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Is overweight and obesity associated with iron status in low-income men and women? A case study from Qwa-Qwa, South Africa

Oldewage-Theron WH, Egal AA and Grobler C

Centre of Sustainable Livelihoods, Vaal University of Technology, South Africa

Abstract

This study was conducted amongst rural households in Qwa-Qwa, SA. Previous research in the same community found that the community was impoverished, suffered from food insecurity and thus poor dietary intakes. However, the prevalence of overweight and obesity was 26.0% and 41.9% in women respectively. Both overweight and iron deficiency are risk factors leading to poor health and mortality and the double burden of overweight/obesity and iron deficiency continues to increase globally. The prevalence of iron status or the association between IDA and obesity has not been examined before in this community.The objective of this study was thus to determine the relationship between poor iron status and overweight or obesity in a low-income rural community in Qwa-Qwa, SA and the examination of the socio-demographic and dietary intake factors contributing to this double burden.

Introduction

Iron deficiency anaemia (IDA), defined as haemoglobin levels below the recommended thresholds, together with the presence of hypochromatic microcytosis [1], is regarded as one of the most common nutritional disorders globally and a public health problem in developed and developing countries [2] with a global prevalence of more than 30% [3]. It is estimated that 469 million women of reproductive age are anaemic globally with at least 50% as a result to dietary iron deficiency [1]. Iron deficiency has been associated with cognitive impairment [4] and with increased risk for cardiovascular disease and all-cause mortality [5] and can thus significantly affect the health and economy of developing countries through physical productivity losses [6]. The increasing prevalence of obesity is also a major global health concern. Despite obesity and IDA being at the opposite ends of the malnutrition scale [7], cross-sectional studies in developing countries have shown that obese people are more prone to risk of iron deficiency [8-10]. High serum ferritin levels is an accurate indicator for body iron stores in healthy individuals and serum ferritin, being an acute-phase reactant, is usually elevated when inflammation is present and thus often observed in the obese [10]. Obesity is thus associated with a chronic, low-grade inflammatory status and thus elevated ferritin levels [11]. Data, however limited, are available from small studies that showed that a chronic adiposity-related inflammation, rather than decreased dietary intake or increased iron requirements due to larger blood volume, may be the causative factor for IDA in obese respondents [8]. IDA in obese individuals thus may be caused by numerous factors, including low dietary iron intakes, poor iron bioavailability due to inflammation as well as impairment to the intestinal iron uptake [10].

South Africa (SA), a country in nutrition transition, is characterized by a "double burden of malnutrition" with under- and over-nutrition occurring in the same population, household or person [8,9]. In SA, the prevalence of IDA is 22.0% for women compared to 12.2% in males [12]. This is considered a mild public health problem [13] with informal urban and rural areas mostly affected. The prevalence of poor iron status, based on serum ferritin levels (<15 ng/ml), is 15.3% in women of productive age. The prevalence of overweight and obesity in SA is 24.8% and 39.2% for women and 20.1% and 10.6% for men respectively [12]. This study was conducted amongst rural households in Qwa-Qwa, SA. Previous research in the same community found that the community was impoverished, suffered from food insecurity and thus poor dietary intakes. However, the prevalence of overweight and obesity was 26.0% [14] and 41.9% in women respectively [15]. Both overweight and iron deficiency are risk factors leading to poor health and mortality and the double burden of overweight/obesity and iron deficiency continues to increase globally [16]. The prevalence of iron status or the association between IDA and obesity has not been examined before in this community. The objective of this study was thus to determine the relationship between poor iron status and overweight or obesity in a low-income rural community in Qwa-Qwa, SA and the examination of the socio-demographic and dietary intake factors contributing to this double burden.

Materials and methods

This study formed part of a cross-sectional, observational baseline survey study undertaken during 2008 and 2009 and the study protocol followed the guidelines laid down in the Declaration of Helsinki and the SA Medical Research Council [17]. All the procedures were approved

Correspondence to: Wilna H Oldewage-Theron PhD (Dietetics), Director for Centre of Sustainable Livelihoods, Vaal University of Technology, Private Bag X021, Vanderbijlpark 1900, South Africa; Tel: +27 16 930 5085; Fax: +27 86 612 8573, **E-mail:** wilna@vut.ac.za

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by the University of the Witwatersrand's Medical Ethics Committee for Research on Human Beings (M080931). Written informed consent was obtained from the respondents after an explanation of the objectives and study procedures.

Data were obtained from the baseline survey data for which a power calculation was used to determine a statistically representative sample size of 270 households [15]. However, exclusion criteria for this part of the study included conditions that could influence body iron stores, namely: reporting of haemorrhage in the preceding 6 months, iron supplementation during the previous year, blood donation in the preceding 6 months, alcohol consumption of more than 50 g/day. This resulted in a purposive sample size of 104 participants, including 20 men and 84 women.

Measurements

Data on age, marital status, education and employment level, as well as household size and the type and size of the house were collected by means of a validated socio-demographic questionnaire [18] completed by trained fieldworkers in one-on-one interviews with the respondents.

Iron status was determined using fasting (>8 hours) venous blood samples after sitting for 15 minutes, drawn by two nursing sisters and a haematologist at a community centre between 07H00 and 10H00 with a Vacutainer needle with minimal use of tourniquets. The blood was placed on ice until separation within two hours of blood collection. Serum was harvested by low-speed centrifugation at 4°C and aliquoted into individual tubes. Serum and plasma were stored at -80°C for two weeks. The biochemical analyses performed included: serum iron (colorimetric, Konelab™ Iron), ferritin (immunoturbidometric method, TOSOH AIA FERR), haemoglobin (Hb) (cyanmetHb-colorimetric method, Sysmex), haematocrit (Hct) (numeric integration, Sysmex), red blood cell count (RBC) (cell-counting auto analyser, Sysmex), mean cell volume (MCV) (optic detection, Sysmex), transferrin (immunoprecipitation, Konelab™) and high-sensitivity C-reactive protein (HS–CRP) (immunoprecipitation, Konelab™). Iron deficiency was defined as having low serum iron, ferritin, transferrin and MCV concentrations and iron deficiency anaemia was defined as low levels of all iron status parameters as well as low Hb levels [19].

A four-stage, multiple-pass interviewing procedure described by Gibson was used for the 24-hour recall questionnaire data collection over a period of two week days and one weekend day [20]. Trained fieldworkers completed the 24-hour recall questionnaires in a one-on-one interview and used food models and household measuring tools (cups, plates, spoons) to assist the respondents in estimating portion sizes. Dietary intake data were analyzed by a registered dietician using the FoodFinder® version 3 software program, developed by the Medical Research Council and based on the SA food composition tables [21]. The mean nutrient intakes of the three days was calculated for total mean energy intakes (kJ/day), total protein intakes (g/day), total iron, haem and non-haem iron (mg/day) and vitamin C (mg/day).

Anthropometric measurements included body weight and height, measured according to standard procedures [22] with a calibrated Philips electronic scale, model HF350 (135 kg/100g) and a Scales 2000 stadiometer respectively. All measurements were taken twice and the average of the two measurements recorded. Body mass index (BMI) was calculated using weight (kg) divided by height squared (m^2) and categorized according to the WHO cut-off points [23]. Waist measurements were taken with a Seca inflexible tape at the umbilicus level whilst standing erect with the abdomen relaxed, feet together and arms relaxed at the side [20]. Two measurements were taken and increased risk was identified at above 88 cm and 102 cm for women and men respectively [20].

Data were analyzed on the Statistical Package for Social Sciences (*SPSS)*, version 22.0. Measured body mass index (BMI) was used to categorize the respondents into underweight (BMI<18.5 kg/m^2), normal weight (≥18.5<25 kg/m^2), overweight (≥25<30 kg/m^2) and obese (≥30 kg/m^2) groups [23]. The Shapiro-Wilk test of normality was used to determine the normal distribution of all variables. Only age, anthropometric and biochemical variables were normally distributed. The socio-demographic data were analyzed for descriptive statistics (frequencies). Descriptive statistics were determined for the different BMI groups (means and standard deviations [SDs] for the normally distributed data and medians for the non-normally distributed data), and a two-tailed independent t-test was conducted to determine significant differences ($p<0.05$) between the groups. Analysis of variance (ANOVA) were used to determine significant differences ($p<0.05$) within the groups. Pearson correlations were used to determine significant relationships between dietary intake and BMI with haematological and biochemical parameters, as well as between the various haematological and biochemical parameters. Only significant relationships are reported in the results.

Six types of double burden of malnutrition in an individual were considered for the analyses. These were the co-existence of (1) overweight with IDA, (2) overweight with ID, (3) obesity with IDA, (4) obesity with ID, (5) high risk of abdominal obesity (waist > 88 cm in women and 102 cm in men respectively) with IDA, and (6) high risk of abdominal obesity with ID. However, due to the absence of IDA in the sample, only the results for the co-existence of ID with overweight, obesity and high risk of abdominal obesity (waist > 88 cm in women and 102 cm in men respectively) are reported respectively.

None of the socio-demographic variables were normally distributed and the log transformation was carried out before linear regression was used to determine the odds ratios for the assessment of associations between the socio-demographic factors and the subject-level binary health outcomes for the six types of double burden.

Results

The mean ± SD age of the respondents was 39.8 ± 13.5 years for the total group with the women (40.5 ± 13.2) being older than the men (36.2 ± 14.9). The socio-demographic results showed that the majority of the respondents were single (including divorced and widowed) (55.1%) and lived in brick houses (82.9%) with three or more rooms (83.5%). A small percentage (12.4%) of the respondents did not attend school whereas 28.3 and 53.1 attended primary and secondary school respectively. Only 21.3% and 6.4% had a regular monthly income being employed and on pension respectively with 80.6% having a monthly household of less than ZAR1500. Most of the respondents indicated that they always (21.2%), often (16.8%) and sometimes (40.7%) did not have enough money to procure food, however, 90.6% of the respondents had a household vegetable garden and the majority consumed the vegetables (93.6%) and 0.8% preserved the vegetables for future use.

Only one woman was underweight and thus the underweight category for women was not reported. The anthropometric results showed 27.4% (n=23) of the women had normal weight whereas 29.8% (n=25) and 41.7% (n=35) were overweight and obese respectively. A small percentage of the men were obese (n=2, 10.0%) and overweight

Table 1. Socio-demographic indicators of the respondents.

Parameter	Percentage (%)
Marital status:	
Single	30.8
Married	44.9
Widowed	20.6
Divorced	3.7
Type of house:	
Brick	82.6
Clay	6.1
Grass	1.7
Zinc/shack	7.8
Other	1.7
Number of rooms in house:	
<2	16.5
3-4	33.9
>4	49.6
Employment status:	
Permanent fulltime	6.4
Permanent part-time	5.3
Unemployed	72.3
Retired	6.4
Self-employed	9.6
Monthly household income:	
<ZAR500	28.2
ZAR501-1000	22.3
ZAR1001-1500	30.1
ZAR1501-2000	6.8
ZAR2001-2500	2.9
>ZAR2500	9.7
Education:	
None	12.4
Primary School	28.3
Secondary School	53.1
College	4.4
Other Post School	1.8
Food security (frequency of money shortage to buy food):	
Always	21.2
Often	16.8
Sometimes	40.7
Seldom	12.4
Never	8.0
Presence of a household vegetable garden	90.6
Use of vegetables:	
Household consumption	93.6
Selling	2.4
Preserving for future use	0.8
Donate to other people	3.2
Smoking	23.6
Partner smoking	34.8

(n=3, 15.0%) respectively with 45.0% (n=9) being of normal weight and 30.0% (n=6) underweight (Table 1). The waist circumference significantly (p=0.000) increased progressively with higher BMI in both genders. The results in Table 1 show that significant differences were observed for weight (p=0.000) and BMI (p=0.000) in the different BMI groups for both the men and women. The women's age significantly (p=0.004) increased progressively with higher BMI. No significant differences were observed in the men's age in the different BMI groups.

The results in Table 2 showed that the mean HS–CRP levels increased progressively with higher BMI in both genders and statistically significant higher levels (p=0.010) were observed in the overweight and obese categories of the women. No significant differences were observed in any of the mean serum iron status parameters between the BMI categories, except for the transferrin levels that decreased progressively with increased BMI in the women (p=0.017). Most of the serum iron parameters showed normal mean levels across all the BMI groups except for the haematocrit and red blood cell count with marginal mean levels in the men, but these were not significant.

Seventeen (17.1) percent of the respondents had iron deficiency based on the serum iron, ferritin, transferrin and MVC levels with no respondents with IDA (low serum iron, ferritin, transferrin, MCV and Hb levels combined). Regarding the double burden of malnutrition, 1.9% of the respondents presented with both ID and overweight. In the obese category, 6.7% of the respondents were iron deficient. Regarding the high risk of abdominal obesity with ID, 8.7% presented with a double burden of malnutrition.

The nutrient intakes are presented in Table 3. The women showed consistently higher dietary fibre, iron and vitamin C intakes than the men although in both genders total energy intakes were low compared to the estimated energy requirements of 9001 kJ and 8070 kJ for healthy moderately active women and men (aged 31-50 years) , respectively [26]. Using the estimated average requirements (EAR), the total energy, dietary fibre [26], iron [27] and vitamin C [28] intakes were low for both genders whereas total protein intake was also low for both genders except for the men in the normal and obese group, but due to the small sample size in these two groups, the data may be skewed. No significant differences were observed in nutrient intakes between the BMI categories of both men and women (Table 3).

A significant positive relationship was observed between BMI and HS–CRP levels (r=0.347, p=0.000) at the 0.01 level (99% confidence level). No significant relationships existed between BMI and the iron status parameters and dietary intake or between the iron status parameters and dietary intakes. However, a significant positive relationship was found between BMI and age (r=0.235, p=0.020).

The regression analysis carried out on the socio-demographic predictors of the double burden of disease showed that age was a predictor for the double burden in all cases except in the double burden of obesity and ID. Most of the variables were predictors of the double burden of abdominal adiposity, whereas a few variables predicted the double burden of obesity with ID. Being married was a predictor for all types of double burden and showed that being married is a positive predictor of ID and overweight and obesity respectively. However, being married is a negative predictor for the double burden of high risk of abdominal adiposity with ID. Staying in a brick house did not predict the double burden, but other types of housing predicted the double burden of overweight and ID as well as the high risk of abdominal adiposity with ID negatively. Being employed was a predictor of the high risk of abdominal adiposity with ID and an income of more than ZAR2000 per month negatively predicted overweight and ID, as well as high risk of abdominal adiposity with ID. Most of the socio-demographic variables were predictors for high risk of abdominal adiposity with ID, except for staying in a brick house, a house with less than four rooms, being unemployed, secondary school education, and a monthly household income of less than ZAR2000. Food insecurity and the presence of a vegetable garden at the household did not predict this double burden (Table 4).

Haem iron intake was a predictor for all the other types of double burden whereas the intake of animal protein, dietary fibre, non-haem

Table 2. Comparison of different BMI categories of all participants with respect to median levels of biochemical and haematological parameters.

Biochemical Parameters	Normal values	Women (n=84)			Men (n=20)				
		BMI (kg/m²)			BMI (kg/m²)				
		≥18.5 <25 mean ± SD n=23 (27.4%)	≥25 <30 mean ± SD n=25 (29.8%)	≥30 mean ± SD n=35 (41.7%)	<18.5 mean ± SD n=6 (30.0%)	≥18.5 <25 mean ± SD n=9 (45.0%)	≥25 <30 mean ± SD n=3 (15.0%)	≥30 mean ± SD n=2 (10.0%)	Significant difference between BMI categories *p*
HS–CRP	< 3 mg/l [24]	3.1 ± 3.6	4.9 ± 3.8	7.7 ± 4.4	7.3 ± 5.8	4.8 ± 4.8	7.5 ± 4.0	11.8 ± 1.1	0.001 (w) 0.348 (m)
Serum iron	11.6-31.3 μmol/l (m) 9.0-30.4 μmol/l (w) [25]	21.2 ± 8.9	26.7 ± 6.6	26.0 ± 12.6	23.2 ± 9.4	26.1 ± 11.4	24.7 ± 3.0	34.3 ± 12.8	0.231 (w) 0.611 (m)
Transferrin	2.0-3.6 g/l [25]	3.0 ± 0.8	2.9 ± 0.5	2.7 ± 0.6	3.5 ± 0.7	3.0 ± 0.7	2.6 ± 0.2	2.4 ± 0.1	0.547 (w) 0.111 (m)
Ferritin	18-250 ng/ml (m) 12-160 ng/ml (w) [25]	36.4 ± 25.8	97.9 ± 107.5	69.9 ± 38.5	176.6 ± 263.4	117.5 ± 65.7	91.8 ± 96.8	100.4 ± 133.3	0.017 (w) 0.862 (m)
Hb	13.5-17.5 g/dl (m) 11.5-15.5 g/dl (w) [24]	15.9 ± 4.1	14.9 ± 3.7	14.0 ± 2.4	14.0 ± 0.8	14.8 ± 1.1	15.1 ± 5.5	13.3 ± 3.4	0.272 (w) 0.501 (m)
Haematocrit	40-52% (m) 36-48% (w) [24]	45.0 ± 12.2	44.0 ± 10.7	41.6 ± 7.1	42.0 ± 2.6	44.9 ± 3.8	45.8 ± 13.2	39.9 ± 7.3	0.296 (w) 0.493 (m)
RBC	4.5-6.5 [24]	5.4 ± 1.6	4.8 ± 1.0	4.7 ± 0.8	4.8 ± 0.3	5.1 ± 0.5	4.9 ± 0.4	4.5 ± 0.7	0.192 (w) 0.563 (m)
MCV	80-95 fl [24]	87.9 ± 6.5	90.6 ± 4.1	88.6 ± 5.7	87.0 ± 2.6	88.0 ± 2.6	94.0 ± 2.5	89.0 ± 1.6	0.416 (w) 0.285 (m)

w=women, m=men

SD=standard deviation

Table 3. Comparison of different BMI categories of all participants with respect to mean nutrient intake levels.

Dietary intake variable	Women (n=84)			Men (n=20)					
	BMI (kg/m²)			BMI (kg/m²)					
	≥18.5 <25 Median (25th, 75th percentile) n=23 (27.4%)	≥25 <30 Median (25th, 75th percentile) n=25 (29.8%)	≥30 Median (25th, 75th percentile) n=35 (41.7%)	<18.5 Median (25th, 75th percentile) n=6 (30.0%)	≥18.5 <25 Median (25th, 75th percentile) n=9 (45.0%)	≥25 <30 Median (25th, 75th percentile) n=3 (15.0%)	≥30 Median (25th, 50th percentile) n=2 (10.0%)	EAR* [26-28]	Significant difference between BMI categories *p*
Total energy (kJ)	4416 (2483; 6327)	3455 (2242; 5406)	2960 (2506; 4589)	3191 (2207; 5406)	4672 (3234; 5622)	4314 (3862; 4314)	3590 (2639; 3590)	9001(w)/ 8070 (m) EER†	0.591 (w) 0.747 (m)
Total protein (g)	35 (19; 47)	27 (20; 53)	37 (19; 57)	31 (15; 44)	42 (34; 77)	35 (33; 35)	70 (38; 70)	49 (w)/41 (m)	0.914 (w) 0.286 (m)
Plant protein (g)	19 (13; 28)	15 (8; 21)	16 (9; 19)	15 (10; 20)	18 (10; 27)	10 (8; 11)	7 (6; 7)		0.238 (w) 0.350 (m)
Animal protein (g)	16 (0; 27)	12 (2; 46)	21 (3; 32)	16 (1; 30)	24 (0; 63)	25 (7; 25)	63 (30; 63)		0.433 (w) 0.347 (m)
Dietary fibre (g)	11 (7; 18)	8 (5; 13)	9 (4; 14)	8 (4; 10)	6 (5; 21)	4 (4; 4)	4 (4; 4)	23 (w)/31 (m)‡	0.408 (w) 0.456 (m)
Iron	5.9 (3.9; 9.4)	5.5 (4.1; 7.9)	6.3 (4.6; 8.6)	4.0 (2.7; 6.8)	5.9 (3.2; 10.4)	4.4 (2.6; 4.4)	5.1 (4.3; 5.1)	8.1 (w)/6.0 (m)	0.364 (w) 0.502 (m)
Haem Iron	1.4 0.0; 1.1)	2.2 (0.0; 1.8)	4.9 (0.0; 0.4)	2.4 (0.0; 0.8)	4.2 (0.0; 1.0)	3.5 (0.0; 0.6)	2.7 (1.0 ; 1.0)		0.755 (w) 0.806 (m)
Non-haem iron	4.5 (1.0; 2.9)	3.5 (0.9; 3.0)	1.4 (0.9; 2.4)	1.6 (0.3 ; 4.0)	1.7 (0.7 ; 4.3)	0.9 (0.0 ; 0.9)	2.4 (2.0 ; 2.4)		0.867 (w) 0.839 (m)
Vitamin C	15.6 (8.8; 39.4)	16.0 (4.9; 23.7)	12.0 (4.6; 21.0)	11.4 (2.8; 23.4)	5.5 (1.5; 16.2)	0.4 (0.0; 0.4)	27.0 (18.0; 27.0)	60 (w)/75 (m)	0.736 (w) 0.101 (m)

*Estimated Average Requirement (EAR) [26-28] for women and men aged 31-50 [26-28]

†Estimated energy requirements (EER) for women were calculated based on mean ± SD age for the women (40.5 ± 13.2 years), mean ± SD height and weight 1.6 ± 0.1 m and 74.1 ± 16.6 kg respectively and moderate activity levels. The EER of 9001kJ was thus calculated as 448 - (7.95 x age [40.5]) + Physical Activity Level (PAL) for low active [1.5] x (11.4 x weight [74.1] x height [1.6]) x 4.18 kJ [26]. Estimated energy requirements (EER) for men were calculated based on mean ± SD age for the men (36.2 ± 14.9 years), mean ± SD height and weight 1.7 ± 0.1 m and 60.9 ± 12.9 kg respectively and moderate activity levels. The EER of 8070 kJ was thus calculated as 448 - (7.95 x age [36.2]) + PAL for low active [1.5] x (11.4 x weight [60.9] x height [1.7]) x 4.18 kJ [26].

‡ Adequate intake (AI) where no EAR available [26-28]

m=men, w = women

Table 4. Significant socio-demographic associations between subject-level double burden of overweight, obesity and high risk of abdominal adiposity with ID.

Variable	Double burden of overweight and ID (n=2, 1.9%) (R^2=1.000, p=0.000)		Double burden of obesity and ID (n=7, 6.7%) (R^2=1.000, p=0.000)		Double burden of high risk of abdominal adiposity and ID (n=9, 8.7%) (R^2=0.661, p=0.000)	
	OR	95% CI	OR	95% CI	OR	95% CI
Age	0.015	0.015;0.015	-	-	0.015	-0.009;0.039
Married	0.088	0.088;0.088	1.000	1.000;1.000	0.017	-0.885;0.919
Single	–	–	1.000	1.000;1.000	-0.253	-1.182;0.676
Brick house	–	–	–	–	–	–
Other house	-0.279	-0.279;-0.279	–	–	-0.141	-0.600;0.319
≥ 4 rooms	-0.103	-0.103;-0.103	–	–	0.002	-0.344; 0.349
< 4 rooms	–	–	–	–		
Employed	–	–	–	–	0.035	-0.354;0.424
Not employed	0.265	0.265;0.265	–	–	–	–
Presence of vegetable garden	–	–	–	–	–	–
No education	–	–	–	–	0.019	-0.664;0.702
Primary school education	0.294	0.294;0.294	–	–	-0.054	-0.632;0.524
Secondary school education	0.382	0.382;0.382	–	–	–	–
College education	–	–	–	–	0.269	-0.944;1.483
Other post school education	–	–	–	–	-0.276	-1.563;1.012
Income <ZAR2000	–	–	–	–	–	–
Income ≥ ZAR2000	-0.206	-0.206;-0.206	–	–	-0.221	-0.847;0.405
Food secure	–	–	–	–	0.162	-0.171;0.495
Food insecure	–	–	–	–	–	–

- Not significant predictors

Table 5. Significant dietary intake associations between subject-level double burden of overweight, obesity and high risk of abdominal adiposity with ID.

Dietary intake predictors	Double burden of overweight and ID (R^2=1.000, p=0.000)		Double burden of obesity and ID (R^2=1.000, p=0.000)		Double burden of high risk of abdominal adiposity and ID (R^2=0.700, p=0.002)	
	OR	95% CI	OR	95% CI	OR	95% CI
Total energy	–	–	0.198	0.162;0.235	1.249	0.017;2.481
Total protein	–	–	–	–	-4.415	-8.465;-0.365
Plant protein	–	–	0.164	0.025;0.303	-0.750	-2.933;1.433
Animal protein	0.163	0.163;0.163	0.047	0.032;0.127	2.327	0.016;4.638
Total fat	–	–	0.024	0.022;0.070	-0.389	-0.914;0.136
Total COH	–	–	–	–	-0.089	-1.822;1.645
Dietary fibre	0.001	0.001;0.001	0.043	0.033;0.119	0.856	-0.256;1.967
Iron	–	–	0.013	-0.094;0.069	0.697	-0.440;1.833
Haem iron	0.578	0.578;0.578	0.022	-0.010;0.053	0.102	-0.363;0.568
Non-haem iron	0.219	0.219;0.219	0.024	-0.111;0.063	-0.582	-1.290;0.125
Vitamin C	0.159	0.159;0.159	0.005	-0.020;0.010	0.018	-0.163;0.198

- Not significant predictors

iron and vitamin C are predictors for the double burden of overweight, obesity as well as the double burden of high risk of abdominal adiposity and ID respectively. Most of the dietary intake variables predicted the double burden with ID (Table 5).

Discussion

The results showed that this was a resource-poor rural community as reflected by the low income and employment rates resulting in most of the households regularly not having enough money for food despite most having a household vegetable garden. Food insecurity was thus a problem in this community. This finding is consistent with the SANHANES that reported the highest prevalence of food security occurring in the black African race group of SA [12]. This was reflected in the poor nutrient intakes of both genders, especially of vitamin C and dietary iron. Dietary intakes were similar across the BMI categories of both men and women, except for total energy, dietary fibre, non-haem iron and vitamin C intakes that decreased and haem iron intakes increased progressively across the BMI categories for the women. Similar trends were observed in the men with animal protein and dietary fibre intakes decreasing progressively across the BMI categories. Furthermore, no significant differences across the BMI categories or between men and women were observed. These results were similar to those observed in a study conducted in Mexican women [8]. Similarly to the Mexican study, lower energy intakes were reported in the overweight and obese women than in the normal weight women, however, the same was not observed in the men. No significant relationships between the dietary intake variables and iron status parameters were observed and it can thus not be concluded that the poor dietary intakes were responsible for the poor iron status in this community.

In South Africa, due to the nutrition transition, the face of malnutrition is changing [29]. Research has also shown that both hunger and obesity are co-existing within the same household [30]. This is especially true for low-income households. Furthermore, obesity is often associated with low income and education levels, especially among women [31]. The anthropometric results showed that 29.8% and 41.7% of the women were overweight and obese respectively compared to a small percentage of the men being overweight (15.0%) and obese (10.0%) respectively. This was consistent with the SANHANES that reported a significantly lower BMI and prevalence of overweight and obesity compared to women [12]. The waist circumference significantly increased progressively with higher BMI. The overweight and obese women were significantly older than the normal weight respondents, however, no significant difference were observed in the age of the men in the different BMI groups of the men.

With regard to iron status, iron deficiency was prevalent with no IDA and thus the double burden of malnutrition with iron deficiency combined with overweight, obesity and high risk of abdominal adiposity was mainly observed in both the men and women. These results exemplified the occurrence of double burden of disease in this resource-poor rural community. A study conducted in Moroccan and Tunisian women showed a much higher prevalence of overweight and obesity with both ID and IDA respectively [16]. Furthermore, the results of this study contradict the national IDA prevalence rate of 22.0% for women and 12.2% for men [12]. This study was conducted in Qwa-Qwa, a mountainous rural area in the Free State of SA. The absence of IDA and the normal mean haemoglobin levels may be the result of the altitude where the respondents reside as haemoglobin concentrations usually increase as a result of adapting to the lower partial oxygen pressure and reduced oxygen saturation of the blood at higher altitudes resulting in an increased red blood cell production to ensure a sufficient oxygen supply to the body tissues [32]. It has recently been found that obesity is associated with chronic, low-grade systemic inflammation which may be associated with IDA [33]. In this study, higher HS–CRP levels were observed in the overweight and obese categories of both women and men. Furthermore, the positive relationship between HS–CRP and BMI indicated chronic inflammation in the higher BMI groups, which is consistent with recent research developments [8,33]. No direct significant relationship between BMI and the iron status parameters were observed. However, both the anthropometric and iron status results confirm that SA, a country in nutrition transition, is consistently characterized by a "double burden of malnutrition" with under- and over-nutrition not only occurring in the same population [8,9], but also in the same individuals. Although no significant relationships existed between the dietary intakes with BMI and iron status parameters, this phenomenon could be explained by a sedentary lifestyle as well as the intake of high energy-dense, poor micronutrient-rich foods or the low intake of micronutrient-rich foods. A carbohydrate-rich diet, based on staples, with low intakes of vegetables and fruit had been observed in this community [15]. Although the total energy intakes were low in both the men and women, a high prevalence of overweight and obesity was observed. Hunger and obesity can exist within the same household [30,34], especially in low-income households, as was found in this community. Furthermore, evidence exists for higher obesity rates being associated with low incomes and low education levels, particularly among women [31]. The observed low median energy intake in this study, the 'food acquisition cycle' proposed by Townsend, Peerson, Love, Achterberg and Murphy [35], may explain the observations in this community more appropriately. Food insecure families overeat when food is plentiful or when money for food is available, which is usually followed by a short period of involuntary food restriction when money is in short supply. This is again followed by overeating, which could be a pattern that results in gradual weight gain over time. However, most of the dietary intake variables predicted the double burden with ID whereas the presence of food insecurity and the presence of a vegetable garden at the household did not predict this double burden in this community. A significant positive relationship was found between BMI and age and concomitantly age was also found to be a predictor of the double burden of disease.

Regarding the socio-economic factors, marital status was associated with the co-existence of ID and overweight and obesity respectively. The co-existence of ID and risk of abdominal obesity was positively associated with employment which could be because employed people may consume more energy-dense meals outside the house. A higher income was negatively associated with the double burden of ID and risk of abdominal obesity. One explanation for this is the effect of prices and income on food choices and dietary intake patterns as the consumption of energy-dense foods and energy dense diets is often an important coping strategy used by low-income consumers to stretch the food budget [36]. Higher incomes can thus result in better food choices such as micronutrient-rich foods like vegetables and fruit as well as more expensive protein sources.

It can be concluded that poor iron status well as overweight and obesity are challenges in this resource-poor community. This study confirmed the prevalence of the double burden of disease that is a characteristic of a country in nutritional transition such as SA. HS–CRP was positively associated with BMI, thus inflammation was associated with overweight and obesity in this study. A relationship between obesity-related chronic, low-grade inflammation and poor iron status have been found in adults [8,33], specifically women [3,9] as well as children [8,9], but the significance of this study is that this relationship was also confirmed for black adults in a resource-poor community in SA. A limitation was the small sample size of the men and the results for the men can thus not be generalized.

It has been reported that a nutritional intervention such as dietary diversification is the optimal solution for addressing poor iron status, but poverty and dietary preferences of people remain the main barriers to this approach [37]. Furthermore, the increasing prevalence of obesity globally is also recognized as a major public health concern [3]. It is recommended that sustainable intervention studies to address poor dietary diversity, such as nutrition education to educate people on affordable, nutrient-dense food choices, be implemented through the strengthening of existing vegetable gardens with micronutrient rich cultivars and promoting the recently reviewed food-based dietary guidelines. Further research is needed to explore the association between obesity and iron status in the elderly as well as the potential cause and effect mechanisms for this relationship [33].

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