ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
Issue: *Adolescent Women's Nutritional Status*
ORIGINAL ARTICLE

The impact of sociodemography, diet, and body size on serum retinol in women 16–35 years of age: SANHANES-1

Whadi-ah Parker,[1] Zandile J. Mchiza,[1] Ronel Sewpaul,[1] Nophiwe Job,[1] Lumbwe Chola,[2] Moses Sithole,[3] and Demetre Labadarios[1]

[1]Population Health, Health Systems and Innovation, Human Sciences Research Council, Cape Town, South Africa. [2]PRICELESS SA, University of Witwatersrand School of Public Health, Parktown, South Africa. [3]Centre for Science, Technology and Innovation Indicators, Human Sciences Research Council, Cape Town, South Africa

Address for correspondence: Whadi-ah Parker, Population Health, Health Systems and Innovation, Human Sciences Research Council, 3rd Floor Merchant House, 116–118 Buitengracht Street, Cape Town 8001, South Africa. wparker@hsrc.ac.za

To determine the current vitamin A status of a nationally representative sample of women aged 16–35 years, compare it with previous national data, and determine the impact of sociodemography, diet, and body size on vitamin A status, we performed secondary analysis of data on South African women who participated in the first South African National Health and Nutrition Examination Survey (SANHANES-1). Vitamin A status was assessed by serum retinol, and the findings are reported as means and prevalences with corresponding 95% confidence intervals. Overall, the age-standardized vitamin A deficiency prevalence was 11.7%, a decrease from previous national data, but serum retinol levels remained lower than in other developing countries. Overall, unweighted, multilevel, multivariate logistic regression showed that vitamin A deficiency was influenced by race only (odds ratio (OR) = 1.89, $P = 0.031$), while weighted multiple logistic regression for 16- to 18-year-olds showed that vitamin A deficiency was influenced by locality (OR = 9.83, $P = 0.005$) and household income (intermediate (OR = 0.2, $P = 0.022$) and upper (OR = 0.25, $P = 0.049$)). Despite the decreased prevalence, vitamin A deficiency remains a moderate public health problem in the country. Opportunities for targeted interventions have been identified.

Keywords: vitamin A deficiency; serum retinol; SANHANES-1; women; South Africa

Introduction

Vitamin A is an essential nutrient that can only be obtained through dietary intake. Foods high in vitamin A include liver, milk, cheese, eggs, green leafy vegetables, and orange/yellow vegetables and fruits or food products fortified with vitamin A. A habitually inadequate dietary intake or impaired absorption results in vitamin A deficiency (VAD).[1,2]

VAD is one of the leading nutrition-associated public health problems affecting the health and survival of children aged 0–5 years and pregnant/lactating women in low-income countries, specifically in communities where poverty, unemployment, and civil unrest are rife.[3,4] Strong evidence suggests that VAD is less common in nonpregnant women, since they are capable of storing up to 1 year's supply of vitamin A in their liver.[5] Hence, the majority of studies on vitamin A status tend to focus on children and pregnant women.

Among others, the markers used for estimating VAD globally by the World Health Organization (WHO) in 2009 were night blindness and a serum retinol concentration of less than 0.70 μmol/L. The WHO estimated that the overall prevalence of night blindness in women and children at risk of VAD was 7.8% (9.8 million) and 0.9% (5.2 million), respectively, while the prevalence of low serum retinol was 15.3% in pregnant women (19.1 million) and 33.3% in children under the age of 5 years (190 million).[3]

The regions most affected by VAD were Africa and Southeast Asia.[3,6] Children who resided in Africa experienced a higher prevalence of night blindness than children in Asia (2.0% (2.55 million) compared with 0.5% (1.01 million)), while children in Asia experienced a higher prevalence of low serum retinol (49.9% (91.5 million)) compared with those in Africa (44.4% (56.4 million)).[3] There

doi: 10.1111/nyas.13504

appears to be an almost equal spread among pregnant women who experience night blindness in both regions (9.8% (3.02 million) in Africa and 9.9% (3.84 million) in Asia), while pregnant women in Asia are more likely to experience low serum retinol (17.3% (6.69 million)) compared with those in Africa (13.5% (4.18 million)).[3]

Since serum retinol is homeostatically controlled, it is not necessarily an efficient marker of vitamin A intake or clinical VAD.[7] However, the percentage of individuals who have a serum retinol concentration below 0.70 μmol/L within a given population provides significant insight into the severity of VAD as a public health problem.[8] On this basis, the WHO estimated that 88 countries had a moderate-to-severe public health problem of VAD in pregnant women, and 102 countries met this criterion for VAD in children under 5 years of age in 2009.[3] However, there has been a considerable decrease in the global prevalence of VAD since the 1990s, such that VAD is no longer rated as one of the top 20 leading risk factors for mortality.[9]

A modest reduction in VAD prevalence has also been observed in South Africa, and recent reviews[10,11] associate this decrease with the initiatives implemented by the South African government since the early 2000s. Some of these initiatives include the Integrated Nutrition Programme (INP),[12] a comprehensive nutrition strategy that includes a national vitamin A supplementation (VAS) program for children 6 months–5 years of age and postpartum women. However, the efficacy of VAS in adults was questioned, as there was no evidence that VAS was beneficial in reducing maternal and infant morbidity and mortality.[13] It is therefore important to note that South Africa adopted the WHO recommendation and stopped VAS for postpartum women in 2011.[13,14] Results from the ObaapaVitA trial in rural Ghana corroborated the evidence that low-dose VAS does not have a beneficial effect on reducing mortality in women of reproductive age.[15] Nevertheless, other important interventions that form part of the INP that have shown promise in reducing nutrient deficiencies in the country are the Food Fortification Programme (FFP),[16] a compulsory government initiative that mandates millers to fortify staple foods (such as the maize meal and flour) with essential nutrients including vitamin A, and the National School Nutrition Programme,[17] a state-funded nutritional program that delivers cooked breakfast or lunch consisting of a starch, a protein, and a vegetable to all quintile 1–3 primary schools nationally. After undertaking research on the burden of disease attributed to vitamin A in South Africa in the year 2000, Nojilana *et al.* supported the notion that the FFP will also contribute to the reduction in the morbidity and mortality associated with VAD in South Africa.[18]

Aside from nutrition interventions, other government interventions, such as social grants (old-age pensions, disability grants, foster-care grants, care-dependency grants, and child-support grants), have been shown to increase women's purchasing power as well as their access to food, thereby contributing to the reduction in food insecurity.[19] The number of beneficiaries receiving social grants has increased sixfold over a period of 20 years, from 2.7 million in 1994 to more than 16 million in 2014.[20] Despite this remarkable achievement, not all South Africans who qualify for these grants are able to access them and are therefore still food insecure.[21]

There is also a growing body of knowledge that suggests that the coexistence of poor diets and infections is common in VAD populations.[3] Indeed, studies conducted in sub-Saharan Africa in the 1990s provided evidence that VAD is more prevalent among HIV and tuberculosis (TB) patients and HIV^+ mothers.[22–33] Furthermore, serum retinol is shown to be affected by several other factors, including retinol-binding protein (RBP) synthesis in the liver; nutritional status; the levels of other nutrients, such as zinc and iron; and body mass index (BMI).[34–36] Studies have also shown that an increase in parity and prolonged lactation increased the risk of VAD.[35] Parity also influences BMI status,[37] which in turn influences VAD.[38,39] Kimmons *et al.* showed that premenopausal women who were overweight or obese were more likely to have micronutrient deficiencies, including VAD.[36] Vitamin A status is influenced by dietary intake—specifically fruit and vegetable intake; however, this statement is not generalizable, as dietary intake is known to be associated with sociodemographic status.[40,41]

South Africa has one of the highest burdens of HIV/AIDS and TB, and as such those affected by these conditions are prone to micronutrient malnutrition as a result of malabsorption of micronutrients.[42] There is a dearth of data on the

vitamin A status of nonpregnant women of reproductive age globally, especially in Africa. While localized studies on VAD have been conducted in South Africa between 1999 and 2005,[43–47] no new national data have been reported since 2005. For instance, despite the available national data on vitamin A status in South Africa,important as they are in mapping the landscape of the nutritional status of South Africans in relation to VAD, such data are limited to children under the age of 9 years and women aged 16–35 years.[4,48,49] The first national data on VAD for South Africa were provided by the South African Vitamin A Consultative Group (SAVACG) study in 1995, which estimated that 33.3% of children under 6 years of age had VAD. The 1999 National Food Consumption Survey (NFCS) indicated that on average 50% of children had a vitamin A intake of less than two-thirds of the recommended daily allowance.[48] The 2005 National Food Consumption Survey Fortification Baseline (NFCS-FB) provided the first national data on the prevalence of VAD (27.2%) in women of reproductive age (defined as women aged 16–35 years).[49] The results of the first South African National Health and Nutrition Examination Survey (SANHANES-1)[50] therefore provide more recent data on the prevalence of VAD in both children and nonpregnant women aged 16–35 years. The outcomes of this survey showed that VAD had decreased in children from 63.6% to 43.6% and in women from 27.2% to 13.3%.[49,50]

The aims of the present study therefore were to determine the current vitamin A status of a nationally representative sample of South African women aged 16–35 years, as documented by the SANHANES 1, and compare it to the data from the NFCS1999, NFCS 2005, and SAVACG surveys and from other developing countries. The secondary aim was to determine the impact of sociodemography, diet, and body size on the vitamin A status of women of different of age groups, especially those aged 16–18 years.

Methods

Study design and study population

The current study is based on data from 9952 South African women aged 15 years and older who participated in the SANHANES-1, a cross-sectional household survey conducted in 2012.[50] The SANHANES-1 obtained data through interviews, clinical examination, and collection of blood specimens from individuals of all ages living in occupied households identified in the survey. Individuals were excluded if they lived in educational institutions, old age homes, hospitals, or uniformed service barracks or were homeless. Data were weighted to represent age, ethnic diversity, and geographic location (in terms of rural and urban settings) based on the 2011 census.[51] Women between the ages of 16 and 35 years were targeted to provide blood specimens for vitamin A status determination, as per the SANHANES-1 inclusion criteria. Of the 9952 women who participated in the SANHANES-1, 4314 women were aged 16–35 years, of which 1205 had valid data on anthropometry and vitamin A. The current secondary analysis included 1205 nonpregnant women aged 16–35 years with valid data on vitamin A status on the basis of serum retinol.

Data collection

A previously validated questionnaire was used to elicit information on (1) sociodemographic characteristics (age, ethnicity, gender, socioeconomic status, marital status, and education level) and (2) dietary intake (using a qualitative food frequency questionnaire) on the basis of foods consumed during the 7 days before the survey. A fruit and vegetable score was calculated to measure fruit and vegetable consumption, based on four questions in the food frequency questionnaire: "During the past 7 days, did you eat (1) fresh fruit juice without added sugar, (2) fresh fruit (all fruit, excluding fruit juices and dried fruit), (3) dark green leafy or dark yellow vegetables and (4) other vegetables/salad e.g. cabbage, tomatoes, excluding potatoes." The frequency of consumption was indicated as (1) none, (2) every day, (3) 1–3 times last week, and (4) 4–6 times last week. If a participant selected option (2) or (4) on a specific question, a score of 2 was allocated; if a participant selected option (3), a score of 1 was allocated, and if a participant selected option (1), a score of 0 was allocated. A total score of 8 was possible. Scores of 0–2, 3–4, and 5–8 were indicative of low, moderate, and high fruit and vegetable consumption, respectively. Dietary diversity, on the other hand, was calculated as the number of food groups, of a total of nine groups, from which participants had consumed food the day before the study.[52] Each food group was only counted once. A score <4 indicated a low dietary diversity, while a score ≥ 4 indicated an acceptable dietary diversity.[52]

Household food security was measured using the Community Childhood Hunger Identification Project index, which consists of eight questions that assess household food security.[53] Data on obstetric history, such as gravidity and parity, were not collected in the SANHANES-1.

Biological and anthropometric measurements

Blood specimens were collected by registered and trained nurses and aliquoted into the appropriate blood specimen collection tubes, mixed as necessary, and stored in cooler boxes (containing ice packs). Blood specimens for vitamin A determination were wrapped in aluminum foil before being stored in the cooler boxes. The cooler boxes were couriered daily to reach the laboratories for analysis within 24 h of blood specimen collection. South African National Accreditation System (SANAS)–accredited laboratories conducted the analysis of the blood specimens. In order to complete the analysis of the blood specimens within the required time frames, two service providers—Pathcare and Lancet laboratories—were appointed to analyze the blood specimens depending on their footprint in different areas in the country. Automated techniques, including Roche Modular, Immulite 2000, BioRad D10, and Abbot Architect, and high-performance liquid chromatography were used for biomarker analyses (serum retinol levels and C-reactive proteins (CRPs)). Vitamin A was determined by one national laboratory (also SANAS accredited), which was subcontracted by the two main contractor laboratories (Pathcare and Lancet). Deviations from the established internal and external quality control procedures had to be reported in accordance with the contractual agreement; however, no deviations were reported. Analytical quality control documentation, which was standard procedure in the two accredited and the single subcontracted laboratories, indicated that the coefficient of variation for the analyses ranged from 0.5% to 3.75%. Further methodological details are available.[50]

VAD was defined by a serum retinol concentration of less than 0.70 μmol/L, while vitamin A sufficiency was defined by a serum retinol concentration equal to or greater than 0.70 μmol/L, as defined by the WHO.[7] Serum CRP level was used as a marker for inflammation,[54] being low, moderate, and high for levels less than 1.0 mg/L, between 1.0 and 3.0 mg/L, and above 3.0 mg/L, respectively.[55]

Anthropometric variables

Body weight and height of the eligible participants were measured using the techniques described by Lee and Nieman.[56] BMI was calculated for all participants as weight (in kilograms, measured using a Seca digital scale, Baseline Scales (Pty) Ltd., South Africa) divided by the square of height (in meters, measured using a Seca 264 Digital Stationary Stadiometer) and was presented as kg/m^2. BMI for age (indicated as a percentile for women aged 16–18 years)[57] and BMI in kg/m^2 (for women aged 19–35 years)[58] cutoff points were used. For women aged 16–18 years, underweight, normal weight, overweight, and obesity were defined as BMI $<$ 5th, BMI $=$ 5th–84.9th, BMI $=$ 85th–94.9th, and BMI $\geq$95th percentiles, respectively.[57] For women aged 19–35 years, underweight, normal weight, overweight, and obesity were defined as BMI $<$18.5, BMI $=$ 18.5–24.9, BMI $=$ 25–29.9, and BMI $\geq$30 kg/m^2, respectively.[58]

Statistical analysis

Data were weighted for age, ethnic diversity, and geographic location to represent the South African population as in the 2011 census.[51] All data entered were checked for errors and cleaned before undertaking the analysis. The secondary analysis was done using STATA version 11.0 (StataCorp, 2009) and Microsoft Excel. The "svy" methods were used to account for unequal sampling probabilities in order to benchmark (standardize) the sample to represent the South African census 2011[51] population estimates. Weighted data were analyzed using univariate, bivariate, and multilevel analysis techniques. Estimates (means and prevalence rates) were reported with their corresponding 95% confidence intervals (CIs). Differences in groups were considered significant if CIs did not overlap and if P values were $<$0.05. Odds ratios (OR) estimates were presented with CIs, and P values were used to confirm significant differences.

Ethical considerations

The Research Ethics Committee of the Human Sciences Research Council (HSRC) provided ethics approval for the SANHANES-1 (REF: REC6/16/11/11). Participation in the study was voluntary, and all participants signed consent and assent forms, as appropriate, after the study had been explained to them. All data and blood specimens collected from the participants were

anonymized. Study identity numbers were used as identifiers of the data and specimens, with all personal information kept separate from the data. Only one primary investigator and the HSRC's chief statistician had access to these details. Permission to use the anonymized SANHANES-1 data was obtained from the principal investigator of SANHANES-1, and a nondisclosure agreement had to be signed.

Results

Characteristics of the participants

Table 1 provides an overview of the sociodemographic characteristics, BMI, and dietary behaviors of women aged 16–35 years. There was a relatively equal distribution (range: 31.5–35.0%) of participants across the three income groups (low: ≤5760 ZAR (432.52 USD), intermediate: 5761–14,400 ZAR (432.60–1081.30 USD), and upper: >14,400 ZAR (1081.30 USD)). The income groups were designed to reflect the minimum cost that an adult would require daily to procure a healthy diet.[59] The majority of women in this study were aged between 19 and 24 years old (34.6%), were black South Africans (85.0%), resided in urban formal areas (53.5%), never married/widowed/separated/divorced (74.7%), and had obtained a secondary education (grade 8–12) (83.7%). Furthermore, nearly two fifths (39.5%) of women were normal weight and only 6.3% were underweight, while 25.8% and 28.4% were overweight and obese, respectively. While two-fifths (40.6%) reported that they were food secure, more than a quarter (27.3%) and almost a third (32.1%) reported that they were at risk of hunger or experienced hunger, respectively.

In terms of dietary behaviors, slightly more than half (53.0%) reported an adequate dietary diversity, while the majority reported that they did not eat foods that were high in vitamin A, including organ meat, eggs, yellow/orange fruit/vegetables, or other vegetables the day before the survey (83.2%, 74.2%, 76.7%, and 63.9%, respectively). However, 72.0% achieved a moderate–high fruit and vegetable intake score. Furthermore, 80.3%, 58.1%, and 67.1% indicated that they ate green leafy vegetables fewer than four times a week, consumed less than one cup of milk daily, and ate fats/oils the day before the survey, respectively.

Vitamin A status of the participants

Overall, the mean serum retinol concentration for women in this study was 1.15 μmol/L. Women in the youngest age group (16–18 years) had the lowest mean serum retinol concentration (1.10 μmol/L), but there were no significant differences in mean values between age groups (Table 2).

Of the 1205 women for whom valid data were available on vitamin A, 11.7% (age standardized) had a serum retinol concentration of less than 0.70 μmol/L and therefore had VAD (Table 2). Overall, only 1% ($n = 12$) had serum retinol concentrations <0.35 μmol/L (data not shown). While no significant differences in vitamin A status were observed with regard to sociodemographic characteristics (Table 2), there was a higher prevalence of VAD in women in the older age group (30–35 years) compared with women in the youngest age group (15.5% versus 8.4%); in black women compared with coloured women (12.7% versus 7.1%); in those residing in urban informal and rural informal areas compared with urban formal areas (15.3% and 15.2% versus 8.8%); in those who resided in households that reported lower incomes compared with higher incomes (15.6% versus 7.9%); those who had no education or achieved secondary education compared with those who achieved higher education (11.4% and 12.3% versus 4.6%), and those who were at risk of hunger compared with those who were food secure (13.9% versus 9.7%). Furthermore, women who were underweight had a higher prevalence of VAD (22.6%) compared with those who were normal weight (13.7%), overweight (11.5%), or obese (13.9%).

Similarly, no significant differences in vitamin A status were observed for the different aspects of dietary behavior listed in Table 2. Nevertheless, women with a low dietary diversity score who did not consume eggs, yellow/orange fruit/vegetables, or other vegetables the day before the survey and consumed more than one cup of milk daily had a consistently higher prevalence of VAD (11.5%, 11.3%, 12.3%, 11.7%, and 13.2%, respectively) than their counterparts.

No meaningful comparisons could be made on the prevalence of VAD between adolescents and adult women by age (16–18 years, 19–24 years, and 25–35 years) owing to the small available sample size ($n = 30$, $n = 46$, and $n = 62$, respectively).

Table 1. Sociodemographic factors and dietary behaviors among women aged 16–35 years with valid data on vitamin A status (SANHANES-1, 2012)

	%	95% CI	*n*
Age group			
16–18	22.5	(17.9–28.0)	229
19–24	34.6	(29.0–40.7)	435
25–29	23.4	(19.2–28.3)	278
30–35	19.4	(15.4–24.3)	263
Race			
Black	85.0	(79.5–89.3)	836
White	0.6	(0.3–1.5)	10
Coloured	10.8	(8.3–14.0)	312
Indian	3.5	(1.1–10.4)	36
Locality			
Urban formal	53.5	(43.8–62.9)	562
Urban informal	13.8	(9.0–20.6)	187
Rural informal (tribal)	25.7	(19.3–33.5)	255
Rural formal (farms)	7.0	(4.6–10.4)	201
Household income[a]			
Low	35.0	(28.2–42.4)	390
Intermediate	33.5	(27.1–40.7)	366
Upper	31.5	(22.7–42.0)	276
Marital status			
Never married/widowed/ separated/divorced	74.7	(66.9–81.2)	706
Married/living together/civil union	25.3	(18.8–33.1)	280
Highest education			
No formal schooling/grade 0–7	10.6	(8.0–13.8)	155
Grade 8–12 (or equivalent)	83.7	(79.8–87.0)	877
Higher education with/without matriculation	5.7	(3.8–8.7)	48
BMI status			
Underweight <18.5 kg/m^2	6.3	(3.2–12.1)	72
Normal weight 18.5–24.9 kg/m^2	39.5	(35.6–43.6)	485
Overweight 25–29.9 kg/m^2	25.8	(21.6–30.6)	296
Obese ≥ 30 kg/m^2	28.4	(23.8–33.5)	309
Food security			
Food secure	40.6	(32.6–49.1)	441
At risk of hunger	27.3	(21.7–33.7)	311
Experience hunger	32.1	(26.3–38.6)	388
Dietary diversity score			
0–3	47.0	(37.7–56.6)	476
4–9	53.0	(43.4–62.3)	531
Ate organ meat the previous day			
No	83.2	(78.4–87.2)	871
Yes	16.8	(12.8–21.6)	160
Ate eggs the previous day			
No	74.2	(65.4–81.4)	837
Yes	25.8	(18.6–34.6)	199
Eat green leafy vegetables ≥ 4 times a week			
<4 times a week	80.3	(75.3–84.4)	879
≥4 times a week	19.7	(15.6–24.7)	222
Ate yellow/orange fruit/vegetables the previous day			
No	76.7	(71.3–81.4)	829
Yes	23.3	(18.6–28.7)	203
Milk average daily consumption			
<1 cup	58.1	(50.0–65.8)	682
≥1 cup	41.9	(34.2–50.0)	403
Ate other vegetables the previous day			
No	63.9	(56.5–70.8)	676
Yes	36.1	(29.2–43.5)	361
Ate fats/oils the previous day			
No	32.9	(28.4–37.8)	372
Yes	67.1	(62.2–71.6)	682
Fruit and vegetable score			
Low (0–2)	28.0	(22.8–33.9)	326
Moderate/high (3–8)	72.0	(66.1–77.2)	761
Total	**100.0**		**1205**

CI, confidence interval; %, percentage.
[a]Household annual income: low: ≤5760 ZAR (432.52 USD); intermediate: 5761–14,400 ZAR (432.60–1081.30 USD); and upper: >14,400 ZAR (1081.30 USD).

In relation to BMI, Figure 1 shows that BMI increased with age and VAD increased with age in under- and normal-weight participants. However, in the 19- to 24- and 25- to 35-year-olds, VAD decreased with an increase in BMI, with the exception of obese 19- to 24-year-olds, who had the highest prevalence of VAD (23.2%).

Weighted bivariate logistic regression for all women aged 16–35 years (Table 3) indicated that women with an intermediate household income who consumed yellow/orange fruit/vegetables the previous day had a reduced likelihood of presenting with VAD (OR = 0.55 (95% CI = 0.30–1.00), $P = 0.048$ and OR = 0.51 (95% CI = 0.26–0.99), $P < 0.046$, respectively). Upon performing weighted multivariate logistic regression (Table 3), the only factor that remained significant was the household income: being in the upper income group reduced the likelihood of women presenting with VAD (OR = 0.31 (95% CI = 0.11–0.87), $P = 0.027$).

Unweighted multilevel bivariate logistic regression for all women aged 16–35 years (Table 3) showed that being a black South African, residing in informal settlements (either urban or rural), and

Table 2. Mean serum retinol and vitamin A status of women aged 16–35 years by sociodemographic factors and dietary behavior (SANHANES-1, 2012)

			Normal (vitamin A ≥ 0.7)		Low (vitamin A <0.7)		Sample
Women 16–35 years	**Mean**	**95% CI**	**%**	**95% CI**	**%**	**95% CI**	***n***
Crude	1.15	(1.10–1.19)	88.5	(85.0–91.3)	11.5	(8.7–15.0)	1205
Age standardized	1.15	(1.10–1.19)	88.3	(84.8–91.2)	11.7	(8.8–15.2)	1205
Age (years)							
16–18	1.10	(1.04–1.16)	91.6	(85.7–95.2)	8.4	(4.8–14.3)	229
19–24	1.16	(1.10–1.21)	88.6	(83.2–92.4)	12.6	(7.6–16.8)	435
25–29	1.15	(1.06–1.25)	88.6	(80.4–93.7)	11.4	(6.3–19.6)	278
30–35	1.16	(1.06–1.27)	84.5	(76.5–90.1)	15.5	(9.9–23.5)	263
Race							
Black	1.12	(1.07–1.18)	87.3	(83.1–90.6)	12.7	(9.4–16.9)	836
White	1.52	(1.19–1.85)	100.0		0.0		10
Coloured	1.27	(1.21–1.33)	92.9	(88.5–95.7)	7.1	(4.3–11.5)	312
Indian	1.06	(0.92–1.21)	86.6	(65.7–95.6)	13.4	(4.4–34.3)	36
Geographic location							
Urban formal	1.20	(1.13–1.27)	91.2	(85.2–94.9)	8.8	(5.1–14.8)	562
Urban informal	1.10	(0.95–1.25)	84.7	(76.4–90.4)	15.3	(9.6–23.6)	187
Rural informal (tribal)	1.07	(1.01–1.13)	84.8	(79.2–89.2)	15.2	(10.8–20.8)	255
Rural formal (farms)	1.17	(1.10–1.24)	88.2	(83.9–91.5)	11.8	(8.5–16.1)	201
BMI status							
Underweight <18.5 kg/m^2	1.03	(0.91–1.16)	77.4	(63.3–87.1)	22.6	(12.9–36.7)	72
Normal weight 18.5–24.9 kg/m^2	1.11	(1.06–1.17)	86.3	(80.8–90.4)	13.7	(9.6–19.2)	485
Overweight 25–29.9 kg/m^2	1.15	(1.09–1.20)	88.5	(82.8–92.5)	11.5	(7.5–17.2)	296
Obese ≥ 30 kg/m^2	1.15	(1.07–1.23)	86.1	(74.8–92.9)	13.9	(7.1–25.2)	309
Household income[a]							
Low	1.11	(1.04–1.18)	84.4	(77.8–89.3)	15.6	(10.7–22.2)	390
Intermediate	1.14	(1.08–1.20)	90.6	(86.1–93.8)	9.4	(6.2–13.9)	366
Upper	1.22	(1.13–1.31)	92.1	(83.9–96.3)	7.9	(3.7–16.1)	276
Marital status							
Never married/widowed/ separated/divorced	1.14	(1.08–1.21)	88.4	(83.8–91.9)	11.6	(8.1–16.2)	706
Married/living together/civil union	1.13	(1.03–1.22)	87.2	(76.5–93.5)	12.8	(6.5–23.5)	280
Highest education							
No formal schooling/grade 0–7	1.14	(1.07–1.21)	88.6	(81.3–93.2)	11.4	(6.8–18.7)	155
Grade 8–12 (or equivalent)	1.14	(1.08–1.19)	87.7	(83.6–90.9)	12.3	(9.1–16.4)	877
Higher education with/without matriculation	1.12	(1.03–1.21)	95.4	(88.4–98.3)	4.6	(1.7–11.6)	48
Household food security							
Food secure	1.18	(1.10–1.25)	90.3	(83.4–94.5)	9.7	(5.5–16.6)	441
At risk of hunger	1.16	(1.07–1.25)	86.1	(78.3–91.4)	13.9	(8.6–21.7)	311
Experience hunger	1.09	(1.03–1.14)	88.9	(84.2–92.3)	11.1	(7.7–15.8)	388
Dietary diversity score							
0–3	1.15	(1.08–1.22)	88.5	(83.5–92.2)	11.5	(7.8–16.5)	476
4–9	1.15	(1.09–1.22)	89.1	(84.0–92.7)	10.9	(7.3–16.0)	531
Ate organ meat the previous day							
No	1.16	(1.10–1.22)	88.7	(84.8–91.7)	11.3	(8.3–15.2)	871
Yes	1.11	(1.03–1.19)	88.2	(76.8–94.4)	11.8	(5.6–23.2)	160

Continued

Table 2. *Continued*

Women 16–35 years	Mean	95% CI	Normal (vitamin A ≥ 0.7) %	Normal (vitamin A ≥ 0.7) 95% CI	Low (vitamin A <0.7) %	Low (vitamin A <0.7) 95% CI	Sample *n*
Ate eggs the previous day							
No	1.15	(1.10–1.21)	88.7	(84.5–91.9)	11.3	(8.1–15.5)	837
Yes	1.18	(1.10–1.26)	90.7	(84.0–94.8)	9.3	(5.2–16.0)	199
Ate yellow/orange fruit/vegetables the previous day							
No	1.15	(1.09–1.20)	87.7	(83.6–90.9)	12.3	(9.1–16.4)	829
Yes	1.16	(1.09–1.24)	93.5	(88.8–96.3)	6.5	(3.7–11.2)	203
Milk average daily consumption							
<1 cup	1.13	(1.08–1.18)	88.2	(83.1–91.9)	11.8	(8.1–16.9)	682
≥ 1 cup	1.16	(1.09–1.22)	86.8	(81.3–90.9)	13.2	(9.1–18.7)	403
Ate other vegetables the previous day							
No	1.16	(1.10–1.23)	88.3	(84.0–91.5)	11.7	(8.5–16.0)	676
Yes	1.13)	(1.06–1.21)	88.8	(82.0–93.3)	11.2	(6.7–18.0)	361
Fruit and vegetable consumption score							
Low (0–2)	1.11	(1.18–0.00)	86.5	(80.6–90.8)	13.5	(9.2–19.4)	326
Moderate/high (3–8)	1.15	(1.09–1.21)	87.5	(82.6–91.2)	12.5	(8.8–17.4)	761

CI, confidence interval; %, percentage.
[a]Household annual income: low: ≤5760 ZAR (432.52 USD); intermediate: 5761–14,400 ZAR (432.60–1081.30 USD); and upper: >14,400 ZAR (1081.30 USD).

experiencing hunger increased the likelihood of women presenting with VAD (OR = 2.47 (95% CI = 1.53–4.00), $P < 0.001$; OR = 1.76 (95% CI = 1.06–2.91), $P = 0.028$; OR = 1.65 (95% CI = 1.04–2.62), $P = 0.035$; and OR = 1.82 (95% CI = 1.16–2.85), $P < 0.009$, respectively). Residing in households that reported an intermediate or upper income, on the other hand, decreased the likelihood of women presenting with VAD (OR = 0.59 (95% CI = 0.37–0.95), $P = 0.029$ and OR = 0.45 (95% CI = 0.26–0.78), $P = 0.004$, respectively). By unweighted multilevel multivariate logistic regression, the only factor that remained significant was race, where being black increased the likelihood of women presenting with VAD (OR = 1.89 (95% CI = 1.06–3.37), $P = 0.031$) compared with their non-black counterparts.

Both weighted bivariate and multiple logistic regression (Table 4) showed no association between sociodemographic factors and VAD in the 19- to 24-year-olds and the 25- to 35-year-olds. However, in the 16- to 18-year-old group, locality and household income were the two sociodemographic factors associated with vitamin A status (Table 4). Participants (16- to 18-year-olds) who resided in informal settlements (both urban and rural) were eight and seven times more likely to have VAD (OR = 7.76 (95% CI = 1.78–33.77), $P = 0.007$ and OR = 6.69 (95% CI = 2.07–21.64), $P = 0.002$), respectively, when compared with their counterparts who lived in urban formal settlements. Conversely, 16- to 18-year-olds who resided in households that reported an intermediate or upper income had decreased likelihood of presenting with VAD (OR = 0.2 (95% CI = 0.05–0.78), $P = 0.021$ and OR = 0.13 (95% CI = 0.03–0.66), $P = 0.014$, respectively). Similar results were found when undertaking multiple logistic regression in this age group (Table 4); residing in urban informal settlements increased the likelihood of women (16–18 years) presenting with VAD (OR = 9.83 (95% CI = 1.99–48.68), $P = 0.005$), and residing in households that reported an intermediate or upper income decreased the likelihood of women (16–18 years) presenting with VAD (OR = 0.2 (95% CI = 0.05–0.79), $P = 0.022$ and OR = 0.25 (95% CI = 0.06–0.99), $P = 0.049$, respectively).

No items relating to dietary behavior were associated with VAD in any of the three age groups (data not shown).

While an in-depth exploration of the relationship between VAD, noncommunicable diseases (NCDs) (diabetes and hypertension), and communicable diseases (HIV and TB) was beyond the scope of this study, the association between VAD and CRP levels

Table 3. Factors associated with poor vitamin A status in women aged 16–35 years (SANHANES-1 2012)

	Weighted logistic regression						Multilevel logistic regression (unweighted)					
	Bivariate regression			Multivariable regression			Bivariate regression			Multivariable regression		
	OR	95% CI (OR)	*P* value		95% CI (OR)	*P* value	OR	95% CI (OR)	*P* value	AOR	95% CI (OR)	*P*–value
Age	1.02	(0.98–1.07)	0.291	0.97	(0.93–1.02)	0.3	0.99	(0.96–1.03)	0.729	0.99	(0.95–1.03)	0.635
Race												
Non-black	Ref.	—	—									
Black	1.88	(0.95–3.70)	0.068	1.12	(0.56–2.24)	0.741	2.47	(1.53–4.00)	**<0.001**	1.89	(1.06–3.37)	**0.031**
Locality												
Urban formal	Ref.	—	—									
Urban informal	1.88	(0.85–4.17)	0.12				1.76	(1.06–2.91)	**0.028**	1.16	(0.61–2.19)	0.649
Rural informal (tribal)	1.84	(0.92–3.66)	0.083				1.65	(1.04–2.62)	**0.035**	0.86	(0.47–1.58)	0.623
Rural formal (farms)	1.49	(0.76–2.93)	0.249				1.29	(0.76–2.20)	0.347	1.26	(0.68–2.35)	0.466
Household income[a]												
Low	Ref.	—	—									
Intermediate	0.55	(0.30–1.00)	**0.048**	0.65	(0.34–1.22)	0.178	0.59	(0.37–0.95)	**0.029**	0.63	(0.39–1.03)	0.067
Upper	0.5	(0.19–1.31)	0.157	0.31	(0.11–0.87)	**0.027**	0.45	(0.26–0.78)	**0.004**	0.55	(0.30–1.00)	0.051
Marital status												
Never married/ widowed/separated/ divorced	Ref.	—	—									
Married/living together/civil union	1.24	(0.62–2.50)	0.539				1.37	(0.88–2.13)	0.163			
Highest education												
No formal schooling/ grade 0–7	Ref.	—	—									
Grade 8–12 (or equivalent)	1.1	(0.57–2.13)	0.784				1	(0.58–1.73)	0.997			
Higher education with/without matriculation	0.38	(0.11–1.32)	0.128				0.86	(0.29–2.53)	0.785			
Hunger score												
Food secure	Ref.	—	—									
At risk of hunger	1.52	(0.70–3.28)	0.29				1.38	(0.85–2.26)	0.197	1.16	(0.66–2.01)	0.608
Experience hunger	1.17	(0.55–2.49)	0.676				1.82	(1.16–2.85)	**0.009**	1.16	(0.68–2.00)	0.588
Dietary diversity score												
Low: 0–3	Ref.	—	—									
High: 4–9	0.95	(0.50–1.80)	0.877				0.9	(0.60–1.35)	0.607			
Ate organ meat the previous day (yes versus no)	1.19	(0.50–2.79)	0.696				0.78	(0.44–1.38)	0.393			
Ate eggs the previous day (yes versus no)	0.79	(0.36–1.75)	0.568				0.88	(0.53–1.48)	0.641			
Eat green leafy vegetables ≥ 4 times a week (yes versus no)	1.55	(0.81–2.96)	0.182				0.94	(0.59–1.50)	0.798			
Red meat consumption												
Do not eat red meat	Ref.	—	—									
Meat with fat on	2.48	(0.67–9.28)	0.175				2.51	(0.77–8.20)	0.129			
Fat removed from the meat	1.87	(0.47–7.37)	0.371				2.09	(0.61–7.15)	0.239			
Ate yellow/orange fruit/vegetables the previous day (yes versus no)	0.51	(0.26–0.99)	**0.046**	0.58	(0.28–1.22)	0.154	0.84	(0.51–1.41)	0.514			
Milk average daily consumption												
<1 cup	Ref.	—	—									
≥ 1 cup	1.13	(0.60–2.11)	0.705				1.21	(0.83–1.77)	0.33			
Ate other vegetables the previous day (yes versus no)	0.92	(0.48–1.76)	0.795				(Model did not converge)					
Ate fats/oils the previous day (yes versus no)	1.23	(0.71–2.12)	0.454				1.06	(0.71–1.58)	0.785			
Fruit and vegetable consumption score												
Low (0–2)	Ref.	—	—									
Moderate/high (3–8)	1.06	(0.59–1.91)	0.852				0.76	(0.51–1.14)	0.184			

CI, confidence interval; %, percentage; Ref., reference value used for comparison. *P* values in bold indicate statistical significance ($P < 0.05$).

[a]Household annual income: low: ≤5760 ZAR (432.52 USD); intermediate: 5761–14,400 ZAR (432.60–1081.30 USD); and upper: >14,400 ZAR (1081.30 USD).

Table 4. Logistic regression results (weighted data) of the effects of sociodemographic characteristics and dietary behaviors on the presence of poor vitamin A status (serum retinol <0.7) by age group, in women aged 16–35 years (SANHANES-1 2012)

	16–18 years				19–24 years				25–35 years			
	Bivariate logistic regression		Multiple logistic regression		Bivariate logistic regression		Multiple logistic regression		Bivariate logistic regression		Multiple logistic regression	
	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value
Age	0.62 (0.32–1.21)	0.16	0.64 (0.33–1.24)	0.18	0.77 (0.59–1.00)	**0.049**	0.76 (0.58–1.00)	**0.049**	1.03 (0.92–1.16)	0.611	1.03 (0.92–1.16)	0.578
Race												
Non-black	Ref.	—	Ref.	—	Ref.	—	Ref.	—	Ref.	—	Ref.	—
Black	1.86 (0.44–7.93)	0.397	0.58 (0.1–3.23)	0.531	1.59 (0.46–5.45)	0.458	1.76 (0.5–6.20)	0.377	2.03 (0.8–5.17)	0.138	2.07 (0.82–5.25)	0.124
Locality												
Urban formal	Ref.	—	Ref.	—	Ref.	—			Ref.	—		
Urban informal	7.76 (1.78–33.77)	**0.007**	9.83 (1.99–48.68)	**0.005**	0.58 (0.19–1.8)	0.34			2.21 (0.73–6.65)	0.158		
Rural informal	6.69 (2.07–21.64)	**0.002**	3.54 (0.9–13.87)	0.069	1.07 (0.38–3.02)	0.897			1.76 (0.64–4.87)	0.273		
Rural formal	3.73 (0.96–14.57)	0.058	2.79 (0.48–16.12)	0.249	1.58 (0.6–4.18)	0.355			0.92 (0.31–2.7)	0.877		
BMI status												
Normal weight 18.5–24.9 kg/m^2	Ref.	—			Ref.	—			Ref.	—		
Underweight <18.5 kg/m^2	0.4 (0.06–2.84)	0.354			2.65 (0.62–11.27)	0.186			2.58 (0.66–10.07)	0.171		
Overweight 25–29.9 kg/m^2	1.87 (0.48–7.32)	0.368			0.92 (0.34–2.48)	0.866			0.61 (0.25–1.5)	0.280		
Obese ≥30 kg/m^2	2.02 (0.29–14.09)	0.474			1.34 (0.35–5.18)	0.67			0.51 (0.21–1.26)	0.145		
Overall health perception												
Very good/good	Ref.	—			Ref.	—			Ref.	—		
Moderate	1.22 (0.16–9.22)	0.848			1.87 (0.47–7.39)	0.37			1.07 (0.43–2.63)	0.889		
Bad/very bad	1[b]				0.21 (0.03–1.8)	0.155			3.68 (0.58–23.33)	0.166		
Household income[a]												
Low	Ref.	—	Ref.	—	Ref.	—			Ref.	—		
Intermediate	0.2 (0.05–0.78)	**0.021**	0.2 (0.05–0.79)	**0.022**	0.76 (0.26–2.17)	0.602			0.66 (0.28–1.56)	0.342		
Upper	0.13 (0.03–0.66)	**0.014**	0.25 (0.06–0.99)	**0.049**	0.39 (0.09–1.75)	0.217			0.77 (0.22–2.7)	0.681		
Marital status	Not applicable	Not applicable										
Never married/ widowed/ separated/divorced					Ref.	—			Ref.	—		
Married/living together/civil union					0.7 (0.25–1.96)	0.495			1.33 (0.53–3.3)	0.541		
Highest education	Not applicable	Not applicable										
No formal schooling/ grade 0–7					Ref.	—			Ref.	—		
Grade 8–12 (or equivalent)					0.72 (0.2–2.63)	0.623			2.01 (0.77–5.25)	0.153		
Higher education with/without matriculation					1[b]				1.35 (0.32–5.65)	0.679		
Hunger score												
Food secure	Ref.	—			Ref.	—			Ref.	—		
At risk of hunger	4.76 (0.89–25.44)	0.068			1.33 (0.35–5.05)	0.676			1.15 (0.32–4.12)	0.834		

Continued

Table 4. *Continued*

	16–18 years				19–24 years				25–35 years			
	Bivariate logistic regression		Multiple logistic regression		Bivariate logistic regression		Multiple logistic regression		Bivariate logistic regression		Multiple logistic regression	
	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value	OR 95% CI	*P* value
Experience hunger	1.7 (0.38–7.53)	0.484			1.04 (0.3–3.62)	0.949			1.26 (0.46–3.47)	0.657		

Notes: Variables with at least one category that was significant ($P < 0.05$) in the bivariate regression were included in the multivariable regression. All multivariable regression models controlled for age and race. Marital status and education status were not included in the regression models for 16- to 18-year-olds because there were small numbers of married women and women with completed high school or tertiary education. CI, confidence interval; %, percentage; Ref., reference value used for comparison. *P* values in bold indicate statistical significance ($P < 0.05$).

[a]Household annual income: low: ≤5760 ZAR (432.52 USD); intermediate: 5761–14,400 ZAR (432.60–1081.30 USD); and upper: >14,400 ZAR (1081.30 USD).

[b]No observed cases where the response variable = 1 for this response category.

was explored, indicating that the prevalence of VAD was significantly higher for women with CRP >3 (20.1%) than for those with CRP 1–3 (7.1%) ($P = 0.0009$) and CRP <1 (6.7%) ($P = 0.0003$) (data not shown).

Discussion

Nearly a decade after the implementation of the VAS (2002)[14] and food fortification (2003)[16] programs in South Africa, the results of the SANHANES-1, conducted in 2012, indicate that the vitamin A status of women aged 16–35 years has indeed improved.[50] The prevalence of VAD in this group has more than halved in this time, from 27.2% in 2005 to 11.7% in the current study.[49] However, since these surveys differed in the nature of their design, with a resulting smaller sample size in the SANHANES-1 study, comparisons should be made with caution.

Despite the dramatic decrease in VAD prevalence in the country, it is disconcerting to note that nonpregnant South African women have the same mean retinol levels (1.15 μmol/L) as pregnant women in Ghana and Nepal[60,61] and lower mean serum retinol levels than nonpregnant women in Vietnam (1.49 μmol/L), Ghana (1.54 μmol/L), Brazil (1.61 μmol/L), and Iran (2.38 μmol/L).[60,62–64] However, it should be borne in mind that the SANHANES-1 did not record parity and gravidity of the women, and as such the lower mean retinol concentrations in our sample could be attributed to the inclusion of postpartum women and women who have had one or more children. In this regard, in a study conducted in Ethiopia, Gebreselassie *et al.*[65] stated that multiparity increases the odds of having VAD by almost twofold (OR = 1.92 (95% CI = 1.02–3.64)). While we did not record parity in the current study, we did investigate VAD prevalence in different age groups (e.g., 16–18, 19–24, 25–29, and 30–35 years) and observed that, although the findings were not significant, VAD prevalence increased with age, with the highest prevalence being in older women (25- to 35-year-olds) in this study. This finding is corroborated by the findings of Gebreselassie *et al.*,[65] which showed that the prevalence of VAD increased with age, with older women being twice as likely to have VAD than younger women. Furthermore, the fact that there is South African evidence for fertility and parity increasing with age is also supportive of the association.[66,67]

It is important to note that more than 50% of South Africans continue to experience a degree of food insecurity (28.3% are at risk of hunger and 26.0% are experiencing hunger) and are battling poverty.[49,50,68,69] Substantiated South African evidence suggests that poverty is fueled by sociodemographic factors (that include economic freedom associated with household income, locality, and ethnicity).[21,69] These factors render South Africans living in these households unable to access nutrient-dense food. The results of the current study have confirmed that these issues remain valid. In fact, some of the results suggest that women who reside in households reporting a higher household income and those who have a higher consumption of nutrient-dense (yellow and orange) fruit and vegetables are less likely to experience VAD, while those who are food insecure are twice as likely to present with VAD. Studies in South Africa[70] and the United States[71] have also shown that the cost of

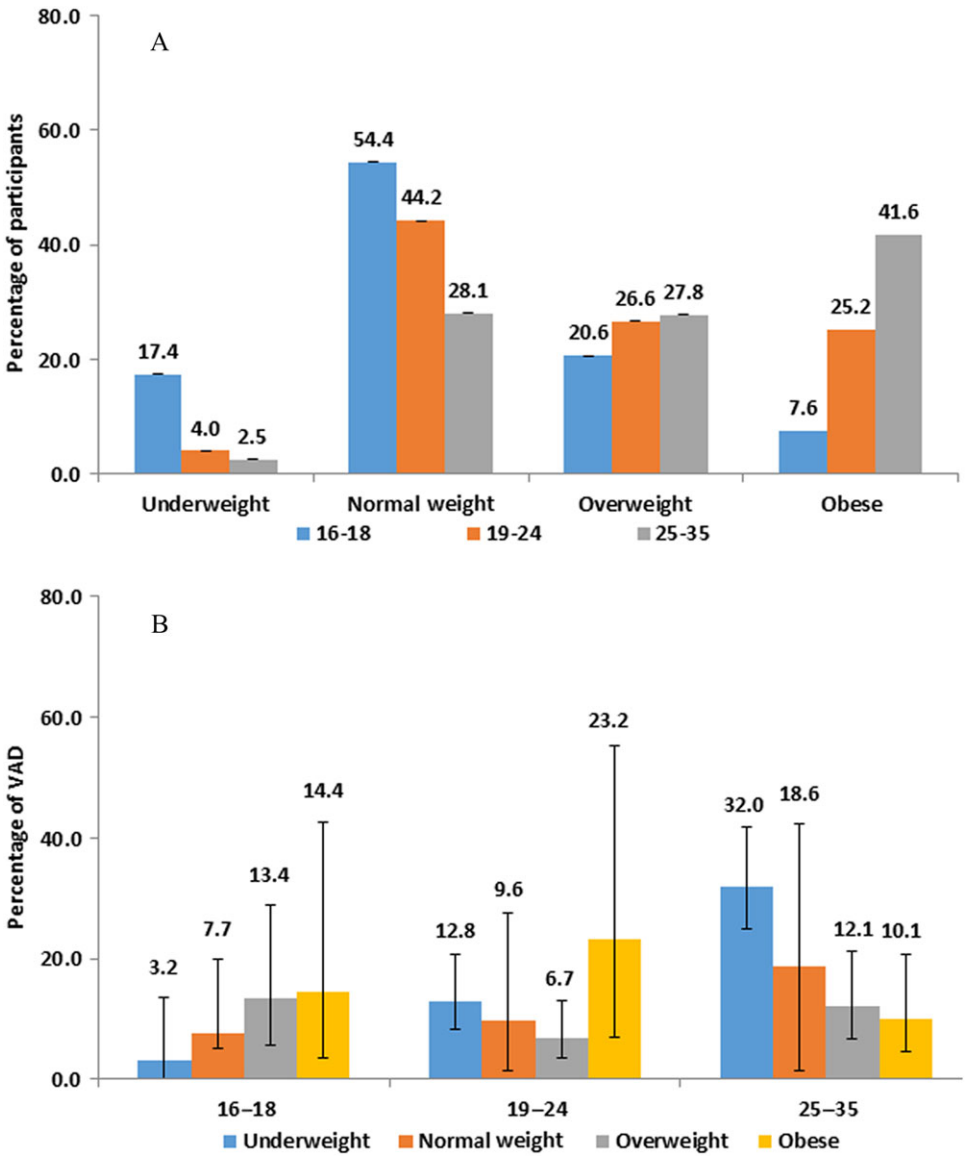

Figure 1. (A) The relationship between BMI and age in women aged 16–35 years in South Africa (SANHANES-1, 2012). (B) The relationship between the prevalence of VAD and BMI in women aged 16–35 years in South Africa by age group (SANHANES-1, 2012).

purchasing nutrient-dense food(s) can be high and, as such, people living in poorer households are more likely to purchase fewer of these nutrient-dense food(s) and thereby consume less.[70,71] Nutrition education regarding purchasing and consumption of low-cost, nutrient-rich foods, such as liver and other organ meats and indigenous green leafy vegetables, should improve the micronutrient status of South Africans, as localized studies have shown that these foods are eaten commonly in poorer segments of South African society.[72] Hence, it was interesting to observe that more than 80% of women in the current study did not consume organ meats and consumed green leafy vegetables fewer than four times a week. By promoting a culture of producing food(s) at a household level instead of relying only on purchasing food(s), access to nutrient dense food(s) could be improved.

Subsistence farming was a common practice in South Africa, with an estimated 4 million people engaging in subsistence farming in 2009, a practice that may not be followed to the same extent currently because of the proliferation of supermarket chains and other food outlets in rural cities and towns.[73,74] Rural households, therefore, may be relying on purchasing rather than producing their own food.[74] An earlier study by Aliber[75] documented that the use of subsistence farming as the main source of income and food had declined from 33% in the year 2000 to 6% in 2004. Aliber[75] also showed that the number of households in South Africa that used subsistence farming as a means of supplementing the food that they purchase has increased from 54% to 88%. In support of these findings, Tibesigwa and Visser,[76] using data from the National Income and Dynamics Survey, showed that 57.8% of households that engage in subsistence farming retained their produce (crops) for consumption. Furthermore, in female-headed households, this number increased to 71.7%.[76] Moreover, a larger proportion of households in urban areas (73.3%) retained crops for consumption than those in rural areas (55.3%).[76] With the results of the current study indicating that women who reside in informal areas (urban and rural) are more likely to present with VAD, with the likelihood being the highest in women aged 16–18 years, it is imperative to mobilize communities to adopt subsistence farming and/or communal food gardens in both rural and urban informal areas alike. The South African government can lead in this intervention program by facilitating access to land in these communities while promoting and supporting small farmers if they are to improve households' access to nutrient-dense and vitamin A–rich foods.

The majority of women residing in informal urban and rural communities in the current study were black South Africans who are economically disadvantaged and whose household income is supplemented by social grants, which is at times not sufficient to improve their purchasing power. It is therefore reasonable to suggest that black women could be the ideal population for a targeted intervention that promotes subsistence farming in informal urban and rural communities of South Africa. This intervention could be targeted at women early in their adolescent years as a means of introducing subsistence farming and as part of nutrition education in their school curriculum. Another important aspect of nutrition and health education is scaling up advocacy regarding the importance of the consumption of vitamin A–rich foods, such as eggs and yellow/orange fruit/vegetables.

The findings of the present analysis also indicate that South African women who are at the opposite ends of the BMI spectrum are the most vulnerable to VAD. In fact, when the relationship between VAD and BMI was investigated, varying trends across the three different age groups were observed. In this case, VAD prevalence seemed to be the highest in 16- to 24-year-old women who were obese, contrasting with the 25- to 35-year-old obese women in whom VAD was less frequent. In fact, VAD prevalence seemed to be highest in 25- to 35-year-old women who were underweight. This age-dependent increase in prevalence of VAD at either end of the BMI spectrum highlights the existence of micronutrient deficiencies in both under- and overnourished South African women. This corroborates findings from international studies, which showed the existence of micronutrient deficiencies, including VAD, in both underweight and obese participants.[36,77,78] Kimmons *et al.*[36] also showed that the serum micronutrient–BMI relationship is age dependent, in that overweight and obese premenopausal women (aged 19–64 years) are the most affected by VAD, with overweight older women less likely to have VAD.[36] While additional studies have been conducted to determine the association between VAD and obesity using RBP4 as a measure of VAD, the results obtained were inconclusive, with some studies reporting that RBP4 levels were positively associated with BMI, while others reported no association between RBP4 and BMI.[79–82]

A possible explanation for the differences between micronutrient status and BMI could be due to obese and overweight 16- to 18-year-old women's diets being nutrient poor and therefore suboptimal, as they are most likely deficient in fruits and vegetables, especially those rich in vitamin A. These assumptions are supported by Medin *et al.*,[83] who showed that overweight and obese adolescent children in Baerum, Norway reported a lower vegetable intake and a corresponding lower concentration of plasma carotenoids.[83] The diet of older women, on the other hand, was more diverse and included nutrient-dense food.[84] Charlton *et al.* confirmed this by showing that obese adult Australian women had higher

odds of consuming all foods, including fruits and vegetables, in larger amounts; hence, their dietary intakes reached the highest quartile for combined fruit and vegetable intake, thereby increasing the likelihood of consuming the recommended intake of five or more fruits and vegetables servings per day.[84] Underweight adult Australian women, on the other hand, consumed less food overall, including fruits and vegetables, and were less likely to meet the recommended targets. Moreover, Azagba and Sharaf[85] corroborated these findings by showing that the BMI of adults in Canada was negatively and significantly associated with fruit and vegetable consumption.[85] However, they cautioned that the relationship between BMI and fruit and vegetable intake was dependent on where the person was on the BMI spectrum.[85] They further suggested that this relationship was mediated by sociodemography, especially income and education levels. Income has been shown to be a strong predictor of VAD in the current analysis, as women belonging to the upper income group were less likely to present with VAD compared with those from the lower income groups, a relationship that was magnified in the women aged 16–18 years in the current study. As such, further research is needed to better understand the association between VAD, BMI, and fruit and vegetable intake. Concurrently, interventions to curb both macro- and micronutrient deficiencies in the country remain mandatory.

While there has been a reduction in the prevalence of VAD in women participating in the SANHANES-1, the mean retinol levels remain lower than those of women in other countries. Thus, despite the implementation of the VAS and food fortification programs, VAD still remains a moderate public health problem in South Africa, as the prevalence remains above 10%. Factors other than nutrient intake, such as inflammation, could be related to communicable diseases (including TB and HIV/AIDS) and NCDs and could be affecting the vitamin A status of South African women. This therefore calls for further studies to monitor the role played by inflammation, as shown by the trend of increasing VAD with an increase in CRP levels in South African women. This relationship between VAD and CRP has been documented in postpartum mothers in South Africa.[72] VAS is still an ongoing program for children aged 0–5 years, but VAS was stopped for postpartum women in 2011.[14] Alternative interventions for alleviating VAD as a public health problem in women of reproductive age should therefore be sought. Mason *et al.*[86] and the Development Bank of South Africa[87] suggest that policies aimed at the eradication of VAD should promote a more frequent intake of vitamin A, thereby targeting interventions on dietary diversity and evaluating/appraising the existing food fortification program. Furthermore, interventions aimed at eradicating food security by providing employment opportunities to enable economic freedom will improve access to vitamin A–rich foods and should be a nonnegotiable item on the South African policy agenda in order to eradicate VAD in the country.

One of the limitations of this study was the small sample size, which was a result of the low response rate (29%) for blood specimen collection in the SANHANES-1, as well as the study design that required collection of questionnaire-based data and clinical data on people of all ages. However, this was accounted for when the data were weighted. Another limitation is that a clear comparison of the outcomes of the current study with other international studies was not possible, since SANHANES-1 defined women of reproductive age as those aged 16–35 years in order for data to be comparable to previous South African data (NFCS-FB),[49] and not 15–49 years as per the WHO definition.[88] The outcomes of the current study could nonetheless be used as a motivation to conduct similar nationally representative studies to better understand the presentation and the mechanisms involved in the pathophysiology of VAD. Moreover, investigating vitamin A status on the basis of serum retinol levels limited the outcomes of the current study, given that serum retinol is not necessarily an efficient marker of vitamin A intake or clinical VAD.[7] Therefore, undertaking additional research using other biological, functional, and histological indicators, as well as clinical signs, such as xerophthalmia, serum retinol-binding proteins, night blindness, and Bitot's spots, among others, would improve the evidence based on the prevalence of VAD in South African women and provide comparisons with existing data based on serum retinol. Finally, including indicators, such as VAS and parity, as some of the confounders of VAD in the target population could have strengthened the study's outcomes, given the evidence that VAD increases with an increase in parity.[65]

In conclusion, most data on VAD are collected via maternal and child health studies, and there is strong evidence on the prevalence of VAD in children and pregnant women globally and regionally. However, there is a dearth of data on the prevalence of VAD in the general population of women aged 16–35 years. The strength of this study is thus that it adds to the body of knowledge on the prevalence of VAD in the general population of women aged 16–35 years, identifies opportunities for targeted interventions, and highlights the most opportune time for the implementation of interventions. Women are typically responsible for procuring and preparing foods in the household. By empowering women and educating women on healthy food choices, we will be able to address both the treatment and prevention of VAD. Proposed longer-term methods of addressing VAD include dietary diversification/modification by promoting the production (at large scales (agriculture) and small scales (home gardens)) and consumption of micronutrient-rich foods. Introduction of indigenous foods (such as yellow sweet potato and green leafy wild vegetables) could also be of great help in curbing VAD in the country.[89–92]

Acknowledgments

All authors contributed to writing this manuscript. We thank all the experts who gave technical support in this research (as they are listed in the SANHANES-1 report). We also extend our gratitude to the community leaders and the South Africans who participated in the survey. SANHANES-1 was funded by the South African Department of Health, the U.K. Department of International Development, and the Human Sciences Research Council (HSRC). The secondary analysis was funded by the Sackler Institute for Nutrition Science, the New York Academy of Sciences.

Competing interests

The authors declare no competing interests.

References

1. World Health Organization. 2017. Micronutrient deficiencies: vitamin A deficiency. Accessed August 23, 2017. http://www.who.int/nutrition/topics/vad/en/.
2. Dieticians of Canada. 2014. Food sources of vitamin A. Accessed August 22, 2017. https://www.dietitians.ca/your-health/nutrition-a-z/vitamins/food-sources-of-vitamin-a.aspx.
3. World Health Organization. 2009. Global prevalence of vitamin A deficiency in populations at risk 1995–2005. WHO Global Database on vitamin A Deficiency. Geneva: World Health Organization.
4. Labadarios, D., A. Van Middelkoop, A. Coutsoudis, *et al.* 1995. Children aged 6–71 months in South Africa, 1994: their anthropometric, vitamin A, iron and immunisation coverage status. The South African Vitamin A Consultative Group (SAVACG), Isando, Johannesburg. Accessed September 28, 2017. http://www.sun.ac.za/english/faculty/healthsciences/Human%20Nutrition/Pages/SAVACG-Report.aspx.
5. Food and Agriculture Organization and World Health Organization. 2001. Human vitamin and mineral requirements. Report of a joint FAO/WHO expert consultation Bangkok, Thailand. Rome: FAO Food and Nutrition Division.
6. Akhtar, S., A. Ahmed, M.A. Randhawa, *et al.* 2013. Prevalence of vitamin A deficiency in South Asia: causes, outcomes and possible remedies. *J. Health Popul. Nutr.* **31:** 413–423.
7. World Health Organization. 2011. Serum retinol concentrations for determining the prevalence of vitamin A deficiency in populations. Vitamin and Mineral Nutrition Information System. Geneva: World Health Organization.
8. World Health Organization.1996. Indicators for assessing vitamin a deficiency and their application in monitoring and evaluation intervention programmes. Geneva: World Health Organization.
9. Murray, C.J.L., R.M. Barber, K.J. Foreman, *et al.* 2015. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. *Lancet* **386:** 2145–2191.
10. Labadarios, D., N.P. Steyn, C. Mgijima, *et al.* 2005. Review of the South African nutrition policy 1994–2002 and targets for 2007: achievements and challenges. *Nutrition* **21:** 100–108.
11. Graham, L., T. Hochfeld, L. Stuart, *et al.* 2015. Evaluation study of the National School Nutrition Programme and the Tiger Brands Foundation in-school breakfast feeding programme in the Lady Frere and Qumbu Districts of the Eastern Cape. Centre for Social Development in Africa, Department of Basic Education, University of Johannesburg, Republic of South Africa. Accessed September 28, 2017. https://www.uj.ac.za/faculties/humanities/csda/Documents/TBF%20Nutrition%20Report%202015%20FINAL%20WEB%20VERSION.PDF.
12. Department of Health. 1998. Integrated Nutrition Programme for South Africa. Summary of Broad Guidelines for Implementation. Pretoria: Department of Health.
13. World Health Organization. 2011. Guideline: vitamin A supplementation in postpartum women. Geneva: World Health Organization.
14. Department of Health, South Africa. 2012. National vitamin a supplementation policy guidelines for South Africa Pretoria: Department of Health.
15. Hurt, L., A. ten Asbroek, S. Amenga-Etego, *et al.* 2013. Effect of vitamin A supplementation on cause-specific mortality in women of reproductive age in Ghana: a secondary analysis from the ObaapaVitA trial. *Bull. World Health Organ.* **91:** 19–27.

16. South African Department of Health. 2016. Foodstuffs, cosmetics and disinfectants ACT, 1972 (ACT No. 54 of 1972). Regulations relating to the fortification of certain foodstuffs. Government Gazette March 3, 2016, Republic of South Africa. Accessed August 23, 2017. http://www.gov.za/sites/www.gov.za/files/39776_gon217.pdf.
17. Department of Basic Education. 2014. National School Nutrition Programme Grants Framework 2014/2015. Pretoria: Department of Basic Education.
18. Nojilana, B., R. Norman, D. Bradshaw, *et al.* 2007. Estimating the burden of disease attributable to vitamin A deficiency in South Africa in 2000. *S. Afr. Med. J.* **97:** 748–753.
19. Van der Berg, S. 2006. Public spending and the poor since the transition to democracy. In *Poverty and Policy in Post-Apartheid South Africa.* H. Bhorat & R. Kanbur, Eds.: 201–231. Cape Town: HSRC Press.
20. Department of Planning, Monitoring and Evaluation, South Africa. 2014. Development indicators 2014. Pretoria: The Presidency, Republic of South Africa.
21. Netshitenzhe, J. 2007. Development indicator mid-term review. The Presidency, Republic of South Africa, Pretoria.
22. Kassu, A., N. van Nhien, M. Nakamori, *et al.* 2007. Deficient serum retinol levels in HIV-infected and uninfected patients with tuberculosis in Gondar, Ethiopia. *Nutr. Res.* **27:** 86–91.
23. Mulu, A., A. Kassu, K. Huruy, *et al.* 2011. Vitamin A deficiency during pregnancy of HIV infected and non-infected women in tropical settings of Northwest Ethiopia. *BMC Public Health* **11:** 569.
24. Kassu, A., B. Andualem, N. Van Nhien, *et al.* 2007. Vitamin A deficiency in patients with diarrhea and HIV infection in Ethiopia. *Asia Pac. J. Clin. Nutr.* **16:** 323–328.
25. Semba, R.D., W.T. Caiaffa, N.M.H. Graham, *et al.* 1995. Vitamin A deficiency and wasting as predictors of mortality in human immunodeficiency virus-infected injection drug users. *J. Infect. Dis.* **171:** 1196–1202.
26. Semba, R.D., N.M.H. Graham, W.T. Caiaffa, *et al.* 1993. Increased mortality associated with vitamin A deficiency during human immunodeficiency virus type 1 infection. *Arch. Intern. Med.* **153:** 2149–2154.
27. Semba, R.D., J.D. Chiphangwi, P.G. Miotti, *et al.* 1994. Maternal vitamin A deficiency and mother-to-child transmission of HIV-1. *Lancet* **343:** 1593–1597.
28. Dushimimana, A., M.N. Graham, J.H. Humphrey, *et al.* 1992. Maternal vitamin A levels and HIV-related birth outcome in Rwanda [Abstract No. POC 4221.]. In *8th International Conference on AIDS*, Amsterdam.
29. Madebo, T., B. Lindtjørn, P. Aukrust, *et al.* 2003. Circulating antioxidants and lipid peroxidation products in untreated tuberculosis patients in Ethiopia. *Am. J. Clin. Nutr.* **78:** 117–122.
30. Semba, R.D., P.G. Miotti, J.D. Chiphangwi, *et al.* 1995. Infant mortality and maternal vitamin A deficiency during human immunodeficiency virus infection. *Clin. Infect. Dis.* **21:** 966–972.
31. Graham, N., M. Bulterys, A. Chao, *et al.* 1993. Effect of maternal vitamin A deficiency on infant mortality and perinatal HIV transmission. In *National Conference on Human Retroviruses and Related Infection*, Johns Hopkins University, Baltimore.
32. Pakasi, T.A., E. Karyadi, Y. Wibowo, *et al.* 2009. Vitamin A deficiency and other factors associated with severe tuberculosis in Timor and Rote Islands, East Nusa Tenggara Province, Indonesia. *Eur. J. Clin. Nutr.* **63:** 1130.
33. Tanaka, T., S. Sakurada, K Kano, *et al.* 2011. Identification of tuberculosis-associated proteins in whole blood supernatant. *BMC Infect. Dis.* **11:** 71.
34. Muñoz, E.C., J.L. Rosado, P. López, *et al.* 2000. Iron and zinc supplementation improves indicators of vitamin A status of Mexican pre-schoolers. *Am. J. Clin. Nutr.* **71:** 789–794.
35. West Jr., K.P. 2003. Vitamin A deficiency disorders in children and women. *Food Nutr. Bull.* **24**(4 Suppl.): S78–S90.
36. Kimmons, J.E., H.M. Blanck, B.C. Tohill, *et al.* 2006. Associations between body mass index and the prevalence of low micronutrient levels among US adults. *MedGenMed* **8:** 59.
37. Abrams, B., B. Heggeseth, D. Rehkopf, *et al.* 2013. Parity and body mass index in US women: a prospective 25-year study. *Obesity* **21:** 1514–1518.
38. Kuo, S.M. & M.M. Halpern. 2011. Lack of association between body mass index and plasma adiponectin levels in healthy adults. *Int. J. Obes.* **35:** 1487.
39. Vitkova, M., E. Klimcakova, M. Kovacikova, *et al.* 2007. Plasma levels and adipose tissue messenger ribonucleic acid expression of retinol-binding protein 4 are reduced during calorie restriction in obese subjects but are not related to diet-induced changes in insulin sensitivity. *J. Clin. Endocrinol. Metab.* **92:** 2330–2335.
40. Smith, A.M. & K.I. Baghurst. 1992. Public health implications of dietary differences between social status and occupational groups. *J. Epidemiol. Community Health* **46:** 409–416.
41. Yoon, Y.S., S.W. Oh & H.S. Park. 2006. Socioeconomic status in relation to obesity and abdominal obesity in Korean adults: a focus on sex differences. *Obesity* **14:** 909–919.
42. Academy of Science of South Africa. 2007. HIV/AIDS, TB and nutrition: scientific inquiry into the nutritional influences on human immunity with special reference to HIV infection and active TB in South Africa. Pretoria: Academy of Science of South Africa.
43. Oelofse, A., M. Faber, J.G. Benadé, *et al.* 1999. The nutritional status of a rural community in KwaZulu-Natal, South Africa: the Ndunakazi project. *Cent. Afr. J. Med.* **45:** 14–19.
44. Faber, M., V.B. Jogessar & A.J.S. Benadé. 2001. Nutritional status and dietary intakes of children aged 2–5 years and their caregivers in a rural South African community. *Int. J. Food Sci. Nutr.* **52:** 401–411.
45. Kruger, H.S., A. Kruger, H.H. Vorster, *et al.* 2005. Urbanization of Africans in the North West Province is associated with better micronutrient status: the transition and health during urbanization study in South Africa. *Nutr. Res.* **25:** 365–375.
46. Sibeko, L.N., M.A. Dhansay, K.E. Charlton, *et al.* 2004. Full-term, peri-urban South African infants under 6 months of age are at risk for early-onset anaemia. *Public Health Nutr.* **7:** 813–820.
47. Visser, M.E., G. Maartens, G. Kossew, *et al.* 2003. Plasma vitamin A and zinc levels in HIV-infected adults in Cape Town, South Africa. *Br. J. Nutr.* **89:** 475–482.

48. Labadarios, D., N.P. Steyn, E. Maunder, *et al.* 2005. The National Food Consumption Survey (NFCS): South Africa, 1999. *Public Health Nutr.* **8:** 533–543.
49. Labadarios, D., R. Swart, E.M.W. Maunder, *et al.* 2008. Executive summary of the National Food Consumption Survey Fortification Baseline (NFCS-FB-I) South Africa, 2005. *S. Afr. J. Clin. Nutr.* **21**(Suppl. 2): 245–300.
50. Shisana, O., D. Labadarios, T. Rehle, *et al.* 2014. The South African National Health and Nutrition Examination Survey, 2012: SANHANES-1: the Health and nutritional status of the nation. Cape Town: HSRC Press. Accessed August 14, 2017. http://www.hsrcpress.ac.za/product.php?productid=2314&cat=0&page=1&featured&freedownload=1.
51. Statistics South Africa. 2012. Census 2011 statistical release—P0301.4. Pretoria: Statistics South Africa.
52. Food and Agriculture Organization. 2010. Guidelines for measuring household and individual dietary diversity. Accessed August 24, 2017. http://www.fao.org/3/a-i1983e.pdf.
53. Wehler, C.A., R.I. Scott & J.J. Anderson. 1992. The Community Childhood Hunger Identification project: a model of domestic hunger—demonstration. *J. Nutr. Educ.* **24:** 295–355.
54. World Health Organization. 2014. C-reactive protein concentrations as a marker of inflammation or infection for interpreting biomarkers of micronutrient status. Vitamin and Mineral Nutrition Information System. Geneva: World Health Organization.
55. Pearson, T.A., G.A. Mensah, R.W. Alexander, *et al.* 2003. Markers of inflammation and cardiovascular disease application to clinical and public health practice: a statement for healthcare professionals from the Centers for Disease Control and Prevention and the American Heart Association. *Circulation* **107:** 499–511.
56. Lee, R.D. & D.A. Nieman. 2013. *Nutritional Assessment.* 6th ed., International ed. Columbus, OH: McGraw-Hill.
57. Centers for Disease Prevention & Control. 2015. About child & teen BMI. Accessed May 25, 2017. https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html.
58. Centers for Disease Prevention & Control. 2015. About adult BMI. Accessed May 25, 2017. https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html.
59. Bonti-Ankomah, S. 2001. Addressing food insecurity in South Africa. In *SARPN Conference on Land Reform and Poverty Alleviation in Southern Africa*, The National Institute for Economic Policy, Pretoria.
60. Kirkwood, B.R., L. Hurt, S. Amenga-Etego, *et al.* 2010. Effect of vitamin A supplementation in women of reproductive age on maternal survival in Ghana (ObaapaVitA): a cluster randomised, placebo-controlled trial. *Lancet* **375:** 1640–1649.
61. West Jr., K.P., J. Katz, S.K. Khatry, *et al.* 1999. Double blind, cluster randomised trial of low dose supplementation with vitamin A or beta carotene on mortality related to pregnancy in Nepal. The NNIPS-2 Study Group. *Br. Med. J.* **318:** 570–575.
62. Laillou, A., T.V. Pham, N.T. Tran, *et al.* 2012. Micronutrient deficits are still public health issues among women and young children in Vietnam. *PLoS One* **7:** e34906.
63. Andreto, L.M., I.K. Grande de Arruda, A.I. Souza, *et al.* 2012. Effects of two maternal vitamin A supplementation regimens on serum retinol in postpartum mothers: a randomised controlled trial in Brazil. *ISRN Public Health* **2012:** 121697.
64. Jafari, S.M., G. Heidari, I. Nabipour, *et al.* 2013. Serum retinol levels are positively correlated with haemoglobin concentrations, independent of iron homeostasis: a population-based study. *Nutr. Res.* **33:** 279–285.
65. Gebreselassie, S.G., F.E. Gase & M.U. Deressa. 2013. Prevalence and correlates of prenatal vitamin A deficiency in rural Sidama, Southern Ethiopia. *J. Health Popul. Nutr.* **31:** 185–194.
66. Statistics South Africa. 2010. Estimation of fertility from the 2007 community survey of South Africa. Pretoria: Statistics South Africa.
67. Statistics South Africa. 2015. Census 2011: fertility in South Africa. Pretoria: Statistics South Africa.
68. Labadarios, D., Z.J.-R. Mchiza, N.P. Steyn, *et al.* 2011. Food security in South Africa: a review of national surveys. *Bull. World Health Organ.* **89:** 891–899.
69. Statistics South Africa. 2014. Poverty trends in South Africa: an examination of absolute poverty between 2006 and 2011. Pretoria: Statistics South Africa.
70. Temple, N.J., N.P. Steyn, J. Fourie, *et al.* 2011. Price and availability of healthy food: a study in rural South Africa. *Nutrition* **27:** 55–58.
71. Drewnowski, A. 2010. The cost of US foods as related to their nutritive value. *Am. J. Clin. Nutr.* **92:** 1181–1188.
72. van Stuijvenberg, M.E., S.E. Schoeman, J. Nel, *et al.* 2017. Serum retinol in post-partum mothers and newborns from an impoverished South African community where liver is frequently eaten and vitamin A deficiency is absent. *Matern. Child Nutr.* **13**. https://doi.org/10.1111/mcn.12223.
73. Aliber, M. 2009. Exploring statistics South Africa's national household surveys as sources of information about food security and subsistence agriculture. Human Sciences Research Council, Pretoria.
74. Baiphethi, M.N. & P.T. Jacobs. 2009. The contribution of subsistence farming to food security in South Africa. *Agrekon* **48:** 459–482.
75. Aliber, M. 2005. Trends and Policy Challenges in the Rural Economy: Four Provincial Case Studies. Cape Town: HSRC Press.
76. Tibesigwa, B. & M. Visser. 2015. Small-scale subsistence farming, food security, climate change and adaptation in South Africa: male–female headed households and urban–rural nexus. Economic Research Southern Africa, Cape Town.
77. Ghalaeh, R.S., Z. Gholi, S.S. Bank, *et al.* 2012. Fruit and vegetable intake, body mass index and waist circumference among young female students in Isfahan. *J. Educ. Health Promot.* **1:** 29.
78. Kaidar-Person, O., B. Person, S. Szomstein, *et al.* 2008. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? *Obes. Surg.* **18:** 1028–1034.
79. Gamble, M.V., R. Ramakrishnan, N.A. Palafox, *et al.* 2001. Retinol binding protein as a surrogate measure for serum retinol: studies in vitamin A-deficient children from the

Republic of the Marshall Islands. *Am. J. Clin. Nutr.* **73:** 594–601.
80. Graham, T.E., Q. Yang, M. Blüher, *et al.* 2006. Retinol-binding protein 4 and insulin resistance in lean, obese, and diabetic subjects. *N. Engl. J. Med.* **354:** 2552–2563.
81. Qi, Q., Z. Yu, X. Ye, *et al.* 2007. Elevated retinol-binding protein 4 levels are associated with metabolic syndrome in Chinese people. *J. Clin. Endocrinol. Metab.* **92:** 4827–4834.
82. Kowalska, I., M. Strączkowski, A. Adamska, *et al.* 2008. Serum retinol binding protein 4 is related to insulin resistance and nonoxidative glucose metabolism in lean and obese women with normal glucose tolerance. *J. Clin. Endocrinol. Metab.* **93:** 2786–2789.
83. Medin, A.C., M.H. Carlsen & L.F. Andersen. 2016. Associations between reported intakes of carotenoid-rich foods and concentrations of carotenoids in plasma: a validation study of a web-based food recall for children and adolescents. *Public Health Nutr.* **19:** 3265–3275.
84. Charlton, K., P. Kowal, M.M. Soriano, *et al.* 2014. Fruit and vegetable intake and body mass index in a large sample of middle-aged Australian men and women. *Nutrients* **6:** 2305–2319.
85. Azagba, S. & M.F. Sharaf. 2012. Fruit and vegetable consumption and body mass index: a quantile regression approach. *J. Prim. Care Community Health* **3:** 210–220.
86. Mason, J., T. Greiner, R. Shrimpton, *et al.* 2014. Vitamin A policies need rethinking. *Int. J. Epidemiol.* **44:** 283–292.
87. Development Bank of Southern Africa. 2008. South Africa nutrition input paper for health roadmap: combating malnutrition in South Africa. September 2008. Accessed August 14, 2017. http://www.dbsa.org.pdf.
88. World Health Organization. 2006. Reproductive Health Indicators: Guidelines for their Generation, Interpretation and Analysis for Global Monitoring. Geneva: World Health Organisation.
89. Modi, M., A. Modi & S. Hendriks. 2006. Potential role for wild vegetables in household food security: a preliminary case study in Kwazulu-Natal, South Africa. *Afr. J. Food Agric. Nutr. Dev.* **6:** 1–13.
90. Ruel, M.T. 2001. *Can Food-Based Strategies Help Reduce Vitamin A and Iron Deficiencies?: A Review of Recent Evidence.* Vol. **5**. Washington, DC: International Food Policy Research Institute.
91. Department of Agriculture, Republic of South Africa. 2002. The integrated food security strategy for South Africa. Pretoria: Department of Agriculture.
92. Shiundu, K.M. 2002. Role of African leafy vegetables (ALVs) in alleviating food and nutrition insecurity in Africa. *Afr. J. Food Nutr. Sci.* **2:** 96–97.