0.006	0.99	(0.99-1.00)	0.047**
Total fat (g)	0.217	1.24	(0.99-1.57)	0.067*
Total trans FA(g)	0.635	1.89	(1.04-3.43)	0.037**
Carbohydrate, avail. (g)	0.111	1.12	(1.00-1.25)	0.049**
Added sugar	0.022	0.98	(0.96-1.00)	0.063*

*** Highly significant (at alpha = 0.01), ** Significant (at alpha = 0.05), * Barely significant (at alpha=0.10)

Discussion

The aim of the study was to the aim of this study was to investigate environmental factors that drive obesity among rural adolescents in Vhembe district in Limpopo province, SA. The current study found associations between obesity and gender, age, source of income, moderate exercise, LDL, HDL, TC/HDL, energy, total fat (g), total trans FA, carbohydrates and added sugar.

The findings showed the prevalence of overweight/obesity to be 21.5%. The prevalence of overweight/obesity was lower than that of 35% reported in rural high schools in Limpopo province South Africa and that reported in the provincial dietary intake study conducted in Gauteng (overweight 27.7% vs obese 39.1%) and the Western Cape (overweight 20.4% vs obese 50.6%) [35, 36]. The prevalence was also lower than 27% of national among adolescents aged 15 to 19 years reported by UNICEF37. Although the prevalence in this study is lower than that of other studies, it is evident that overweight and obesity exists in the rural population [38].

The results of the study suggest that being female increased the odds of being obese. Studies tracking the determinants of obesity arrived at similar conclusions where it was reported being female was a determinant of obesity and females were twice likely to be obese than males [39, 40]. A possible explanation may be that female adolescents tend to have higher BMI because of rapid growth and early sexual maturity [41].

An increase in age was associated with the odds of being obese. Similarly, the study conducted in India reported that adolescents above 14 years and older had 2.09 times more odds of being obese [42]. Toriola et al. [23] and Shisana et al. [43] confirm that the prevalence of obesity increases with the age, peaking at age 12 years and declining thereafter. This may be due to the increase in adipose tissue and overall body weight in adolescents during puberty [44]. According to Kimani-Murage et al. [4], the risk of obesity increases with sexual maturation, indicating a higher risk as the adolescent transitions to adulthood.

In this study, obesity was associated with an increased source of income of the parents. The results of the study are consistent with the findings of Choukem et al.45 where high SES was strongly associated with obesity among children, with almost 2.5 times more likely to be obese than those with low SES. Concurrently a study conducted on Moroccan adolescents, reported that high family income was a determinant of obesity.46 Money gives children a certain degree of autonomy in purchasing and consumption some of which entail health risks such as smoking and substance abuse [47-50]. Studies from US, Europe, India, Korea and Vietnam suggest that pocket money is a potential risk factor for child's unhealthy eating and thus overweight and obesity [51].

The present study reveals that high TC, LDL, and low HDL were associated with obesity. Similarly, Ghomari-Boukhatem et al. [52] reported elevated TC, LDL-C, TG and low HDL-C as risk factors for obesity. Furthermore, a study conducted in the USA among children and adolescents shows that youth with obesity had a higher prevalence of high TC and low HDL-C than those with normal weight [53]. Bibilon et al. [54] stated that obese children were associated with the existence of at least one abnormal lipoprotein concentration. This association was expected since overweight and obese people are likely to eat a high-fat diet, and to have high cholesterol consequently. Tibazarwa et al. [55] found that obesity was associated with threefold increase hypercholesterolemia in Soweto.

Moderate exercise was associated with a decrease in obesity in this study. The results show that boys were more physically active than girls. These results support the increasing global trend towards sedentary lifestyle which leads to increased overweight/obese prevalence among children and adolescents [56]. The results suggest that low levels of physical activity could not impact on BMI. The activity levels peak at age 13-14 years and decrease thereafter [57]. The low activity levels place adolescents at high risk of obesity later in adulthood [57].

High consumption of energy, total fats, total trans fats, carbohydrates and added sugar were reported as determinants of obesity in the current study. Allioua et al.[58] also reported that high consumption of fats was associated with obesity among adolescents. A high energy intake is a major risk factor for obesity in children and adults [43]. In addition, high energy intake together with high total fats, high saturated fats, high carbohydrates, high added sugar and low fibre intake has been classified as western diet which contributes to the development of chronic diseases [43]. Studies show that a high intake of fats and sugar increases the risk of childhood obesity, as well as non-communicable diseases such as type 2 diabetes and CVD, later in life [59]. Adolescents are nutritionally vulnerable; they frequently make poor food choices [60]. Furthermore, school children spend more time at school and most vendors sell energy-dense food such as crisps, fat cakes, French fries, sweets, and carbonated sweet drinks [61]. Schools should have policies in place to prohibit vendor to sell such foods, this may reduce the prevalence of overweight/obesity.

Conclusion and Recommendations

The prevalence of obesity was 21.6% and it was higher in girls than boys. The determinants of obesity included age, gender, source of income of parents, LDL, low HDL, energy intake, Total trans fats, and carbohydrates. Majority of adolescents were living a sedentary lifestyle. The results found in this study confirm a trend that is seen in urban adolescents. Diet and lifestyle modification is recommended to reduce the onset of obesity among children and adolescents.

Department of Education, together with health professionals, and policymakers should develop a nutrition guide for food sold by vendors and revisit its school feeding scheme for optimal benefits. Nutrition education about healthy choices during childhood and adolescence should be given to parents during school parent meetings. The inclusion of the 60 minutes of physical activity should be included in the curriculum. There is a need to conduct more studies to address gaps in government intervention programmes in South Africa with a view to promoting adolescent health.

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Competing Interests

We have no competing interest to disclose.

Author's contribution

B.B. and S.M. Conceptualised the study. B.B. Data curation. B.B and S.M. analysed the data, wrote the draft, and approve final version.

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