The use of predefined diet quality scores in the context of CVD risk during urbanization in the South African Prospective Urban and Rural Epidemiological (PURE) study

Robin C Dolman[1],*, Edelweiss Wentzel-Viljoen[1], Johann C Jerling[1], Edith JM Feskens[2], Annamarie Kruger[3] and Marlien Pieters[1]

[1]Centre of Excellence for Nutrition (CEN), North West University, Potchefstroom, 2520 South Africa: [2]Division of Human Nutrition, Wageningen University, Wageningen, The Netherlands: [3]Africa Unit for Trans disciplinary Health Research (AUTHeR), North West University, Potchefstroom, South Africa

Abstract

Objective: Urbanization is generally associated with increased CVD risk and accompanying dietary changes. Little is known regarding the association between increased CVD risk and dietary changes using approaches such as diet quality. The relevance of predefined diet quality scores (DQS) in non-Western developing countries has not yet been established.

Design: The association between dietary intakes and CVD risk factors was investigated using two DQS, adapted to the black South African diet. Dietary intake data were collected using a quantitative FFQ. CVD risk was determined by analysing known CVD risk factors.

Setting: Urban and rural areas in North West Province, South Africa.

Subjects: Apparently healthy volunteers from the South African Prospective Urban and Rural Epidemiological (PURE) study population (n 1710).

Results: CVD risk factors were significantly increased in the urban participants, especially women. Urban men and women had significantly higher intakes of both macro- and micronutrients with macronutrient intakes well within the recommended CVD guidelines. While micronutrient intakes were generally higher in the urban groups than in the rural groups, intakes of selected micronutrients were low in both groups. Both DQS indicated improved diet quality in the urban groups and good agreement was shown between the scores, although they seemed to measure different aspects of diet quality.

Conclusions: The apparent paradox between improved diet quality and increased CVD risk in the urban groups can be explained when interpreting the cut-offs used in the scores against the absolute intakes of individual nutrients. Predefined DQS as well as current guidelines for CVD prevention should be interpreted with caution in non-Western developing countries.

Keywords
Diet quality scores
Urbanization
CVD risk

In developing countries, the process of urbanization and modernization of lifestyles has marked effects on populations. While still battling infectious diseases, these countries are also facing an increase in non-communicable diseases[1]. With urbanization in low- and middle-income countries there is an increase in socio-economic status, which is usually accompanied by an increase in most risk factors for CVD[2]. These risk factors include obesity and increased dietary intakes of total fat and saturated fat, as has been observed in the North West Province of South Africa in the Transition and Health during Urbanization in South Africans (THUSA) study[3], as well as in other developing countries[4]. Among numerous other factors, this increase in CVD risk has been ascribed to a worsening diet in populations as they transition from a rural to an urban lifestyle. Traditionally, in South Africa, the diet was low in fat and sugar and rich in fibre[5]. Due to urbanization and the resultant increase in socio-economic status, the diet now tends to be richer in animal products, refined grains, fats, salt and sugar, and lower in fibre[3,6].

Until now, the effect of urbanization on diet has been investigated by looking mostly at the nutrient composition of diets. However, the failure of single-nutrient supplementation to protect against CVD[7] and cancers[8,9] highlighted the fact that it was important to develop a more holistic view of food intake. Foods are biochemically complex and contain compounds that may interact with each other. By investigating not only nutrients but also

foods and dietary quality, the complexity of dietary behaviours and interactions are taken into account. One way of assessing dietary quality is to use theoretically defined dietary patterns that are based on current nutrition knowledge. These theoretical or predefined diet quality scores (DQS) consist of foods and/or nutrients which are considered to be important to health[10].

In a critical review of predefined DQS, Waijers et al. (2007)[10] made recommendations regarding the decisions that need to be made when constructing a DQS. It is advised that a score should contain two macronutrients (fat, carbohydrate or protein) to ensure overall balance. It is also desirable to let the score be proportional to intake, instead of using simple cut-off values, or else to design a scoring range. To avoid confounding by energy intake, scores should depend on or be adjusted for energy intake. Another important issue to be taken into account is that food intake is culturally determined and therefore general dietary habits within the population being studied need to be considered when the score items and their cut-offs are chosen. The score should also be constructed in such a way that an acceptable dietary variety is ensured of obtaining a high score, but variety does not necessarily have to be included as a score item. It is also advisable to select more than one score when evaluating diet quality[11].

Using these criteria, two scores were selected from the numerous available DQS to assess diet quality in our study population. The first is a score developed by Thiele et al.[12] which was adapted to the South African diet and renamed the Adapted Thiele Score (see 'Materials and methods' section for more details); the second is the Healthy Diet Indicator (HDI)[13]. The rationale for electing to use these specific DQS over the other known scores is that not only nutrients but also food groups are included, and that diet quality is assessed in relation to known and proven dietary guidelines specifically for the prevention of CVD. It will also be relatively simple to fit South African foods into the food groups used in these scores.

The aim of the present study was therefore to relate the dietary intakes of the South African Prospective Urban and Rural Epidemiological (PURE) study population (n 2010) using both nutrient intakes and diet quality, to CVD risk associated with urbanization. The PURE study is a large-scale cohort study that tracks changing lifestyles, risk factors and chronic disease using periodic standardized data collection in urban and rural areas of seventeen countries in transition[14].

Materials and methods

The present study used baseline data collected over a 12-week period in 2005, from 2010 randomly selected volunteers in the South African arm of the PURE study. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human volunteers were approved by the Ethics Committee of the North West University, South Africa (No. 04M10). The volunteers signed informed consent before commencement of the study, after the study was explained to them in their home language. All data were treated confidentially and all analyses were performed with coded data. Black South African men (n 750) and women (n 1260) older than 35 years were recruited from 6000 randomly selected households. From these households, 1006 volunteers were recruited from rural (living under tribal law) and 1004 from urban areas (living in informal and formal settlements surrounding cities) in the North West Province of South Africa. Volunteers were included if they were apparently healthy. Exclusion criteria were the use of chronic medication for non-communicable diseases and/or any self-reported illness. For various reasons dietary intake and anthropometric data could not be collected from some volunteers, who were consequently excluded from the data set, resulting in the total study population of 1710.

Details regarding the collection of socio-economic information, anthropometry measurements, blood collection, blood pressure and physical activity have been reported previously[15–17].

A culturally sensitive quantitative (QFFQ) was completed by trained field workers in the respondents' language of choice. The QFFQ with good reproducibility[18] was previously developed[19] and validated in this population using 7 d weighed records and biomarkers[20]. Portion sizes were estimated using food portion photographs[21], appropriate utensils and containers and examples of specific foods. Portion sizes were reported in household measurements and converted to weights using standard tables[22]. The QFFQ was completed for foods eaten over the previous 30 d. The food intake was coded according to the South African Food Composition Database System of the South African Medical Research Council and then used to calculate the nutrient and food group intakes[23–25].

Diet quality scores

Table 1 presents the components and cut-off points of the HDI[13] and the Deficiency Score/Excess Score by Thiele et al.[12], which were used in the present study. The score by Thiele et al. suggested using up to thirty nutrients in a Deficiency Score to identify a preferable diet quality and using six nutrients in an Excess Score to identify a nonpreferable diet quality. After assessing the completeness of the relevant micronutrients in the South African Food Composition Database System, nineteen nutrients were used for the Deficiency Score in the present study and the suggested six were used for the Excess Score. The Estimated Average Requirement (EAR) or Adequate Intake (AI), when an EAR was not available, was used as cut-off points in the score[26–30]. Intake was then calculated as a percentage of the EAR or AI. Intake equal to or higher

Table 1 Components of diet quality scores

Nutrient or food group (daily intake)	Units	Age (years)	Cut-off values	
			Men	Women
Healthy Diet Indicator[13]				
SFA*	g		<10	<10
PUFA*	g		6–10	6–10
Protein*	%TE		10–15	10–15
Complex carbohydrates*	%TE		50–70	50–70
Dietary fibre*	g		>25	>25
Fruit and vegetables*	g		>400	>400
Pulses, nuts and seeds*	g		>30	>30
Mono- and disaccharides*	%TE		<10	<10
Cholesterol*	mg		<300	<300
Deficiency Score[12]				
Protein†	%TE		15	15
Carbohydrate†	%TE		55	55
Total fibre‡	g	<51	38	25
		>51	30	21
Ca‡	mg	19–50	1000	1000
		>51	1200	1200
Mg§	mg	>31	350	265
Fe§	mg	31–50	6·0	8·1
		>50	6·0	5·0
Zn§	mg	>31	9·4	6·8
Mn‡	mg	>31	2·3	1·8
K‡	mg	>31	4700	4700
Cu§	μg	>31	700	700
Vitamin A§	μg	>31	625	500
Thiamin§	mg	>31	1·0	0·9
Riboflavin§	mg	>31	1·1	0·9
Niacin§	mg	>31	12	11
Vitamin B$_6$§	mg	31–50	1·1	1·1
		>51	1·4	1·3
Folate§	μg	>31	320	320
Vitamin B$_{12}$§	μg	>31	2·0	2·0
Pantothenic acid‡	mg	>31	5·0	5·0
Vitamin C§	mg	>31	75	60
Excess Score[12]				
Total fat*	%TE		30	30
Saturated:unsaturated fatty acids			1:2	1:2
Cholesterol*	mg		<300	<300
Alcohol‖	g		30	15
Added sugar*†	%TE		10	10
Na‡	mg	31–50	1500	1500
		>51	1300	1300

%TE, percentage of total energy (excluding energy from alcohol).
*Criteria used for cut-off values are WHO guidelines for prevention of chronic disease[34].
†Dietary reference intake: Acceptable Macronutrient Distribution Ranges[30].
‡Dietary reference intake: Adequate Intake[26–29].
§Dietary reference intake: Estimated Average Requirement[26–29].
‖From Van Heerden and Parry[46].

than the EAR or AI was allocated 100 %. The scores were added up, giving a total of 1900 for the Deficiency Score and 600 for the Excess Score. To simplify the interpretation, it was decided to combine the Deficiency Score and Excess Score into one score by subtracting the Excess Score from the Deficiency Score, now called the Adapted Thiele Score. This principle of being 'penalized' for non-preferable dietary intakes is used in most DQS[31–33]. The original HDI score was adapted for the present study by first using the more recent WHO prevention of CVD guidelines[34] for the cut-off points and second by changing the scoring system from a dichotomous variable (1 or 0) to a continuous score in order to provide a more sensitive scoring range, instead of using very strict cut-offs.

An additional modification regarding Na intake was made, due to the fact that the QFFQ did not specifically evaluate the intake of discretionary salt. Charlton *et al.*[35] showed that discretionary salt intake made up 45·5 % of total Na intake in black South Africans. The Na intake of the population was therefore adjusted by adding 46 % to the Na intake. Another modification was made regarding the cut-off point for fat, since the fat intake of this population was quite low with a mean of 24 % of total energy. The cut-off for total fat intake in the Excess Score was lowered from 35 % to 30 %, so that those taking a higher fat intake within the study population would be 'penalized'. The last adjustment that was made was to remove the contribution of alcohol to total energy intake.

The median intake of alcohol was alarmingly high, particularly in the men, as has been previously described[36]. This was diluting the contribution of the macronutrients to energy, particularly in those with a very high alcohol intake.

Statistical analysis

Data were analysed using the statistical software package IBM SPSS Statistics 20. A *P* value ≤0·05 was regarded as statistically significant. Normally distributed variables are reported as mean and 95% confidence interval, and non-normally distributed data as median and 25th–75th percentile. Mann–Whitney *U* tests were used for comparisons between two groups. ANOVA, with *post hoc* comparisons, was used for comparison between three or more groups. Bland–Altman plots were constructed to assess the agreement between the two DQS.

Results

Table 2 provides details on the general characteristics of the total study population, as well as for the rural men and women and the urban men and women separately. The urban women had a significantly higher BMI, waist circumference, TAG, C-reactive protein and fasting glucose levels than their rural counterparts. Both systolic and diastolic blood pressures were significantly higher in the urban men and women, compared with the rural groups. The same was seen for plasminogen activator inhibitor-1 levels. The rural groups were significantly more active than their urban counterparts. In the rural groups the majority of men and women were uneducated, while in the urban groups, the majority had a primary school education. About 17% of the total group were newly diagnosed as HIV positive, with no significant differences between the rural and urban groups.

Table 3 provides the mean DQS scores and the mean intakes of the nutrients and foods that were used in the calculation of the DQS for the rural and urban groups. This table shows that the urban men and women had significantly higher dietary intakes than their rural counterparts for all nutrients and foods, except for carbohydrate as a percentage of energy. Table 3 also provides the percentage difference between the urban and rural groups' intakes, where urban intakes are expressed as a percentage increase or decrease compared with the rural intakes. Fat intake was over 40% and Na intake over 100% higher in the urban groups. Intakes of vitamin C, vitamin B$_{12}$, vitamin A and riboflavin in the urban groups were more than double the intakes in the rural groups, with Ca intake in urban women being more than twice as high as that seen in rural women.

It is also evident that although nutrients such as total fat as a percentage of energy and cholesterol, as well as foods such as fruit and vegetables and pulses, nuts and seeds were significantly higher in the urban than the rural

groups, they were still below the relevant guidelines. The median percentage of energy from total fat in the urban groups, although still below, was however approaching the CVD guideline of 30%. When looking at Table 4, it is clear that micronutrient intakes of this population are of concern, as can be seen from the large percentage of both the rural and urban groups that did not meet the EAR/AI. When comparing micronutrients expressed as a percentage of the EAR/AI, it is clear that the urban groups' median intakes were above 100% for twelve of the eighteen micronutrients (Fe, vitamin B$_{12}$, Cu, thiamin, vitamin A, niacin, vitamin B$_6$, folate, riboflavin, Zn, Mn and Mg), while it was not the case for the rural groups (four only). Despite the higher micronutrient intakes in the urban groups compared with the rural groups, micronutrients specifically linked to CVD prevention such as fibre, Ca, K and vitamin C were far below the EAR/AI in both the rural and urban groups.

Both DQS also indicated improved diet quality in the urban groups compared with the rural groups (Table 3). The HDI indicated a 7% and 5% increase in diet quality in the urban men and women respectively compared with their rural counterparts. When comparing the Deficiency Scores and Excess Scores which make up the Adapted Thiele Score, it is clear that the rural–urban increases of the Deficiency Score (17% and 17% for men and women respectively) were higher than the increases in the Excess Score (0·4% and 2%). In order to determine the agreement between the two DQS, each participant's scores were expressed as a percentage of the total score. The scores as percentages of the total were then correlated with each other. The two scores correlated significantly with each other for both the rural ($r = 0·6$; $P < 0·0001$) and the urban ($r = 0·7$; $P < 0·0001$) groups. In order to determine whether the differences between the scores were consistent across the total range of DQS values, Bland–Altman plots were constructed (Fig. 1). At a percentage of less than 70% of the total possible DQS, the HDI gave consistently higher scores than the Adapted Thiele Score, while at a percentage of greater than 70% the Adapted Thiele Score gave consistently higher scores. This explains the agreement between the two scores in the rural group, where the median DQS expressed as a percentage of the total was about 70% (72% for HDI in men and women; 72% and 73% for Adapted Thiele Score in men and women respectively), and the disagreement between the two scores in the urban groups with the higher DQS (where the median HDI was 77% and 76% for men and women respectively and the Adapted Thiele Score was 84% for both men and women).

Discussion

The present study is one of only a few to investigate the association between increased CVD risk during

Table 2 Comparison of general characteristics of study participants according to sex and rural/urban grouping: apparently healthy volunteers from the South African Prospective Urban and Rural Epidemiological (PURE) study population (n 1710)

	Total (n 1710)		Men Rural (n 314)		Urban (n 328)			Women Rural (n 588)		Urban (n 480)		
	Median or mean	P25–P75 or 95 % CI	Median or mean	P25–P75 or 95 % CI	Median or mean	P25–P75 or 95 % CI	P	Median or mean	P25–P75 or 95 % CI	Median or mean	P25–P75 or 95 % CI	P
Age (years)	48·0	41·0–56·0	48·0	41·0–56·3	49·0	42·0–58·0	0·33	46·0	40·0–54·0	48·5	42·0–58·8	<0·0001
BMI (kg/m^2)	22·8	19·3–28·4	19·7	18·1–22·3	20·0	18·3–22·8	0·43	24·6	20·7–30·2	27·0	22·2–32·5	<0·0001
WC (cm)	77·0	70·2–87·4	74·6	70·1–80·5	74·4	70·0–81·4	0·85	78·2	69·3–89·1	82·1	72·7–92·6	<0·0001
TC (mmol/l)	5·03	1·33, 1·42	4·72	1·24, 1·45	4·89	1·20, 1·40	0·11	5·12	1·30, 1·45	5·22	1·33, 1·51	0·23
HDL-C (mmol/l)	1·42	1·06–1·89	1·41	1·02–1·95	1·52	1·13–2·05	0·06	1·41	1·09–1·85	1·36	1·01–1·78	0·21
LDL-C (mmol/l)	3·25	1·18, 1·26	2·96	1·10, 1·29	3·02	1·09, 1·28	0·56	3·36	1·17, 1·31	3·46	1·13, 1·28	0·19
TAG (mmol/l)	1·09	0·82–1·54	0·96	0·75–1·34	1·00	0·79–1·46	0·21	1·10	0·82–1·49	1·21	0·89–1·79	<0·001
SBP (mmHg)	133	132, 134	132	129, 135	138	135, 140	<0·01	127	125, 129	137	134, 139	<0·0001
DBP (mmHg)	87·4	86·7, 88·0	84·9	83·2, 86·6	88·0	86·5, 89·6	<0·01	86·6	85·4, 87·7	89·5	88·3, 90·8	<0·001
CRP (mg/l)	3·20	0·93–9·20	2·70	0·63–8·04	2·29	0·83–7·53	0·85	3·50	1·03–9·20	3·87	1·43–11·40	0·04
FG (mmol/l)	4·80	4·30–5·30	4·70	4·40–5·10	4·80	4·20–5·40	0·38	4·80	4·40–5·20	4·95	4·30–5·50	0·01
PAI-1 (U/ml)	4·27	1·24–7·99	1·95	0·00–4·72	2·85	0·18–6·74	<0·01	4·59	1·84–7·76	6·28	3·25–10·68	<0·0001
PAI (n 1645)	3·0	2·5–3·2	3·0	2·6–3·4	2·7	2·4–3·0	<0·0001	3·1	2·7–3·4	2·7	2·5–3·0	<0·0001
	n	%	n	%	n	%	P	n	%	n	%	P
Education	(n 1608)		(n 294)		(n 311)			(n 553)		(n 450)		
None	592	36·8	155	52·7	79	25·4	<0·00001	265	47·9	93	20·7	<0·00001
Primary school	668	41·5	92	31·3	150	48·2	<0·00001	169	30·6	257	57·1	<0·00001
Secondary school	336	20·9	43	14·6	78	25·1	<0·001	118	21·3	97	21·6	0·91
University/college	12	0·8	4	1·4	4	1·3	0·92	1	0·2	3	0·7	0·23
HIV status (newly diagnosed)	(n 1703)		(n 314)		(n 327)			(n 586)		(n 476)		
Positive	290	17·0	56	17·8	49	15·0	0·34	101	17·2	84	17·7	0·83
Negative	1413	83·0	258	82·2	278	85·0	0·34	485	82·8	392	82·4	0·86
Smoking status	(n 1702)		(n 313)		(n 325)			(n 587)		(n 477)		
Former	69	4·1	21	6·7	24	7·3	0·73	15	2·6	9	1·9	0·44
Current	897	52·7	173	55·3	209	64·3	<0·01	289	49·2	226	47·4	0·56
Never	736	43·2	119	38·0	325	28·3	<0·001	283	48·2	242	50·7	0·42

P25, 25th percentile; P75, 75th percentile; WC, waist circumference; TC, total cholesterol; HDL-C, HDL-cholesterol; LDL-C, LDL-cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure; CRP, C-reactive protein; FG, fasting glucose; PAI-1, plasminogen activator inhibitor-1; PAI, physical activity index.
Normally distributed data reported as mean and 95% confidence interval; non-parametric data reported as median and 25th–75th percentile.

Table 3 Comparison of nutrient and food group intakes, and diet quality scores, according to sex and rural/urban grouping: apparently healthy volunteers from the South African Prospective Urban and Rural Epidemiological (PURE) study population (n 1710)

	Men					Women				
	Rural (n 314)		Urban (n 328)		% difference between R and U*	Rural (n 588)		Urban (n 480)		% difference between R and U*
	Median	P25–P75	Median	P25–P75		Median	P25–P75	Median	P25–P75	
Nutrients										
Energy (kJ)	6029†	4765–7757	8603†	6516–11 288	42	5677‡	4446–7169	7664‡	5366–10 401	35
Protein (%TE)	11·6†	10·4–12·9	13·2†	12·0–14·2	13	11·1‡	10·0–12·3	12·9‡	11·8–14·1	16
Carbohydrate (%TE)	69·9†	64·9–73·9	59·9†	56·0–64·2	↓14	68·9‡	63·5–73·2	58·0‡	53·6–62·9	↓16
Total fat (%TE)	18·7†	15·0–23·3	26·7†	22·8–29·9	43	19·9‡	15·9–24·6	29·1‡	24·4–33·0	46
SFA (%TE)	3·94†	2·59–5·25	6·47†	5·34–7·79	64	4·14‡	2·90–5·77	7·19‡	5·92–8·77	74
PUFA (%TE)	6·10†	4·24–7·86	7·49†	6·14–9·19	23	6·61‡	4·86–8·52	8·17‡	6·56–9·71	24
Cholesterol (mg)	106†	56–153	234†	149–331	121	95‡	49–151	205‡	131–310	115
Added sugar (%TE)	6·13†	3·51–8·86	6·94†	4·63–9·88	13	6·76‡	3·79–10·40	8·38‡	6·08–11·10	24
Alcohol (g)	2·04†	0·00–28·60	11·6†	0·00–26·70	469	0·00‡	0·00–0·00	0·00‡	0·00–10·20	0
Dietary fibre (g)	18·1†	12·6–24·2	24·0†	16·5–33·2	33	16·5‡	12·5–21·3	20·4‡	13·3–28·5	24
Ca (mg)	213†	139–309	369†	277–535	73	186‡	114–267	368‡	263–586	98
Mg (mg)	277†	194–421	379†	277–519	37	225‡	172–299	296‡	203–402	32
Fe (mg)	11·9†	8·7–15·2	15·1†	10·8–20·9	27	10·6‡	8·1–13·4	12·3‡	8·3–17·5	16
Zn (mg)	8·27†	6·24–10·80	11·8†	8·58–16·80	43	7·34‡	5·62–9·34	9·62‡	6·74–14·00	31
Mn (mg)	1554†	834–3051	2488†	1765–3482	60	1158‡	667–1829	1998‡	1359–2913	73
K (mg)	1309†	956–1714	1988†	1449–2741	52	1160‡	905–1499	1828‡	1193–2488	58
Na (mg)	726†	361–1063	1673†	1179–2370	130	674‡	406–1039	1808‡	1229–2684	168
Cu (μg)	102†	76–139	139†	103–186	36	95‡	70–121	126‡	85–173	33
Vitamin A (μg)	409†	257–648	809†	523–1439	98	452‡	289–693	828‡	408–1398	83
Thiamin (mg)	1·54†	1·12–2·02	1·78†	1·31–2·68	16	1·36‡	1·04–1·74	1·41‡	0·98–2·10	4
Riboflavin (mg)	0·8†	0·6–1·4	1·5†	1·1–2·0	88	0·7‡	0·5–1·0	1·3‡	0·9–1·9	86
Niacin (mg)	11·3†	8·6–16·3	17·2†	13·0–23·2	52	9·9‡	7·6–12·6	14·3‡	9·9–20·4	44
Vitamin B6 (mg)	1·21†	0·84–1·61	1·67†	1·14–2·56	38	1·10‡	0·84–1·43	1·40‡	0·89–2·06	27
Folate (μg)	359†	228–460	438†	304–625	57	317‡	224–417	339‡	235–490	7
Vitamin B12 (μg)	1·52†	0·82–2·90	4·47†	2·45–7·47	194	1·54‡	0·68–2·93	4·00‡	2·08–6·74	159
Pantothenic acid (mg)	2·70†	1·92–3·63	4·65†	3·17–6·22	72	2·47‡	1·87–3·32	4·20‡	2·77–5·72	70
Vitamin C (mg)	11·2†	6·1–15·5	30·7†	17·8–55·4	174	11·9‡	7·3–17·6	32·1‡	17·0–53·9	170
Foods										
Fruit & vegetables (g)	58·9†	33·8–83·0	129†	81·4–216	119	69·3‡	43·6–100	148‡	84·6–231	114
Pulses, nuts, seeds (g)	0·0†	0·0–10·0	9·6†	0·0–28·6	860	0·0‡	0·0–11·6	11·0‡	0·0–29·4	900
Diet quality scores										
Adapted Thiele Score	1364†	1172–1504	1594†	1448–1662	17	1381‡	1169–1512	1592‡	1388–1684	15
% of total score		72		84			72		84	
Deficiency Score	1409†	1196–1549	1649†	1520–1753	17	1413‡	1215–1547	1657‡	1444–1765	17
New Excess Score	583	500–600	595	541–600	0·4	553	495–591	555	500–588	2
Healthy Diet Indicator	6·46†	5·91–6·89	6·94†	6·36–7·44	7	6·48‡	6·03–6·95	6·82‡	6·11–7·36	5
% of total score		72		77			72		76	

P25, 25th percentile; P75, 75th percentile; R, rural; U, urban; %TE, percentage of total energy.
Data reported as median and P25–P75.
*% indicates increase except for ↓ for carbohydrate, which indicates a decrease.
†Significant difference between rural and urban men: $P < 0.01$.
‡Significant difference between rural and urban women: $P < 0.01$.

Table 4 Nutrient intake expressed as a percentage of the EAR/AI for micronutrients and percentage who did not meet the EAR/AI: apparently healthy volunteers from the South African Prospective Urban and Rural Epidemiological (PURE) study population (*n* 1710)

	% of EAR/AI								Did not meet EAR/AI									
	Rural				Urban						Rural				Urban			
	Men (*n* 314)		Women (*n* 588)		Men (*n* 328)		Women (*n* 480)		Total (*n* 1710)		Men (*n* 314)		Women (*n* 588)		Men (*n* 328)		Women (*n* 480)	
	Median	P25–P75	Median	P25–P75	Median	P25–P75	Median	P25–P75	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Dietary fibre (g)	52·7*	36·4–71·4	70·0†	52·9–89·8	71·0*	46·7–100	85·7†	56·2–124	77·6	1327	95·2	299	84·5	497	75·0	246	59·4	285
Ca (mg)	19·4*	12·4–28·9	15·5†	9·5–22·2	35·3*	25·5–49·0	30·6†	21·9–48·8	99·0	1692	99·0	311	100·0	588	96·3	316	99·4	477
Mg (mg)	79·2*	55·5–120	70·4†	53·8–93·6	108*	79·0–148	92†	63·5–126	62·7	1072	66·6	209	80·1	471	40·6	133	54·0	259
Fe (mg)	198*	144–254	154†	109–200	252*	180–348	185†	125–278	14·7	251	13·7	43	18·0	106	7·0	23	16·5	79
Zn (mg)	88·0*	66·4–114	108†	82·7–137	126	91·3–178	141†	97·9–206	39·4	674	60·8	191	42·9	252	31·4	103	26·7	128
Mn (mg)	67·6*	36·2–133	64·3†	37·0–102	108*	76·7–151	111†	75·4–162	58·6	1002	67·2	211	74·3	437	46·0	151	42·3	203
K (mg)	27·9*	20·3–36·5	24·7†	19·2–31·9	42·3*	30·8–58·3	38·9†	25·4–52·9	99·0	1693	99·7	313	99·7	586	97·3	319	99·0	475
Na (mg)	30·9*	18·1–47·6	29·3†	17·0–44·9	73·2*	53·5–107	76·2†	51·3–112	84·6	1446	97·1	305	98·0	576	71·0	233	69·2	332
Cu (μg)	146*	108–199	135†	99·4–173	199*	147–265	181†	122–247	18·9	323	19·4	61	25·2	148	11·0	36	16·3	78
Vitamin A (μg)	81·8*	51·5–130	72·3†	46·2–111	162*	105–288	133†	65·4–225	49·7	849	62·4	196	68·2	401	23·5	77	36·5	175
Thiamin (mg)	154*	112–202	151†	115–194	178*	131–268	157†	109–234	17·5	299	20·1	63	16·0	94	14·0	46	20·0	96
Riboflavin (mg)	75·4*	56·0–122	77·9†	57·0–108	132*	65·9–181	145†	96·0–206	50·2	858	68·5	215	71·1	418	26·8	88	39·9	137
Niacin (mg)	94·5*	71·6–136	90·0†	68·7–114	143*	108–194	130†	89·0–185	44·2	755	55·1	173	61·6	362	19·5	64	32·5	156
Vitamin B_6 (mg)	98·1*	69–128	95·8†	69·9–122	137*	87·6–211	117†	75·4–179	45·5	778	50·3	158	54·9	323	31·1	102	40·6	195
Folate (μg)	112*	71·3–144	98·9†	69·9–130	137*	95·1–195	106†	73·3–153	43·2	738	42·4	133	51·5	303	27·1	89	44·4	213
Vitamin B_{12} (μg)	76·1*	41·1–145	77·2†	33·8–146	223*	123–374	200†	104–337	42·5	727	61·2	192	61·2	360	18·9	62	23·5	113
Pantothenic acid (mg)	54·1*	38·5–72·6	49·4†	37·4–66·3	93·0*	63·4–125	83·9†	55·4–114	77·5	1326	89·5	281	93·7	551	56·7	186	64·2	308
Vitamin C (mg)	14·9*	8·1–20·7	19·8†	12·1–29·3	41·0*	23·7–73·9	53·0†	28·3–89·8	91·9	1572	99·7	313	98·1	577	89·0	292	81·0	389

EAR, Estimated Average Requirement; AI, Adequate Intake; P25, 25th percentile; P75, 75th percentile.
EAR/AI dietary reference intakes are from the US Institute of Medicine[26–29].
*Significant difference between rural and urban men: $P < 0.00001$.
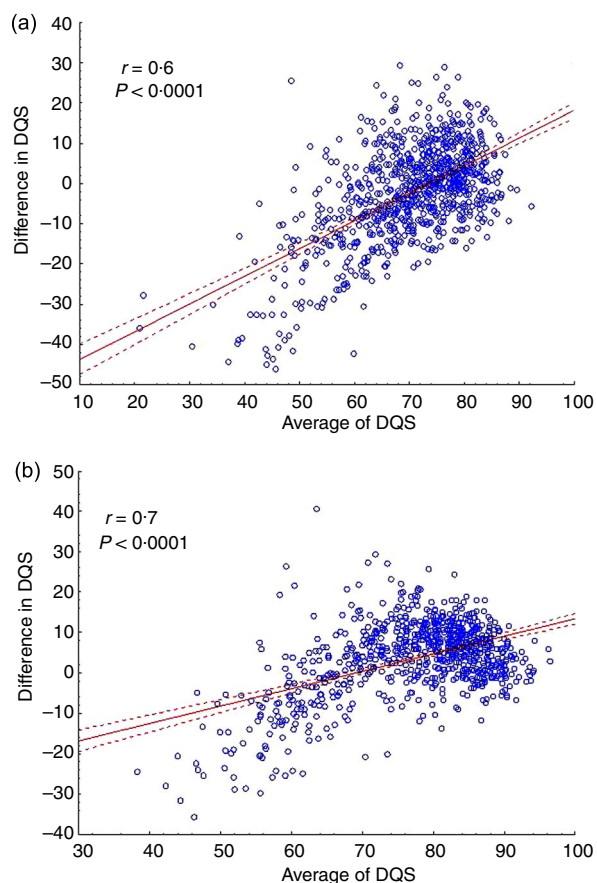†Significant difference between rural and urban women: $P < 0.01$.

Fig. 1 (colour online) Bland–Altman plots showing the agreement between two predefined diet quality scores (DQS; the Healthy Diet Indicator[13] and the Adapted Thiele Score[12]) in apparently healthy volunteers from the South African Prospective Urban and Rural Epidemiological (PURE) study population (*n* 1710): (a) rural group and (b) urban group

urbanization in a developing country and dietary intake by not only looking at individual nutrients, but also investigating dietary patterns by means of predefined DQS. It should be kept in mind that DQS have primarily been developed for Western countries and that their relevance for non-Western populations has not yet been confirmed[37]. As can be seen from the increased levels of known CVD risk factors in our (black South African) study population, it is clear that the urban participants, especially urban women, were at an increased risk of CVD compared with their rural counterparts. Urban men smoked more than rural men, while there was no difference in HIV status between the groups. The rural group as a whole was furthermore less educated than the urban group, and significantly more active. The urban group with the higher risk for CVD therefore smoked more, was less active and with a higher education than the rural group with the lower CVD risk. Increasing CVD risk in populations undergoing urbanization has been described previously and changing dietary intake is accepted as one of the contributing factors[3,4]. For example, irregular fruit

and vegetable intake has been identified as one of the nine risk factors that accounted for $\approx 97.4\%$ of observed acute myocardial infarctions in African populations[4]. Additionally, low dairy consumption, and high fat and red meat consumption, has been observed in an urbanizing South African population, who also presented with an increased risk for CVD[3,38].

It has been understood that the traditional African rural diet is healthier and protective against CVD in that it is higher in fibre and fruit and vegetables and lower in animal products[5]. However, as can be seen from Table 3, in our population, the urban groups (both men and women) had significantly higher intakes of all macro- and micronutrients, except for carbohydrate as a percentage of energy, which was significantly lower in the urban groups. These levels of intakes were markedly higher when looking at the percentage difference in intake between the rural and urban groups. Of particular interest is total fat as a percentage of energy was 40% higher in the urban compared with the rural groups. Although the median intake in the urban groups was still below the CVD guideline of 30%, it was, however, only just below, suggesting that at least 50% of the population was consuming fat at a level of (and higher than) the guideline. SFA, PUFA and cholesterol intakes were, on the other hand, well within the recommended ranges in both groups. This relatively low fat intake is similar to what has been seen in previous studies (THUSA) in this population[38].

Despite the increased micronutrient intakes in the urban groups, intakes for some of the micronutrients were disconcertingly low when compared with the EAR/AI. More than 80% of the population (in both urban and rural groups) for example did not reach the EAR/AI for dietary fibre, Ca, vitamin C and K. Interestingly these are also the micronutrients for which some evidence exists for protection against CVD, although most authors agree that dietary advice should not focus on the individual micronutrients but rather on food sources, such as fruit and vegetables[39–42]. In this population, fruit and vegetable intake was less than half the recommended 400 g of fruit and vegetables per day, even in the urban group. Fruit and vegetables are good sources of dietary fibre, K, folate, antioxidants and minerals such as Mg[43] and a low intake has been shown to contribute to CVD such as IHD and ischaemic stroke[44]. On the other hand, for the other micronutrients, the urban group had median intakes above 100% of the EAR/AI. In 2003, the South African Department of Health embarked on a National Food Fortification Program, resulting in staple foods such as maize meal and bread flour being fortified with vitamin A, thiamin, riboflavin, niacin, pyridoxine, folic acid, Fe and Zn[45]. Therefore, the bread and maize meal porridge that make up the major component of the diet in this population are fortified, likely explaining the higher intakes of these micronutrients.

When comparing dietary intakes of the rural and urban participants using predefined DQS, both scores indicated an improved diet quality in the urban participants. The two scores agreed relatively well, although the HDI gave consistently higher values at low scores (<70% of the total) and the Adapted Thiele Score consistently higher values at high scores (>70% of the total). This could be due to the fact that they are designed to measure different aspects of diet quality, in that the HDI measures diet quality according to dietary risk for chronic diseases of lifestyle such as CVD (prudency), while the Adapted Thiele Score additionally measures adequacy, as can be seen from the cut-offs used in each score.

An additional factor that may contribute to the discrepancy between the two scores is that the weights of the constituting factors differ between the two scores. In the Adapted Thiele Score micronutrients contribute 1700 of the total 1900 points (100 points allocated for each nutrient), while in the HDI, micronutrient intakes are reflected in only three of the nine components, i.e. dietary fibre, fruit and vegetables, and pulses, nuts and seeds. Therefore in the urban groups, where more participants had micronutrient intakes higher than the EAR/AI, this improved micronutrient intake will result in a larger improvement in the Adapted Thiele Score, in which micronutrient intakes represent a larger portion of the score compared with the HDI. Regardless of the differences between the two DQS discussed above, however, both scores indicated improved diet quality in the urban groups, despite the increased CVD risk, placing doubt on the use of these DQS in this population in relation to CVD risk prevention. On a nutrient level, however, the urban groups also showed 'improved' intakes, with higher micronutrient intakes and although macronutrients were also higher, they were still below CVD prevention guidelines.

A different picture emerges, however, when looking at the results from a different perspective. It is clear that the fat intakes in the urban groups are fast approaching the CVD guideline of 30% of total energy and also that the intakes of micronutrients with suggested CVD protection were particularly low even in the urban groups. It is therefore possible that without the protective effect of these micronutrients, the 40% higher fat intakes in the urban groups, despite not being higher than the CVD prevention cut-off, may already result in increased CVD risk factors. Macronutrient guidelines in populations with low micronutrient intakes therefore need to be interpreted with caution and may need to be revisited to take these low intakes into consideration.

Finally, the use of DQS in populations with such low macro- and micronutrient intakes should also be interpreted with caution. The likely reason why the DQS indicated improved diet quality in the urban compared with the rural groups is that the urban groups had higher micronutrient intakes than the rural groups and also

when compared with the EAR. From Table 4 it is clear that the median intakes of the urban groups for twelve of the eighteen micronutrients were greater than 100% while in the rural groups only four were higher. Since the EAR/AI was used as the cut-off values in the Adapted Thiele Score, this would mean more urban participants would have a higher Deficiency Score than the rural participants, as can be seen from the median 17% higher Deficiency Score of the urban groups. Due to the relatively low fat intakes of this population, however, while intakes were higher in the urban groups, they did not yet reach the CVD cut-off and those participants would therefore not be penalized in the DQS for high fat intakes. This is supported by the small increase in the Excess Score in the urban compared with the rural groups (0·4% and 2%). Therefore, the higher micronutrient intake in the urban groups is reflected in the DQS while the higher fat intake is not, resulting in a net higher DQS.

Conclusion

Urbanization in black South Africans is associated with increased CVD risk, especially in women. Urban men and women had significantly higher intakes of both macro- and micronutrients, with macronutrient intakes well within the recommended CVD guidelines. While micronutrient intakes were generally higher in the urban groups than in the rural groups, intakes of selected micronutrients were disconcertingly low in both groups. Both DQS indicated improved diet quality in the urban groups and good agreement was shown between the scores, although they seemed to measure different aspects of diet quality. When interpreting and selecting DQS, it should be clear how these cut-offs protect against the development of CVD; in other words, if a higher amount of a specific nutrient will protect against (adequacy) or cause (prudency) CVD. When applying predefined DQS in non-Western populations for the purpose of CVD risk prevention, the scores should furthermore be interpreted against the background of the absolute levels of nutrient intakes, how these intakes relate to the cut-offs used and be tailored to the specific population. Current guidelines for prevention of CVD may need to be revisited for populations with low dietary intakes, due to the absence of the protective effect that results from adequate micronutrient intakes.

Acknowledgements

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