Micronutrient dilution associated with alcohol and added sugar intake in the THUSA population

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SUMMARY

The micronutrient intake of the average South African is not optimal. National fortification of staple foods does not solve all micronutrient deficiencies. Furthermore, urbanisation causes a shift in food intake, increasing the availability of cheaper and more energy dense food and drinks that are often lacking in micronutrients. It is unclear whether the current literature provides sufficient evidence of nutrient dilution by the moderate consumption of alcohol and/or added sugar. The aim of the present study was to evaluate the dietary intakes of a population in nutrition transition and determine the effect of intake of alcohol and added sugars on intakes of micronutrients and food groups to provide information for the development of preventive strategies in public health. A number of countries, including South Africa, suggest limited alcohol and sugar intakes in the Food Based Dietary Guidelines but do not quantify this recommendation.

Data from the "Transition and Health during Urbanisation in South Africa" survey (THUSA) were analysed for dietary intakes (as determined by a validated quantified food frequency questionnaire), age and body mass index (BMI). The THUSA study was conducted during 1996 and 1998 in the North West Province and included 1854 "apparently healthy" respondents aged 15 years and older from 37 randomly selected sites from rural and urban areas. Alcohol intake (absolute intake and percentage of energy) was the highest for men living in middle class urban areas. With increased urbanisation, the type of beer shifted from sorghum based to commercial beer. Sixty-one percent of men and 25% of women reported that they consumed alcohol at the time of the survey. Eighteen percent of men and 11.7% of women consumed more than 30g and 15g alcohol per day, respectively (intakes which are regarded as moderate). Men and women consuming the most alcohol had significantly higher mean intakes of most macro and micronutrients. However, the intake of vitamin B_{12}, B_6, folate, vitamin E and vitamin C did not meet the recommended dietary intake (RDA) across all levels of alcohol intake. Although the total energy intake increased with increased alcohol intake, there was no significant difference between the mean BMI of men or women with different levels of intake.

One third of the population consumed more than a 100g of added sugar daily. Intake of sugar was the highest in the farm dwellers but the intake of sweets, cakes, cookies and cold drinks was the highest in the urban areas. As sugar intake increased so did energy, carbohydrates and most micronutrients. However, the intake of vitamin B_{12}, folate, vitamin C and calcium did not meet the RDA across all levels of sugar intake. BMI did not differ between respondents with the highest and lowest sugar intake and no association was found between BMI and sugar intake.

The THUSA study was conducted before fortification of staple food became law in October 2003. Maize meal and wheat flour are nowadays fortified with certain vitamins and minerals which may alleviate some micronutrient deficiencies. For future research it is imperative to establish the reasons for low intake of certain micronutrients rather than to look at a single food item in the diets of the South African adult population. Proper education on the intake of cheaper food sources of micronutrients needs to be highlighted at all levels of the health sector.

Key words

Urbanisation, alcohol intake, added sugar intake, micronutrient status, micronutrient dilution

OPSOMMING

Mikronutriëntinname van die gemiddelde Suid Afrikaner is nie optimaal nie. Die verrryking van stapelvoedsel op 'n nasionale vlak los ook nie alle vitamien en mineraaltekorte op nie. Verder het verstedeliking 'n verandering in voedselinname tot gevolg, met meer toeganklike en goedkoper energiedigte en soms nutriëntarme voedsel en drank. Dit is onduidelik of die huidige literatuur voldoende bewyse verskaf van nutriëntverdunning deur die matige gebruik van alkohol of bygevoegde suiker. Die doel van hierdie studie was om die dieetinnames van 'n populasie tydens voedselverandering te evalueer en te bepaal of die inname van alkohol of bygevoegde suiker 'n effek op mikronutriënt- en voedselgroepinname het ten einde inligting te verskaf vir die ontwikkeling van voorkomende strategieë vir publieke gesondheid. 'n Aantal lande, insluitend Suid Afrika, beveel aan dat suiker en alkohol in beperkte hoeveelhede ingeneem moet word, maar kwantifiseer nie hoeveelhede van inname in die aanbevelings nie.

Gegewens van die "Transition and Health during Urbanisation in South Africa" (THUSA)-studie is geanaliseer vir dieetinname (soos bepaal deur 'n gevalideerde gekwantifiseerde voedselfrekwensievraelys), ouderdom en liggaamsmassa-indeks (LMI). Die THUSA-studie is onderneem vanaf 1996 tot 1998 in die Noord Wes-provinsie en het 1854 "öenskynlik gesonde" vrywilligers, 15 jaar en ouer, ingesluit vanuit 37 ewekansig geselekteerde plekke van landelike tot stedelike gebiede. Alkoholinname (absolute inname asook persentasie energie) was die hoogste in die mans wat in middelklas stedelike gebiede gewoon het. Met verstedeliking het die tipe drank verskuif vanaf tradisionele sorghumbier na kommersiële bier. Een-en-sestig persent van die mans en 25% van die vrouens het alkohol gebruik tydens die studie. Agttien persent van die mans en 11.7% van die vrouens het meer as 30g en 15g alkohol respektiewelik per dag gebruik (beskou as matige inname). Mans en vrouens wat die meeste alkohol gebruik het, het ook aansienlik meer makro- en mikronutriënte ingeneem. Daarteenoor het die inname van vitamien B_{12}, B_6, folaat, vitamien E en vitamien C nie voldoen aan die aanbevole dieetinname vir alle vlakke van alkoholinname nie. Totale energieinname het verhoog met verhoogde alkoholinname, maar daar was geen betekenisvolle verskille tussen die gemiddelde LMI van die mans of vrouens met veskillende vlakke van inname nie.

Een derde van die populasie het meer as 100g bygevoegde suiker daagliks ingeneem. Die inname van suiker was die hoogste onder die vrywilligers wat op plase gebly het, hoewel die inname van lekkers, koek, koekies en koeldranke die hoogste in die stedelike gebiede was. Met verhoging in die inname van suiker het die inname van energie, koolhidrate en die meeste mikronutriënte ook verhoog. Die inname van vitamien B_{12}, folaat, vitamien C en kalsium het egter nie voldoen aan die aanbevole dieetinnames op alle vlakke van suikerinname nie. LMI het nie verskil tussen die vrywilligers wat minder of meer suiker ingeneem het nie en geen assosiasie is gevind tussen LMI en suikerinname nie.

Die THUSA-studie is onderneem voor die nasionale wetgewing vir die verryking van stapelvoedsel in Oktober 2003. Mieliemeel en koringmeel word deesdae verryk met sekere vitamiene en minerale wat tekorte kan verlig. Vir toekomstige navorsing is dit noodsaaklik dat daar inligting ingewin word oor die redes vir die lae inname van sekere mikronutriënte, eerder as om na een voedselitem in die daaglikse voedselinname van die Suid Afrikaanse populasie te kyk. Voldoende opleiding oor goedkoper voedselbronne van mikronutriënte is noodsaaklik op alle vlakke van die gesondheidsektor.

Sleutelwoorde

Verstedeliking, alkoholinname, bygevoegde suikerinname, mikronutriëntstatus, mikronutriëntverdunning

CONTENTS

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LIST OF ABBREVIATIONS, CHAPTER 1 - 6

BMI	body mass index
CHD	coronary heart disease
DONALD	Dortmund Nutritional and Anthropometrical Longitudinally Designed
DRI	Dietary Reference Intake
EAR	Estimated Average Requirement
FBDG	food based dietary guidelines
FAO	Food and Agriculture Organization
g	gram
GI	gastrointestinal
HbA1c	glycosylated hemoglobin
HCC	hepatocellular carcinoma
HDL	high density lipoprotein
kJ	kilojoule
MI	myocardial infarction
MRC	Medical Research Council
NCD	non-communicable diseases
NFCS	National Food Consumption Survey
NMES	non-milk extrinsic sugar
RDA	Recommended Dietary Allowance
RR	relative risk
SADHS	South African Demographic and Health Survey
TD	thiamin deficiency
TE	total energy
THUSA	Transition and Health during Urbanisation in South Africa
UK	United Kingdom
USA	United States of America
WE	Wernicke's encephalopathy
WHO	World Health Organization
µg	microgram

CHAPTER 1: INTRODUCTION

1.1 Background and motivation

South Africa is undergoing rapid urbanisation, especially the African population, seeking a better life in the more affluent urbanised areas (Vorster, 2002). People are moving away from the rural areas to live in and around the cities of South Africa to improve their socioeconomic conditions. Urbanisation causes a shift in food intake, increasing the availability of cheaper and more energy dense food and drinks often lacking in micronutrients (Popkin, 1994). Plant based products, higher in fibre and micronutrients are being substituted with animal products high in fat and energy (James *et al.,* 2000; Nel & Steyn, 2002). This dietary shift is characterised by a Western type diet, higher in saturated fat, refined foods and added sugar (Popkin, 1994) often referred to as an atherogenic dietary pattern (Bourne *et al.*, 1993). This suggests that improvements in socio-economic status do not necessarily lead to improved nutritional status, but are adding to the burden of disease in South Africa (Bourne *et al.,* 2002).

Sugar and foods containing high levels of sugar are increasingly being added to the diets of urbanised dwellers (Bourne *et al.*, 1993; Labadarios *et al.,* 2005). The National Food Consumption Survey (NFCS) revealed that urbanised children (aged 1 - 9 years) used 42 - 59g of sugar per day compared to 26 - 41g of sugar per day for their rural counterparts (Labadarios *et al.,* 2005). Adults residing in urban areas seem to follow the same pattern of sugar consumption as children, consuming 38 - 52g per day with the highest intake of sugar in the female group (15 - 18 years) amounting to more than 14% of TE as sugar (Bourne *et al.*, 1993).

Urban areas not only have higher availability of cheaper unhealthy foods but higher rates of alcohol drinking are also recorded in urban areas than in the rural areas (Parry *et al.*, 2005). Both the type and amount of alcohol consumed are changing. Traditional low alcohol home brewed sorghum beer is being substituted with high alcohol content beverages like barley beer, spirits and wine (Parry *et al.,* 2004). There is an increased availability and accessibility of commercial high alcoholic beverages, especially in more urbanised areas (Room *et al.*, 2002). Nel and Steyn (2002) reported an average alcohol intake in rural areas of 38g per day, almost half of the 67g per day alcohol consumed by people living in urban areas. In the South African Demographic and Health Survey (SADHS) in 1998, 45% of men and 17% of women admitted to using alcohol and nearly 30% of adult males reported to use alcohol excessively compared to 10% of females (Parry *et al.*, 2005).

Both sugar and alcohol consumption may cause micronutrient dilution when consumed at high levels (Charlton *et al.,* 1998; Charlton *et al.,* 2005; Lieber, 2004). High added sugar intake can have a satiating affect on the consumer and cause reduction in the consumption of most nutrients and servings of grains, vegetables, fruits and dairy products (Krantz *et al.*, 2005). Consuming more than 18% of total energy as sugar can dilute micronutrient intake, especially thiamin, riboflavin, vitamin B6, folate, vitamin C, calcium, iron, magnesium, zinc and selenium (Charlton *et al.,* 2005). Light to moderate alcohol consumption (one drink per day for women and two drinks per day for men) has been described as healthy (Dicastelnuovo *et al.,* 2006). However, drinking more than two to three drinks per day can cause micronutrient dilution, either displacing nutrients or interfering with the metabolism (Lieber, 2004), causing deficiencies of thiamin (Singleton and Martin, 2001), vitamin B6, B12 and folate (Zhang *et al.,* 2003) and antioxidants (Ringstad *et al.*, 1993).

Any dietary component that is causing micronutrient dilution in South Africa needs urgent attention from health professionals. The overall mean intake of certain vitamins and minerals in South Africa reflected a nutritionally depleted diet (Bourne *et al.*, 1993). Children had a deficient intake of calcium, iron, zinc, selenium, vitamin A, D, C and E, riboflavin, niacin, vitamin B6 and folate (Labadarios *et al.,* 2005). There was some alleviation from micronutrient deficiencies after it became compulsory to fortify South African staple food, maize meal and wheat flour, with vitamin A, iron, zinc, folic acid, thiamin, niacin, vitamin B_6 and riboflavin in October 2003 (Steyn *et al.,* 2006). However, fortification does not solve all micronutrient deficiencies and a deficiency of calcium, iron, folate and vitamin B6 are still common in both adults and children in South Africa (Steyn *et al.,* 2006).

The impact of micronutrient deficiencies is established early in life. It leads to poor growth, poor cognitive abilities, lethargy, poor attention and greater severity and rates of infection (Demment *et al.*, 2003). Alcohol and sugar may cause micronutrient dilution and aggravate micronutrient deficiencies in a community already suffering from nutrient deficiencies. In light of this, South Africa has developed guidelines for safe and sensible alcohol consumption (Van Heerden & Parry, 2001) and there was enough evidence to support a food-based dietary guideline (FBDG) on sugar consumption (Steyn *et al.*, 2003a).

1.2 Aims and objectives

The aim of this mini-dissertation was to investigate the possibility of micronutrient dilution by alcohol and also of sugar in the diet of adults in nutrition transition.

The objectives of this study were as follows:

- to identify the level of alcohol and sugar intake in a sample of people representing South Africans in nutrition transition;
- to investigate whether high consumers of alcohol and sugar meet the recommended intakes of micronutrients as suggested by the Institute of Medicine (IOM, 2003); and
- to investigate if and at what level sugar and alcohol intakes lead to micronutrient dilution.

1.3 THUSA population

Data for the present study was drawn from the "Transition and Health during Urbanisation of South Africans" (THUSA) study, a cross-sectional multi-disciplinary survey conducted between 1996 and 1998. Adult volunteers were selected from 37 randomly selected sites throughout the North West Province of South Africa. A total of 1757 apparently healthy volunteers, consisting of 742 men and 1015 non-pregnant non-lactating women were recruited. They were between the ages of 15 and 65 years with no known medical disease and were not using chronic medication. The main aim of the THUSA survey was to assess the effect of urbanisation and the impact of demographic transition on health determinants and status of Africans and to provide information for appropriate health interventions. The volunteers were stratified into five levels of urbanisation according to their place of dwelling and type of employment. The strata included: (1) deep rural tribal areas, (2) commercial farms, (3) informal housing areas or squatter camps, (4) established urban townships and (5) "upper" urban areas. For this study Stratum 1 and 2 were regarded as rural, 3 as transitional and stratum 4 and 5 were considered upper urban.

Urbanisaton is associated with an increase in certain determinants improving state of living but it is accompanied by deterioration in others, especially among people in transition (Vorster *et al.,* 2000). In the present study the volunteers were pooled together and grouped according to different levels of sugar and alcohol intake. It is hypothesised that sugar and alcohol intake at high levels may cause micronutrient dilution. This is of importance especially in a population in transition with a malnutrition pattern similar to that of overnutrition accompanied by undernutrition, thus increasing the risks of noncommunicable diseases (NCDs) in this population.

1.4 Structure of mini-dissertation

This mini-dissertation is presented in article format. Chapter 1 is the introductory chapter, explaining the change in food intake in South Africa currently undergoing a nutrition transition and stating the aim and objectives of the study. Chapter 2 is a literature survey seeking to explain the risks and benefits of sugar and alcohol consumption on the nutritional well-being of the consumer with special reference to micronutrient dilution. Following the background information in Chapter 2, Chapter 3 reports the results of the effect of alcohol intake on micronutrient intakes of the participants in the THUSA survey. Chapter 4 reports the results of the effect of sugar intake on micronutrient intakes and body mass index (BMI) of the participants. Chapter 3 and 4 were submitted as articles to the South African Journal of Clinical Nutrition and the reference style is that of the journal whilst the reference style of the North-West University was used elsewhere in the document. The last chapter, Chapter 5, draws conclusions on the alcohol and sugar intake in the THUSA population and the impact of these foods on micronutrient intakes.

1.5 Author's contributions

The articles that are included in this mini-dissertation were prepared by several authors and their contributions are listed below. A statement from the co-authors has been included, confirming their responsibility in the study and providing their permission to include these articles in the mini-dissertation.

Name	Role in the study	Signature
Mrs. M. Serfontein B.Sc. Dietetics	Responsible for the literature searches, data analyses and interpretation and text drafting	
Prof. C.S. Venter D.Sc. Dietetics	Supervisor, assistance with dietary data collection and co-drafting of text	
Prof. A. Kruger PhD. Nutrition	Statistical analysis and interpretation and co-supervisor	
Prof. U. MacIntyre PhD. Nutrition	Supervised dietary data collection	

CHAPTER 2: LITERATURE REVIEW

2.1 Alcohol consumption and nutrition status

2.1.1 Introduction

Alcoholic beverages have been used in human societies since the beginning of recorded history (Boutayeb & Boutayeb, 2005). After the European colonial expansion, new forms of alcoholic beverages were introduced and products prepared at home changed into industrialised commodities more accessible to the general public (Room *et al.*, 2002). Alcohol consumption has increased in the last decades especially in developing countries (Boutayeb & Boutayeb, 2005). In South Africa, currently undergoing a nutrition transition, alcohol intake has changed from the traditional use of low alcoholic home brewed beer to the use of commercial alcoholic beverages with a higher alcohol content (Parry *et al.*, 2000). Adverse effects of excessive alcohol consumption as well as beneficial effects of moderate alcohol consumption have been studied (Dufour, 1999). In a meta analysis (Di Castelnuovo *et al.*, 2006) including more than a million men and women, the authors reported that low alcohol consumption (one drink per day for women and two drinks per day for men) is associated with reduced total mortality while high alcohol intake is associated with increased mortality. It was estimated that more than 37 000 deaths in South Africa were attributable to alcohol in 2000. For every female death attributable to alcohol there were more than four male deaths (Schneider *et al.*, 2007).

Alcohol consumption causally relates to more than sixty different medical conditions, but for most of these diseases there is a dose-response relation to volume of alcohol consumption, with risk of disease increasing with higher volume (Rhem *et al.*, 2003). In 2000 it was estimated that globally, alcohol caused 20-30% of oesophagus cancer, liver disease, epilepsy, motor vehicle accidents and other hazards (Boutayeb & Boutayeb, 2005). Alcohol intake has also been linked with a linear increased risk of breast cancer (Zhang *et al.*, 1999). Research from South Africa suggests a particularly high burden of harm associated with the misuse of alcohol (reviewed by Parry *et al.*, 2005). On the other hand, moderate drinking may be associated with reduced risk of heart attack, atherosclerosis, stroke and reduced risk of osteoporosis in postmenopausal women

(Dufour, 1999). How much alcohol is then safe to consume to receive the benefits of alcohol? Where does alcohol consumption become a hazard to the consumers' health?

The relation between alcohol consumption and health outcomes is complex. Both the amount and pattern of drinking is important for the effect of alcohol (Room *et al.*, 2005). Alcohol intake can be grouped into four levels. Abstainers: < 12 drinks in the past year; light drinkers: 0.3g – 6g alcohol per day (1 – 13 drinks per month); moderate drinkers: 6.5g – 30g alcohol per day (4 – 14 drinks per week) and heavy drinkers: > 30g alcohol per day (more than two drinks per day) (Dawson *et al.*, 1995). There is also a fifth pattern of drinking where a person may seem to be a moderate drinker, drinking 4 to 14 drinks per week but in reality the person is drinking this on one night. This is called risky drinking or binge drinking. This type of behaviour even among light drinkers overrides the benefits of light to moderate drinking (Mukamal *et al.*, 2005). In South Africa 45% of men and 17% of women participating in the SADHS (1998) reported that they were currently drinking alcohol and more than 30% engaged in risky drinking, defined in this survey as more than five drinks per day for men and more than three drinks for women (Parry *et al.,* 2004).

Alcohol use is associated with numerous diseases. Governments, especially in developing countries, often welcome the development of new alcohol markets because of financial and economic reasons (WHO, 2000). The question asked is: Does the negative effect of alcohol consumption outweigh the benefits in a developing country in transition?

Benefits of alcohol

Cardiovascular health benefits are the most important health effects of light to moderate drinking in high risk as well as lower risk individuals. Light and moderate alcohol consumption seems to play a role in the reduction of coronary heart disease (CHD) largely by raising high density lipoprotein (HDL) cholesterol levels (Suh *et al.,* 1992). It is well known that high HDL cholesterol levels in the body are associated with protection of the heart (Whitney & Rolfes, 2002). Enhanced insulin sensitivity (Conigrave *et al.,* 2001), improvement in inflammation (Muakamal *et al.,* 2005) and reduction in triglyceride levels (Davies *et al.*, 2002) also seem to play a role in the benefits of light to moderate drinking. Conigrave *et al.* (2001) reported that there was a 36% lower risk for diabetes in people consuming moderate amounts of alcohol compared to abstainers. In an eight year case control study of men and women with previous incidence of myocardial infarction (MI), light to moderate drinking was associated with a lower risk of MI (Mukamal *et al.*, 2005). Compared to non-drinkers, people who consumed 1 – 14 drinks per week had a 19% reduction in overall mortality and a 36% reduction in death from ischaemic heart disease (Yuan *et al.,* 1997). This is often referred to the "French paradox", first described by Renaud and De Lorgeril (1992) who observed that the French suffered less cardiovascular disease even though their saturated fat intake was relatively high, suggesting that moderate alcohol intake may protect against CHD. Different biomarkers were assessed by Mukamal *et al.* (2005) to determine the role alcohol plays in lowering the risk for a MI incident. An increase in HDL cholesterol accounted for 36% of the inverse association in women and more than 50% in men. A reduction in fribrinogen and glycosylated haemoglobin (HbA_{1c}) levels were also associated with the positive effect, and together with HDL cholesterol, these three biomarkers accounted for 75% in women and 100% in men of the inverse association (Mukamal *et al.,* 2005). Furthermore, resveratrol is found in the skin of red grapes and is a constituent of red wine. It has polyphenolic compounds that have antioxidant, anti-inflammatory and potentially anti-atherogenic effects (Whitney & Rolfes, 2002). This is one of the compounds that can also play a role in the health benefits of moderate alcohol consumption.

Consumption of one drink per day for women and one to two drinks per day for men reduces mortality by 18% (Di Castelnuovo *et al.*, 2006). However, increasing the amount of drinks per day to more than one drink for women and more than two drinks per day for men was associated with increased mortality in a dose-dependant fashion (Di Castelnuovo *et al.*, 2006; Nilssen *et al.*, 2005). Alcohol consumption seems to be most protective when done daily and in moderation.

This review will focus primarily on the effect that alcohol may have on the nutritional status of the consumer.

2.1.2 Impact of alcohol on disease

Cancer

Alcohol intake may cause cancer of the oral cavity, pharynx, esophagus, liver and colo-rectum (Pöschl *et al.*, 2004), and increases the risk of breast cancer (Smith-Warner *et al.*, 1998). One of the functions of vitamin A in the body is to regulate normal epithelial cell growth, function and differentiation (Whitney & Rolfes, 2002). Chronic alcohol consumption interferes with vitamin A metabolism that leads to a deficiency of this vitamin (Seitz, 2000). This is one of the nutritional factors that contribute to the developing of cancer in chronic alcoholics. Many of the studies done on the relationship between alcohol and cancer have focused on the risk of developing breast cancer (Singletary & Gapstur, 2001). Alcohol's impact on hormone status provides one plausible explanation of the etiologic relationship between alcohol and breast cancer carcinogenesis (Singletary & Gapstur, 2001). Nutritional factors of considerable interest may include the influence of alcohol consumption (regardless of the type) on the disposition or function of essential nutrients found in fruits and vegetables that may be cancer protective (Zhang *et al.*, 1999). Zhang *et al.* (1999) suggested that the excess risk of breast cancer associated with alcohol consumption may be reduced by a higher intake of folate. The authors reported that women consuming more than 15g/day alcohol and whose intake of the water-soluble vitamin folate was less than 300µg/day had a higher relative risk (RR) for breast cancer than women consuming the same amount of alcohol per day but with folate intakes greater than 300µg/day. These results are shared by other studies (Negri *et al.,* 2000; Rohan *et al.,* 2000; Sellers *et al.,* 2001).

Obesity

Alcohol has a high energy density (29.7 kJ/g) and it is commonly assumed that alcohol consumption in excess accentuates the risk for body weight gain and for the development of obesity (Wannamethee & Shaper, 2003). The role of alcohol energy and body weight has been studied using three different approaches: epidemiology (alcohol intake and body weight), psychophysiologic investigations (alcohol and appetite) and metabolic studies (effects of alcohol intake on energy expenditure and substrate oxidation) (Jequier, 1999).

Epidemiology: The effect of alcohol as an energy source and its role in the development of obesity or primary malnutrition have been the subject of many studies over many years, with contrasting results (Addolorato *et al.*, 1998). The question 'Do alcohol calories count?' (Suter, 1995) still appears to be unresolved, especially with regard to chronic alcohol abuse (Addolorato *et al.*, 1998). Addolorato *et al.* (1998) evaluated the influence of chronic alcohol abuse on body composition and energy metabolism in 32 chronic alcoholic patients compared to 32 healthy social drinkers. The body weight and triceps skinfold of the chronic alcoholic patients were significantly lower than the control group even though the kilojoules from food and alcohol were significantly higher in the alcoholics compared to the social drinkers (Addolorato *et al.*, 1998). A large, eight year prospective study (Wannamathee *et al.*, 2004) reported that light and moderate female drinkers had a lower mean BMI and lower odds of weight gain than female non-drinkers even though there was little difference in total non-alcoholic kilojoule (kJ) intake between the non-drinkers and women consuming alcohol. Heavy drinkers had the lowest intake of non-alcoholic kilojoules with the highest odds of weight gain. Light and moderate drinkers (0.1 – 29.9g alcohol per day) had a lower intake of trans-fat, protein and sugar compared to non-drinkers. Heavy drinkers had the lowest intake of all dietary factors, total kJ, trans-fat, fibre, saturated fat, protein and sugar (Wannamathee *et al.*, 2004). These results correlate with the results of Arif and Rohrer (2005), reporting that light to moderate drinkers had lower odds of obesity compared to non-drinkers. Body weight is affected by quantity and as well as frequency of drinks. It seems that binge and heavy drinking increases the odds of weight gain compared to light to moderate drinking (Arif & Rohrer, 2005; Wannamathee & Shaper, 2003; Wannamathee *et al.*, 2004).

Psychophysiologic investigations: Westenterp-Platenga and Verwegen (1999) made an assessment of the effects on energy intake of an aperitif compared with those of a water appetizer and three fruit juices. An alcohol preload was given to the respondents 30 minutes before lunch. After the alcohol preload, there was no compensation for food intake therefore adding to total daily energy intake. The respondents receiving the alcohol preload ate faster and the meal lasted longer than the respondents who only received juice and water. The authors concluded that alcohol increases appetite in the short term (Westenterp-Platenga & Verwegen, 1999). The mechanism is not clear, but alcohol suppresses fatty acid oxidation and increase short term thermogenesis, and it may also affect neurochemical systems involved in the control of appetite (Westenterp-Platenga & Verwegen, 1999).

Metabolic alterations: The third reason why alcohol intake can alter body weight regulation is because alcohol cannot be stored in the body and is oxidised before most nutrients (Lieber, 2004). Alcohol ingestion reduces fat oxidation, which results in a positive fat balance (Murgatroyd *et al.,* 1996). The oxidation of alcohol in chronic alcohol users in the microsomal ethanol oxidation system leads to increased thermogenesis, heat loss and lack of retention of chemical energy, also without the production of NADH and ATP. This can explain weight loss of chronic alcohol users (Addolorato *et al.*, 1998).

2.1.3 Impact of alcohol on nutrient dilution

From the moment an alcoholic beverage enters the body it receives absolute priority. Alcohol cannot be stored in the body and it is toxic, so it is absorbed and metabolised before most nutrients, often at the expense of other metabolic pathways (Suter, 2005).

Unlike other drugs, alcohol is rich in energy with 29.7 kJ per gram, a value that exceeds the energy content of carbohydrates or protein (Lieber, 2004). Unlike carbohydrates and proteins, alcohol is seen as mostly empty kJ providing the body with a limited amount of micronutrients like calcium, magnesium, zinc, riboflavin and niacin. On the other hand, traditional sorghum beer and commercial beer contain some micronutrients such as magnesium, zinc, manganese, riboflavin and niacin (MRC, Food Finder 3). Nutrient deficiencies may occur with alcohol abuse because alcohol may displace normal nutrients. This may result in inadequate nutrient intake causing malnutrition (Lieber, 2004) interference with the metabolism of certain nutrients causing malabsorption (Sellers *et al.,* 2001; Zhang *et al.,* 2003) and the direct toxic effect of alcohol and its metabolites (Zhang *et al.,* 2003). Alcohol intake interferes with the metabolism of thiamin, vitamin B_6, B_{12}, folate, iron and antioxidants.

Thiamin deficiency

Alcohol consumption can damage the brain through numerous mechanisms. One mechanism is the reduced levels of the essential vitamin, thiamin, often found in chronic alcoholics. Thiamin occupies a special site on the membranes of nerve cells; to this extent the processes in nerves and in their responding tissues, the muscles, depend heavily on thiamin (Whitney & Rolfes, 2002). Chronic alcoholism can result in thiamin deficiency (TD) through a number of mechanisms, including inadequate dietary intake, reduced absorption or a decrease in the rate of conversion to the active metabolite (Langlais, 1995). Reduced levels of thiamin interfere with numerous cellular functions, resulting in serious brain disorders, including Wernicke-Korsakoff syndrome, which is found predominantly in alcoholics. Wernicke encephalopathy (WE) (clinical form of thiamin deficiency) is characterised by acute confusion, ataxia and eye movement abnormalities (opthalmoplegia and nystagmus) (Homewood & Bond, 1999). Failure to treat WE adequately leads to a chronic form of the disease (Korsakoff psychosis) characterised by severe short-term memory loss, paralysis of the eye muscle, poor muscle coordination and damaged nerves (Thomson *et al.,* 2002).

Alcoholism is the most common cause of TD (Singleton & Martin, 2001). Alcohol and its metabolite acetaldehyde can interact extensively with thiamin utilisation at the molecular level. It can influence thiamin transport, diphosphorylation, modification and turnover of thiamin requiring enzymes (Singleton & Martin, 2001). TD is accompanied by diverse changes in brain glucose metabolism. As a result, there is decreased lipid incorporation into myelin, marked alterations in biosynthesis and turnover of several neurotransmitters including acetylcholine and glutamate. Focal regions of metabolic (lactic) acidosis and intracellular calcium accumulation may contribute to the neurotoxic effects of alcohol (Singleton & Martin, 2001).

Vitamin B_6 (Pyridoxine), vitamin B_{12} (Cobalamin) and folate deficiency

Alcohol and its metabolite, acetaldehyde, increase the destruction and excretion of vitamin B_6, vitamin B_{12} and folate (Whitney & Rolfes, 2002). Vitamin B_6 plays an important role in the formation of red blood cells and converting tryptophane to niacin and serotonin (Whitney & Rolfes, 2002) and converting homocysteine to cysteine (Zhang *et al.,* 2003). Alcohol dislodges vitamin B_6 from its protective binding protein destroying the vitamin B_6

and causing a deficiency (Whitney & Rolfes, 2002). Alcohol has a dramatic effect on folate, disrupting intestinal absorption and interfering with uptake and storage in the liver and increasing the excretion through urinary loss (Halsted, 1995). Folate is needed for tissue growth, especially in the gastrointestinal (GI) tract, and a deficiency will lead to GI tract deterioration (Whitney & Rolfes, 2002). Folate deficiency together with alcohol intake has also been linked to a higher risk of breast cancer (Zhang *et al.*, 1999). Vitamin B_{12} and folate are closely related, depending on each other for activation. Vitamin B_{12} removes a methyl group to activate the folate coenzyme and when folate gives up its methyl group, the vitamin B_{12} coenzyme becomes activated (Whitney & Rolfes, 2002).

Vitamin B_6, B_{12} and folate play a role in converting homocysteine to methionine. Alcohol may cause deficiencies of these vitamins resulting in reduced conversion and increased levels of homocysteine (Cravo & Camilo, 2000; Zhang *et al.,* 2003). Increased homocysteine levels are associated with a 30 times greater risk of premature occlusive vascular disease (Cravo & Camilo, 2000). De la Vega *et al.* (2001) analysed the prevalence of hyperhomocysteinaemia in men with heavy alcohol intake. They observed increased serum homocysteine levels related to low serum folate, erythrocytic folate, serum vitamin B_{12} and plasma vitamin B_6. They also reported a decrease in serum homocysteine and an increase in serum and erythrocyte folate, vitamin B_{12} and B_6 levels after 15 days of alcohol withdrawal. The interaction between alcohol and folate intake has been observed as a risk of coronary heart disease (Jiang *et al.*, 2003), breast cancer (Zhang *et al.*, 2003) and colon cancer (Sellers *et al.*, 2001).

Light to moderate drinking increases HDL cholesterol and has a beneficial effect on arteries (Sellers *et al.*, 2001). Heavy drinkers on the other hand show high HDL cholesterol levels but also high homocysteine levels, a damaging factor for arteries. This means that heavy alcohol intake may alter two opposite biochemical systems related to arterial damage (Sellers *et al.*, 2001).

Iron

Iron overload in black South Africans has been a topic of research since the 1920's (Gordeuk *et al.,* 1996). The liver is the major iron-storing organ and it is common among Sub-Saharan Africans to have iron overload to a degree that it causes liver damage (Gordeuk, 1992). Iron overload is known as haemochromatosis, and is usually caused by a genetic disorder that enhances iron absorption (Hunt & Roughead, 2000). Long term iron intake above normal levels, may cause haemosiderosis, a condition characterised by large deposits of the iron storage protein haemosiderin in the liver and other tissue (Whitney & Rolfes, 2002). Iron overload is of great importance because it is linked to certain cancers, especially hepatocellular carcinoma (HCC) (Mandishona *et al.*, 1998), esophageal cancer (Matsha *et al.,* 2006) and also tuberculosis (Gordeuk *et al.,* 1996). Initially it was thought that iron overload was the result of some metabolic defect induced by chronic malnutrition, but dietary iron seems to be the chief factor with most of the iron derived from the utensils, iron drums and cans, used to brew traditional beer (Gordeuk *et al.,* 1996). This type of iron overload is common in Sub-Saharan Africa, achieving a prevalence of 10% in some communities (Gordeuk, 1992). Matsha *et al.* (2006) investigated the association of oesophageal cancer with the consumption of home brewed beer, with an iron content 258-fold higher than the commercial Castle Lager beer. Their results showed that there was no link between iron overload from home brewed beer and esophageal cancer; however, Mandishona *et al.* (1998) showed that Africans with dietary iron overload are at increased risk of developing HCC.

Antioxidants

Alcohol can affect a wide range of organ systems due to the destructive effects of alcohol metabolites and nutrient deficiencies (Lecomte *et al.,* 1994). Tocopherol, ascorbic acid, selenium and carotenoids are antioxidants that protect the body against the damage of oxidative stress (Whitney & Rolfes, 2002). Lower levels of these antioxidants have been shown in alcoholics, suggesting a potentially important lack of protection against free radicals and oxygen-derived reactive species (Lecomte *et al.,* 1994). Even in moderate drinkers, ascorbic acid, selenium and vitamin E are altered (Ringstad *et al.*, 1993). However, resveratrol is an antioxidant in red wine that may play a role in the positive effect of moderate drinking (Whitney & Rolfes, 2002). It seems that alcohol consumption leads to the development of oxidative stress, adding to liver cell damage and the development of liver injury (Caballeria, 2003).

2.1.4 Guidelines for alcohol intake

In South Africa, a safe level of intake is recommended, with a limit of 2 – 3 drinks per day as shown in Table 2.1 which indicates the recommendations for daily intake of alcohol of different countries around the world and which were adapted from www.icap.org/PolicyIssues/DrinkingGuidelines/StandardUnitsTable/tabid/253/Default.aspx. It is clear from the guidelines that there is no consensus on alcohol intake. In general, European countries recommend less than 5% of daily energy intake or 15g/day and 20g/day for women and men, respectively. The UK recommends 3-4 units/day for men and 2-3 units /day for women (defining one unit as 8g alcohol). Pregnant women are urged by may countries to abstain from alcohol consumption because of fetal damage caused by alcohol (fetal alcohol syndrome), of which the prevalence in South Africa has been shown to be much higher than in countries such as the USA (van Heerden & Parry, 2001).

Table 2.1 Recommended alcohol intake of different countries

Country	Source	Men	Women	Standard Drink (grams of ethanol)	Suggested/Other
Australia	National Health and Medical Research Council (NHMRC) [http://www.nhmrc.gov.au] and Australian Government Department of Health and Ageing [http://www.alcohol.gov.au]	No more than 4 standard drinks a day, on average and never more than 6 standard drinks in one day.	No more than 2 standard drinks a day, on average and never more than 4 standard drinks in one day.	10g	Everyone should have 1 or 2 alcohol-free days every week. **Note:** The guidelines are currently under review by the NHMRC in collaboration with the Australian Government Department of Health and Ageing. The revised draft, *Australian Alcohol Guidelines for Low-risk Drinking*, is now available for public consultation (the draft advises that both men and women limit their alcohol consumption to 2 standard drinks or less in any one day and states that "not drinking is the safest option" for youths aged under 15 years and women who are pregnant, are planning to become pregnant, or are breastfeeding). Progress on the revised guidelines can be traced at: http://www.nhmrc.gov.au/consult/index.htm.
Austria	Bundesministerium fur Arbeit, Gesundheit und Soziales (Federal Ministry for Labour, Health and Social Affairs) [http://www.bmsg.gv.at/]	24g pure ethanol per day	16g pure ethanol per day	10g	In addition the hazardous limit (unacceptable risk for health consequences) is defined as 40g / 60g alcohol.
Canada	Centre for Addiction & Mental Health	Not to exceed 2 units per day (27.2g/day); not to exceed 14 units per week (190g/week)	Not to exceed 2 units/day (27.2g/day); not to exceed 9 units per week (12g/week)	13.6g	Low risk drinking guidelines: [http://www.camh.net/addiction/pims/pdfs/lowrisk_drinking.pdf] **Note:** The drinking guidelines do not apply to pregnant women.
	Health Canada (Sante Canada)	N/A	N/A	13.6g	Moderate drinking means no more than 1 drink a day, and no more than 7 drinks a week. More than 4 drinks on one occasion, or more than 14 drinks a week is a risk to health and safety. If you are pregnant or breast-feeding, avoid alcohol.

Country	Source	Men	Women	Standard Drink (grams of ethanol)	Suggested/Other
Czech Republic	National Institute of Public Health [http:www.szu.cz]	Less than 24g per day	Less than 16g per day	N/A	The recommendations are for adults (over 18), who are healthy (without disease) and not engaged in risky behaviours or taking medication.
Denmark	Sundhedsstyrelsen (National Board of Health, NBH)] [http://www.sst.dk/english/index.asp]	No more than 21 alcohol units (252g) a week	No more than 14 (168g) units a week	12g	The National Board of Health recommends that children under the age of 15 should not drink.
Finland	Oy Alko AB (Alko Inc.) [http://www.alko.fi/]	Not to exceed 15 units/week (165g/week)	Not to exceed 10 units/week (110g/week)	11g	N/A
France	Ministry of Health, Youth & Sports [http://www.jeunesse-sports.gouv.fr]	Not to exceed 20g/day	Not to exceed 20g/day	12g/beer, 8g/wine	According to « La santé vient en mangeant : le guide alimentaire pour tous », National Program for Health & Nutrition (PNNS): Those who drink should reduce their consumption. Pregnant women should not drink. Do not drink and drive.
	National Academy of Medicine	Not to exceed 5 units/day (60g/day)	Not to exceed 3 units/day (36g/day)	12g	N/A
Hong Kong	Department of Health & Social Security	Not to exceed 3-4 units/day, not to exceed 21units/week	Not to exceed 2-3 units/day, not to exceed 14 units/week	1 unit = glass/wine or pint/beer	N/A
Iceland	Alcohol and Drug Abuse Prevention Council	N/A	N/A	N/A	Pregnant women and women who are breastfeeding are advised to abstain from alcohol.
Indonesia	Ministry of Health	N/A	N/A	N/A	National Dietary Guidelines state: avoid drinking alcoholic beverages.
Ireland	Department of Health	21 units/week (210g/week)	14 units/week (140g/week)	10g	See: http://www.healthpromotion.ie/topics/alcohol/alcofacts/facts_about_alcohol
Israel	Ministry of Education, Psychological & Counseling Services	N/A	N/A	N/A	Recommendations for particular populations: pregnant women should not drink; students should avoid drinking more than one unit at a time; avoid alcohol if taking medication.
Italy	Ministry for Agriculture & Forestry and National Institute for Food & Nutrition	Less than 40g per day	Less than 40g per day	12g	Nutritional Guidelines (Linee guida per una sana alimentazione Italiana) state: The acceptable daily quantity of alcohol is 0.6g per kilo of body weight. The limit not to be exceeded is 1.0g per kilo of body weight. If only wine is consumed then the guidelines suggest that less or equal to 450ml (3 glasses) for men and less or equal to 350 ml (2 glasses) for women to be divided between lunch and dinner. Avoid consumption during evolutive age, pregnancy, breast-feeding and reduce it when in old age. Avoid alcohol before driving or when using dangerous machinery, or if undergoing drug therapy. [Legislation: Law Decree 28 Dec. 1998 converted in Law 26 Feb. 1999 n. 39 – Chapter "The aims of Health" pg. 17-18]

Country	Source	Men	Women	Standard Drink (grams of ethanol)	Suggested/Other
Japan	Ministry of Health, Labour & Welfare	1-2 units/day (19.75-39.5g/day)		19.75g	N/A
Luxembourg	Ministry of Health	N/A	N/A	N/A	Health authorities promote moderate alcohol consumption without specifying limits of daily or weekly intake that should not be exceeded; individuals are advised to refrain from drinking when driving. Children and adolescents under 16 years of age and young drivers are the main target groups of these health messages.
Netherlands	Stichting Verantwoord Alcoholgebruik (Stiva) [www.stive.nl]	Not to exceed 4 units/day (39.6g/day)	Not to exceed 2 units/day (19.8g/day)	9.9g	Advise not to drink at least 2 days within a week. Avoid alcohol when pregnant, driving or operating machinery and if an adolescent. Women with a low body weight are advised to drink less than the recommended daily limit.
New Zealand	Alcohol Liquor Advisory Council (ALAC)	Not to exceed 3 units/day (30g/day), not to exceed 21units/ week (210g/week)	Not to exceed 2 units/day (20g/day), not to exceed 14 units/week (140g/week)	10g	Should not exceed 6 units/day (60g/day) for men, 4 units/day (40g/day) for women on special single drinking occasions. Alcohol-containing drinks are high in energy density and may contribute to weight gain. Have some alcohol-free days each week. To reduce the risk of cancer, no alcohol is recommended. To reduce cardiovascular risk, consume only moderate amounts of alcohol. When serving drinks, ensure non-alcoholic drinks and food are available. Provide non-alcoholic and low-alcohol beverages when serving alcohol. Eat food when drinking alcohol. Restrict or avoid alcohol when driving, when operating machinery or when in the water.
	The Ministry of Health	N/A	N/A	N/A	The *Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women: A Background Paper* recommends women to avoid drinking alcohol at all during pregnancy, unless prescribed during pregnancy and breastfeeding. See http://www.moh.govt.nz/moh.nsf/by+unid/F4F10903136588EFCC25716200123030?Open.
Norway	Directorate for Health & Social Welfare	N/A	N/A	N/A	Situational abstinence is recommended, such as when driving, during pregnancy, at work or in the company of children and young people.
	Alkokutt [http://www.alkokutt.no]	N/A	N/A	N/A	Allcokutt suggests: Never to drink on an empty stomach. Show respect to people who do not drink alcohol. Remember that women hold less alcohol than men. Listen to experienced professionals. Be on guard against drinking-pressure, even among friends. Remember time and place where you should not drink alcohol. Never drink alone. Quit in good time, it's never a shame to say no. Don't drink as an adolescent.

Country	Source	Men	Women	Standard Drink (grams of ethanol)	Suggested/Other
Philippines	Department of Health	N/A	N/A	N/A	National Dietary Guidelines state: for a healthy lifestyle and good nutrition, exercise regularly, do not smoke and avoid drinking alcoholic beverages.
Poland	State Agency for Prevention of Alcohol Related Problems	2 units/day (20g/day) up to 5 times/week (not to exceed 100g/week)	1 unit/day (10g/day) up to 5 times/week (not to exceed 50g/week)	10g	Not official guidelines, based on WHO recommendations. Suggest 2 alcohol-free days/week.
Portugal	National Council on Food and Nutrition	2-3 units/day (28-42g/day)	1-2 units/day (14-28g/day)	14g	Based only on wine consumption.
Romania	Ministry of Health	Not to exceed 32.5g beer/day or 20.7g wine/day	Not to exceed 32.5g beer/day or 20.7g wine/day	N/A	N/A
Singapore	Ministry of Health	N/A	N/A	N/A	National Dietary Guidelines state: Limit alcohol intake to not more than 2 standard drinks a day (about 30g alcohol).
Slovenia	Institute of Public Health of Slovenia	Not to exceed 20g/day and not *to exceed 50g/drinking occasion*	Not to exceed 10g/day *and not to exceed* 30g/drinking occasion	N/A	N/A
South Africa	South African National Council on Alcoholism & Drug Dependence	Not to exceed 21 units/week (252g/week)	Not to exceed 14 units/week (168g/week)	N/A	The government's position is outlined in a brochure titled "Healthy Lifestyles" (1995). It calls for using alcohol in moderation and states: "Limit yourself to no more than 2 to 3 drinks a day".
Spain	Ministry of Health and Spanish Institute for the Investigation of Beverage Alcohol	Not to exceed 3 units/day (30g/day)	Not to exceed 3 units/day (30g/day)	10g	Wine officially considered as an integral part of a Mediterranean diet.
	Basque Country: Department of Health & Social Security	Not to exceed 70g/day	Not to exceed 70g/day	N/A	N/A
	Catalonia: Central Authority	Not to exceed 4-5 units/day (32-50g/day)	Not to exceed 4-5 units/day (32-50g/day)	8-10g	N/A
Sweden	Vetenskapsradet (Swedish Research Council) [http://www.vr.se/English/]	Not to exceed 20g/day	Not to exceed 20g/day	N/A	It is recognized that a moderate alcohol intake may have certain positive medical effects.

Country	Source	Men	Women	Standard Drink (grams of ethanol)	Suggested/Other
Switzerland	Swiss Federal Commission for Alcohol Problems and Institut Suisse de Prevention de l'Alcoolisme et Autre Toxicomanies (Swiss Institute for the Prevention of Alcohol & Drugs Problems)	Not to exceed 2 units/day (not to exceed 24g/day)	Not to exceed 2 units/day (not to exceed 24g/day)	10-12g	Special notes: not to exceed 4 units/event, not to exceed 1 unit/hour. No alcohol for youngsters; no alcohol during sports; no alcohol while operating machinery or before driving. Women have to be particularly cautious.
Thailand	Ministry of Public Health	N/A	N/A	N/A	National Dietary Guidelines state: avoid or reduce the consumption of alcoholic beverages.
United Arab Emirates	Ministry of Health	N/A	N/A	N/A	No official guidelines. Alcohol is available in hotels to guests and visitors. Expatriate residents must possess a liquor permit, available to non-Muslims. Retail outlets sell only to permit holders for personal consumption. Providing alcohol to others is forbidden.
United Kingdom	Department of Health	3-4 units/day (24-32g/day), not to exceed 21 units/week (168g/week)	2-3 units/day (16-24g/day), not to exceed 14 units/week (112g/week)	8g	Advises women who are pregnant or who are trying to get pregnant to drink no more than 1 - 2 units of alcohol per week. Recognize that moderate drinking for men over 40 and postmenopausal women confer health benefits including, lower risk of coronary heart disease, ischemic stroke and gallstones.
	Scottish Executive	3-4 units/day (not to exceed 32g/day)	2-3 units/day (not to exceed 24g/day)	8g	Uses "Sensible Drinking Guidelines" as part of national alcohol strategy.
United States	Department of Agriculture and Department of Health & Human Services	1-2 units/day (14-28g/day), not to exceed 14 units/week (196g/week)	1 unit/day (14g/day), not to exceed 7units/week (98g/week)	14g	*Nutrition and your health: Dietary guidelines for Americans (5th ed.)* recognizes that "moderate drinking may lower the risk of coronary heart disease, among men over 45 and women over 55; exceeding moderate consumption can raise the risk for accidents, high blood pressure, stroke, violence, suicide, birth defects and certain cancers; a safe level of alcohol intake has not been established for women at any time during pregnancy; avoid drinking before, or when driving; consume alcohol with food, to slow absorption".
	National Institute of Alcohol Abuse and Alcoholism (NIAAA)	Not to exceed 4 units/day (56g/day), not to exceed 14units/week (196g/week)	Not to exceed 3 units/day (42g/day), not to exceed 7units/week (98g/week)	14g	N/A
	American Heart Association	Not to exceed 2 units/day (28g/day)	Not to exceed 1 unit/day (14g/day)	14g	See AHA Dietary Guidelines.

Adapted from: //www.icap.org/PolicyIssues/DrinkingGuidelines/StandardUnitsTable/tabid/253/Default.aspx.

2.2 Sugar consumption and nutrition status

2.2.1 Introduction

Sugar is appreciated for its sweetness and the attractiveness it adds to the diet. Sugar is relatively high in energy (17 kJ/g), readily available and is of a relatively low price, which contributes to the suggested higher intake by lower income families (Rasmussen *et al.,* 1998). In developing countries many people are abandoning traditional diets that are rich in fibre and grain for diets that include increased levels of sugar, oils and saturated fats. This follows a trend similar to Europe and North America, where fat and sugar account for more than half of their energy intake (Chopra *et al.*, 2002).

There is a difference between total sugar and added sugar in the diet. Sugar can occur naturally in food like milk (lactose) and fruit (fructose), and forms then part of daily total sugar intake (Kranz *et al.*, 2005). These foods are nutrient dense and also provide the body with essential micronutrients (Whitney & Rolfes, 2002). "Added sugar" refers to all monosaccharides and disaccharides that are added to foods and drinks during preparation and cooking (Krebs-Smith, 2001). Added sugar is energy dense but does not provide the body with any health benefits other than adding energy to the diet (Yudkin, 1972). However, it is important to look at the source of the added sugar in the diet (Rennie & Livingstone, 2007). Fortified foods, which are often high in added sugars like fruit juice beverages, dairy products and cereals (Alexy *et al.*, 2002), may contribute considerably to the daily intake of vitamins and minerals (Sichert-Hellert *et al.*, 2000; Berner *et al.*, 2001). When added sugars are consumed as part of a nutrient dense food (for example, presweetened breakfast cereals, sweetened yogurt) they may be associated with an increase in the nutrient density of the diet, whereas sugar-sweetened beverages, sugars, sweets and sweetened grains have a negative impact on diet quality (Frary *et al.*, 2004).

2.2.2 Guidelines for sugar consumption

Sugar intake between countries is difficult to define and compare. The reason for this discrepancy is mainly because different terminology is used to define dietary sugar (Ruxton *et al.,* 1999). In the United Kingdom the terms intrinsic sugar (natural in fruit and milk) and extrinsic sugar (added to food and natural in fruit juice), also called 'non-milk extrinsic sugar' (NMES), are used to define sugar (Ruxton *et al.,* 1999). Other European countries and South Africa use the term total sugar and added sugar to distinguish between sugars naturally in milk and fruit and those added to food during processing and preparation (Ruxton *et al.,* 1999). Even the term added sugar seems to have different definitions in different countries. Added sugar was defined by Alexy *et al.* (2002) as all refined sugars (for example, sucrose, maltose, lactose, glucose and dextrin) used as an ingredient in processed foods or added at home in the kitchen or at the table. Charlton *et al.* (1998 and 2005) defined added sugar intake as sucrose, either added to food during manufacturing or added at the table also including fructose from honey. In the present study added sugar included all sugar added to food in the kitchen or at the table as well as miscellaneous sweets that included candy, chocolate, cookies, cakes and sweetened cold drinks (MacIntyre *et al.,* 2002). Table 2.2 lists the guidelines for recommended sugar intake in 15 European countries and South Africa.

2.2.3 Sugar intakes in South Africa

Added sugar is consumed by 77% of the adult South African population (Steyn *et al.*, 2003b). There are differences in sugar intake between urban and rural areas. The intake of added sugar by people living in urban areas and participating in the BRISK study (survey to determine the risk factors for coronary heart disease in the black population of the Cape Peninsula) was higher than in rural areas (Bourne *et al.*, 1993). Walker *et al.* (1981) reported that adolescents living in urban areas consumed almost double the amount of sugar (118g – 141g) than those living in rural areas (69g – 97g). This view was shared by data from the review of the literature on nutrient intakes of South Africans (SANSS) in 1995, reporting the highest intake of sugar amongst urban African men and women (Vorster *et al.*, 1997).

Table 2.2: National recommendations for sugar intakes in fifteen European countries and South Africa (Adapted from Ruxton *et al.*, 1999)	
Country	**Sugar guideline**
Austria	No quatitative recommendation
Belgium	No quatitative recommendation: total CHO should provide 55 - 75% TE with starch contributing minimum 50%, moderate sugar intake (Ministere des Affaires Sociales, de la Sante Publique et de l'Environnement, 1997)
Denmark	Maximum 10% energy from added sugar for children and people on low energy diets (Asp, 1997)
Finland	Maximum 10% energy from added sugar for children and people on low energy diets (National Nutrition Council, 1989)
France	No quatitative recommendation (Dupin *et al.*, 1992)
Germany	Maximum 10% total energy from sucrose (Deutsche Gesellschaft fur Ernahrung, 1991)
Greece	Maximum 10% total energy from added sugar (Ruxton *et al.*, 1999))
Ireland	No quatitative recommendation
Italy	Between 10-15% energy from total sugar (Ruxton *et al.,* 1999))
Luxembourg	See Belgium data
The Netherlands	Up to 25% energy from total sugar (Voorlichtingsbureau voor de Voeding, Zo eet Nederland 1992, 1993)
Portugal	No quatitative recommendation
Spain	Maximum 10% energy from added sugar (Ruxton *et al.*, 1999)
Sweden	Maximum 10% energy from added sugar for children and people on low energy diets (Asp, 1997)
United Kingdom	Maximum 10% energy from NMES (Department of Health, 1991)
South Africa	Sugar intake < 40g/day in areas in which water is not fluoridated and ≤ 55g/day in fluoridated areas. 6 - 10% energy from added sugar (Steyn *et al.*, 2003a)
CHO, carbohydrate; TE, total energy	

Data from the NFCS shows that children living in urban areas consumed more sugar (12% of total energy, TE) than children living in rural areas (10% of TE) (Labadarios *et al.,* 2005). In rural adults (ages of 20 to 65 years) participating in the DIKGALE demographic survey, mean sugar intake was between 4.2 and 5.2% of TE (Steyn *et al.,* 2001). Mean added sugar intake of female adolescents residing in urbanised areas and participating in the cross-sectional study on the prevalence of coronary risk factors (BRISK) study, was 14.6% of TE (Bourne *et al.,* 1993), a value exceeding the recommended 10% of TE intake by the WHO for the prevention of caries (WHO/FAO, 2003). Many countries have the recommended 10% TE of the WHO as a set objective (Sheiham, 2001). In contrast to these guidelines, the National Academy of Sciences recommends a Dietary Reference Intake (DRI) of 25% or less of total energy from added sugar, based on evidence of potentially adverse consequences on outcomes including biomarkers (for example, blood lipids), behaviour, dental caries, obesity, coronary heart disease and nutrient intakes (Institute of Medicine, 2002).

Nutrient density, the nutrient intake per energy intake, is commonly used as an indicator of dietary quality (Alexy *et al.*, 2002). A high nutrient density is particularly important if total energy intake is low, e.g., for the prevention or treatment of obesity, or if the requirement of a specific nutrient is increased, e.g., because of growth demands. Studies have shown that as the dietary content of added sugar rises, densities of several essential nutrients decline (Charlton *et al.*, 2005), and both the BMI and frequency of obesity increases (Ludwig *et al.*, 2001). In South Africa the intake of sugar is of great concern because of the double burden of disease. On the one hand sugar may be a good energy source for low income families where undernutrition is of great concern, but on the other hand it is reported that sugar may displace other nutrients resulting in reduced levels of certain nutrients (Kranz *et al.,* 2005), as well as adding empty kilojoules to the diet that may result in weight gain and obesity (Ludwig *et al.,* 2001).

2.2.4 Impact of sugar consumption on disease

According to Steyn *et al.* (2003a), the argument that people should limit intake of sugar added to food is based on evidence that a high intake of sugar increases the risk of certain chronic diseases and dental caries (Newbrun, 1982) and obesity (Ludwig *et al.*, 2001). In the case of dental caries there is consensus about the relationship between frequency of sugar intake and the incidence of decay (Johnson & Frayry, 2001), although associations between sugar intake and the incidence of caries rarely reached statistical significance in populations where fluoride use was adequate (Ruxton *et al.*, 1999). However, there is no consensus in the literature on whether high consumption of sugar displaces micronutrient-rich foods from the diet and decreases the intakes of essential nutrients (Overby *et al.,* 2003). The association between sugar intake and obesity is also debatable (Alexy *et al.*, 2003; Overby *et al.,* 2003; Vasilaras *et al.,* 2004; Kranz *et al.*, 2005).

Obesity

One of the major consequences of changes in the diet associated with urbanisation is the increased prevalence of obesity in the last decade (Popkin 2004). One of the main anthropometric findings of the NFCS was that one in ten children between the ages of one to nine years old was overweight with the highest prevalence among children living in urban areas (Labadarios *et al.*, 2005). In 1998 the SADHS reported that 56.6% of the women had a BMI above that of healthy weight (BMI ≥ 25) (Puoane *et al.*, 2002). These results correlate with data from the THUSA survey also reporting that more than half of the women (53.8%) were overweight (Kruger *et al.*, 2002) with obesity rates increasing with urbanisation (Vorster *et al.*, 2005). Obesity (especially abdominal obesity) was associated with higher blood pressure, lower concentration of HDL cholesterol and higher triglyceride, fasting serum glucose and insulin levels (Kruger *et al.*, 2001). However, Kruger *et al.* (2002) found that physical inactivity was the major determinant of obesity in the women in the THUSA study and that total energy and fat intake correlated positively with BMI.

Diets that are limited in added sugars have been shown to reduce total energy and induce weight loss (Mann *et al.*, 1970). Diets high in added sugars, especially from sweetened beverages like soft drinks, are more likely to cause weight gain compared to diets higher in energy free and artificially sweetened drinks (Ludwig *et al.*, 2001). It has been estimated that each additional can or glass of sugar sweetened beverages per day increases the risk of becoming obese by 60% (Matte, 1996). In a 19 month study of school children in the United States of America, Ludwig *et al.* (2001) reported that the BMI and obesity of the participants increased when more sugar sweetened drinks were consumed. The physiological effects of energy intake and satiety appear to be different for energy in solid foods and energy in fluids. It may be because fluid intake causes less gastric distension and faster transit time, reducing the feeling of fullness. Food intake is then poorly adjusted to account for energy intake from beverages (Matte, 1996). However, Vasilaras *et al.* (2004) reported that higher sugar intakes resulted in lower energy intakes due to the satiating effect of sugar that they observed in their research. They also reported lower mean BMI in the participants consuming higher levels of sugar. This may be explained by a reduction in fat intake seen with higher intakes of sugar, indicating that the intake of sugar partially replaced fat intake. This provides a possible explanation why increased sugar intake did not result in increased body weight in some studies (Beck & Ovesen, 2002; Alexy *et al.*, 2003; Kranz *et al.*, 2005). The same pattern was seen amongst older people in South Africa (Charlton *et al.*, 1998). The BMI of the participants did not differ between the ones consuming the most sugar and those consuming the least sugar. Older men and women with the highest intake of sugar also reported significantly lower intake of fat and protein (Charlton *et al.*, 1998). According to Ruxton *et al.* (1999), evidence shows that higher intakes of sugar were related to leanness, not obesity.

Fat appears to be the principal dietary determinant in obesity rather than sugar (FAO, 1998). In epidemiological and intervention studies, a high sugar intake was associated with a low intake of dietary fat and vice-versa, which does not support a population dietary guideline for sugar intake on the grounds of a relationship with obesity (WHO, 1996).

2.2.5 Impact of sugar on nutrient dilution

Sugar and the impact it has on micronutrient dilution has been extensively studied throughout the years (Table 2.3). Sugar is made up of glucose and fructose and contains no other micronutrients or fibre. The argument is that high intakes of sugar can lead to a reduced intake of other nutrient dense foods in various food groups, thus making it difficult for the individual to achieve adequate levels of nutrient intake (Baghurst *et al.*, 1992).

Forshee and Storey (2001) argued that the impact of added sugars is so small that it would require very large changes in sugar consumption to have any positive or negative effect on the quality of the diet. On the other hand, Overby *et al.* (2003) reported a 30 – 40% reduction in fruit and vegetable consumption in children consuming the most sugar and Kranz *et al.* (2005) showed that children consuming the least sugar seemed to consume one extra serving of grain, fruit and dairy products compared to children consuming >25% added sugar. These food groups are of great importance in young children that need certain micronutrients for optimal health and growth (Kranz *et al.*, 2005).

Evidence that high sugar intake causes micronutrient dilution is inconclusive (Table 2.3). In a review published by Gibson (2007) the author states that evidence supporting the negative impact of sugars on micronutrient intake was usually weak. It is important to consider that in a population with sufficient energy intake, the Recommended Dietary

Allowance (RDA) of micronutrients can be achieved through a wide range of sugar intake (Gibson, 2007). It has been argued that low energy intakes are a better indicator of micronutrient adequacy than dietary sugars concentration (Department of Health and Social Security, 1989; Gibson, 2001). In South Africa, Charlton *et al.* (2005) reported that older South Africans, especially the African population had an inadequate dietary intake and suboptimal nutritional status. High sugar intake worsened the diet quality of women, but energy intake was the most predictive factor of micronutrient intake.

The "Dortmund Nutritional and Anthropometric Longitudinally Designed" (DONALD) study is an observational study that started in the middle of 1985 with children and adults of different ages (Alexy *et al.,* 2002). The study was developed to track the development of healthy subjects from infancy to adulthood collecting data on diet, metabolism and growth. The researchers evaluated the effects of fortification on nutrient density of foods with added sugars in children and adolescents. The results indicated that added sugar was positively associated with energy and fortified food intake in all age groups. Nutrient dilution by added sugars was small and was counteracted by the fortification of sugar sweetened products. The authors reported that participants with the highest energy intakes consumed higher proportions of low nutrient dense foods, indicating that fortification of food can mask the possible nutrient dilution effect of added sugar in the diet (Alexy *et al.*, 2002). In a second part of the DONALD study, Alexy *et al.* (2003) reported that there was no clear indication of micronutrient dilution questioning a quantitative limit on intake of added sugars. However, the DONALD study sample was not representative, with upper social class families over-represented (Alexy *et al.,* 2003). This does not reflect the food intake of the THUSA participants, a population in nutrition transition (MacIntyre *et al.*, 2002).

Most of the evidence investigating sugar intake and the effect it has on micronutrient status come from cross-sectional observational studies (Gibson, 2007). For future research it is necessary to have intervention studies if one wants to predict the outcome of different levels of added sugar on micronutrient status.

Table 2.3 Observational studies of sugar intake and micronutrient dilution effect (Adapted from Gibson, 2007)					
Study	**Country**	**Definition of sugar**	**Age group**	**Added sugars intake (%E)**	**Results**
Gibson (1993)	UK	Total sugar	Children	≥ 23%	Inconsistent trends were observed
Bolton-Smith *et al.* (1995)	UK	NMES	Adults		Lower intakes of antioxidants and fibre
Naismith *et al.* (1995)	UK	Total sugar	Children		Lower intakes of niacin, but still above Recommended Nutrient Intake. Intake of Ca and vitamin C increased
Gibson (1997a)	UK	NMES	Adults	≤ 17% NMES	Non linear relationship between higher sugar intake and micronutrient intake
Gibson (1997b)	UK	NMES	Pre-school	> 20%	Lower intakes of Ca, Fe, Zn, thiamin, riboflavin, folate and vitamin D. Higher intakes of vitamin C
Charlton *et al.* (1998)	South Africa	Added sugar	Older adults	10 – 20%	Nutrient dilution of thiamin, vitamin E, Fe, Zn, Cu, Mg among men and all nutrients except vitamin D and E among women
Farris *et al.* (1998)	USA	Total sugar	Children	≥ 19%	Lower intakes of Fe, Zn, niacin, vitamin B_6 and E. Higher intake of Ca and vitamin D
Baghurst *et al.* (1999)	Australia	Added sugar	Adults	> 19.3% (men) > 18.4% (women)	Dilution of vitamin B_6, folate, carotene, Mg and vitamin C (only women). Higher intake of Ca (only men)
Bowman (1999)	USA	Added sugar	All	> 18%	Lower intakes of vitamin A, C, B_{12}, folate Ca, P, Mg, Fe
Forshee & Storey, (2001)	USA	Added sugar	Children and adolescents	No quantitative intake indicator	Higher intake of vitamin C, Fe, folate in children. Higher intake of vitamin C and Fe in adolescents.
Gibson (2001)	UK	NMES	Older adults	8 - 15%	Intake of micronutrients was best at moderate levels of NMES intake (8 - 15%)
Alexy et al. (2002)	Germany	Added sugar	Children	No quantitative intake indicator	No significant nutrient dilution effect.
Beck and Ovesen, (2002)	Denmark	Added sugar	Older adults	≥ 20%	Decrease in nutrient density for vitamin A, D, E, thiamin, B_6, folate and B_{12}, Fe, Zn and I. Also decrease in fibre
Alexy *et al.* (2003)	Germany	Added sugar	Children	No quantitative intake indicator	Slight nutrient-dilution effect and reduction in intake of important food groups (fruit and vegetables).
Overby *et al.* (2004)	Norway	Added sugar	Children	15-18%	Lower intakes of vitamin D, thiamin, ribolflavin, Ca and Fe
Charlton *et al.* (2005)	South Africa	Added sugar	Older adults	> 18%	Nutrient dilution of thiamin, riboflavin, niacin, vitamin B_6, folate, pantothenic acid, biotin, vitamin C, Ca, Fe, Mg, phosphorus, zinc, Cu, selenium and fibre (only women)
Krantz *et al.* (2006)	USA	Added sugar	Children	≥ 25%	Nutrient dilution of Ca, Fe, folate, vitamin A and B_{12} also lowest intake of grains, vegetables, fruit and dairy

NMES = Non milk extrinsic sugar

Limitations to draw conclusions from all the studies are the terminology used to determine the type of sugar that was used and also whether sugar was investigated in absolute intakes or as a % of the TE (Charlton *et al.,* 2005). Steyn *et al.* (2003a) reviewed existing evidence of the effect of sugar as an energy source, the role it plays in dental caries, protein-energy malnutrition, micronutrient dilution and obesity, to establish a guideline for sugar intake in South Africa. With regard to dental caries, the authors recommended that sugar intake should be < 40g/day in areas where water is not fluoridated and ≤ 55g/day in fluoridated areas. Sugar intake should not exceed 6 – 10% of total energy. The frequency, quantity and timing of sugar consumption have a great impact on dental caries. The proposed guideline was "Eat and drink food and drinks containing sugar sparingly and not between meals" (Steyn *et al.*, 2003).

Very high levels of added sugar in the diets of people with poor nutrient intakes should be limited, even more so, when sugar is consumed at the expense of other more nutritious food rich in micronutrients and fibre. In South Africa, as in all countries, emphasis should be placed on the consumption of a healthy balanced diet guided by the food based dietary guidelines.

Conclusion

Both alcohol and sugar add energy to the diet without adding much to the nutritional value of the diet. Traditional home brewed alcoholic beverages do add some micronutrients but the intake of these beverages is being substituted with high alcoholic beverages as people move to more urbanised areas. There is also a change in food patterns with urbanisation. Simple meals of grain, legumes, fruit and vegetables rich in complex carbohydrates and nutrients are often being abandoned for foods higher in sugar and fat (Popkin, 1994). The pattern observed in the THUSA study differed somewhat in this respect. Urban subjects consumed more animal derived foods, fats and oils and less maize porridge, as was expected, but more fruit and vegetables, resulting in a more varied diet with better micronutrient densities (Vorster *et al.*, 2005).

It is important to examine the diet of an individual in its whole, and not just a single ingredient such as alcohol or sugar. Any observed associations between added sugar and alcohol intakes and micronutrient intakes are dependent on the foods that are consumed (Rennie & Livingstone, 2007). Dietary intakes are complex and if only one component of the diet is evaluated in relation to other nutrients, it overlooks other foods, like fortified cereal or breads' interaction on nutrient densities (Rennie & Livingstone, 2007). South Africa is suffering from a double burden of disease with overnutrition often hand in hand with undernutrition (Labadarios *et al.*, 2005). Nutrient dilution in a public health perspective will depend on the level of a certain nutrient as part of the daily diet and the prevalence of a deficiency in the community (Gibson, 2001). The consumption of alcohol and sugar by the THUSA population, and the effect thereof on micronutrient consumption, will be discussed in the next two chapters, which are presented as articles submitted to the South African Journal of Clinical Nutrition.

CHAPTER 3: ARTICLE

Alcohol intake and micronutrient density in a population in transition: the THUSA study

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Abstract

Objective. To investigate the possibility of micronutrient dilution by alcohol in the diets of an adult population in nutrition transition.

Design. A cross sectional, comparative, population based study.

Setting. The African population of the North West Province, South Africa

Subjects. One thousand seven hundred and fifty seven participants (742 men, 1015 women) aged 15 years and older from 37 randomly selected sites from rural and urban areas.

Outcome measures. Outcome measures included alcohol consumption at different levels of urbanisation. Nutrient intakes in different alcohol intake categories (abstainers, light to moderate and heavy drinkers) as well as body mass indices of men and women separately.

Results. Sixty one percent of men and twenty five percent of women reported alcohol consumption. Percentage energy provided by alcohol were 2.8% and 1.5% for light to moderate drinking men and women respectively and 18.1% and 11.7% for heavy drinkers, defined as those consuming more than 30g alcohol/day for men and more than 15g alcohol/day for women. Sorghum and commercial beers were the most popular alcoholic beverages. Alcohol intake increased from rural to middle class urban, with a shift from sorghum to commercial beer with urbanisation. Men and women consuming the most alcohol had significantly higher mean intakes of most macro and micronutrients. For both men and women only percentage energy from fat reduced significantly as alcohol intake increased. Intake of some micronutrients did not meet the Dietary Reference Intake (DRI, Estimated Average Requirement (EAR)) at all levels of alcohol consumption. However, the DRIs for pantothenic acid, biotin and zinc were met only in men consuming the most alcohol. There was no significant difference in BMI across the different alcohol categories although the total energy intake increased with an increase in alcohol consumption.

Conclusion. In this population in transition, urbanisation increased the consumption of alcoholic beverages. Mean energy intake from alcohol of heavy drinking men (18.1% of total energy, TE) and women (11.7% of TE) was significantly higher than the other groups but this did not cause an overall micronutrient dilution effect. It seems that respondents, who have the money to buy alcoholic drinks, can possibly also afford more healthy and nutritious food.

Introduction

South Africa is undergoing a rapid urbanisation, especially the African population, seeking a better life in the more affluent urbanised areas.[1] People are moving away from the rural areas to live in and around the cities of South Africa to improve their socio-economic conditions. Urbanisation causes a shift in food intake, increasing the availability of cheaper and more energy dense food and drinks that are often lacking in micronutrients.[2] Urban areas not only have higher availability of cheaper unhealthy foods but higher rates of drinking were also recorded in urban areas than in the rural areas by Parry *et al.*[3] in the 1998 South African Demographic and Health Survey (SADHS). Alcohol consumption was almost half in the rural areas (38g per day) compared to 67g alcohol intake per day for their urban counterparts. Forty-five percent of South African men and 17% of women participating in the SADHS reported that they were currently drinking alcohol and in the North West Province current drinking was reported by 47% of men and 17% of women.[3] Both the type and amount of alcohol consumed are changing. Traditional low alcohol home brewed sorghum beer is being substituted with commercial beer, spirits and wine.[4]

Alcohol consumption may cause micronutrient dilution when consumed at high levels.[5] Light to moderate alcohol consumption has been described as healthy.[6] Moderate drinking can be described as one drink per day for women (15g alcohol/day) and two drinks per day for men (30g alcohol/day).[7] However, drinking more than two to three drinks per day (for women and men respectively) can cause micronutrient dilution, either displacing nutrients or interfering with the metabolism.[5] This can lead to deficiencies of micronutrients such as thiamin[8], vitamin B6, B12, folate[9] and antioxidants.[10] Therefore, South Africa has developed guidelines for safe and sensible alcohol consumption[11] to guide people to make the correct choices when consuming alcohol.

Any dietary component that is causing micronutrient dilution in South Africa needs urgent attention from health professionals. The overall mean intake of certain vitamins and minerals in South Africa reflected a nutritionally depleted diet.[12] There was some alleviation from micronutrient deficiencies after it became compulsory to fortify South African staple foods, maize meal and wheat flour with vitamin A, iron, zinc, folate, thiamin, niacin, vitamin B_6 and riboflavin in October 2003.[13] However, fortification does not solve all micronutrient deficiencies and a deficiency of calcium, iron, folate and vitamin B_6 are still common in both adults and children.[13]

In the present study data from the "Transition and Health during Urbanisation in South Africa" survey (THUSA) were analysed to determine the level of micronutrient dilution caused by alcohol in this community in transition. The THUSA study (see Vorster *et al.*[14]) was undertaken during 1996 and 1998 to compare the prevalence of known risk factors for non-communicable diseases in Africans in the North West Province at different stages of urbanisation and to provide information for the development of preventive strategies.

METHODS

Study design, subject selection and organisational procedures

A statistical model was used to recruit 1854 "apparently healthy" volunteers, aged 15 years and older from 37 randomly selected sites from rural and urban areas. The participants were stratified into five levels of urbanisation based on area of residence and type of income as rural, farm, informal settlement, middle class urban and upper class urban. Pregnant and lactating women, individuals taking chronic medication and inebriated volunteers were excluded. The study was approved by the Ethics Committee of the Potchefstroom University (Ethics number 4M5-95) and all participants signed an informed consent form after the procedures were explained to them in their own language.

Demographic information, health histories and dietary intake data were obtained during individual interviews by specially trained, multilingual fieldworkers in the language of the subject's choice, using questionnaires specially designed or adapted and validated for this population. Dietary intakes were measured with a culture sensitive quantitative food frequency questionnaire (QFFQ), which was validated against a seven-day weighed food record and biomarkers[15] as well as a combination of statistical methods.[16] Reproducibility of the questionnaire was tested on a subsample of 144 respondents.[17] Anthropometric measurements (height, weight, body circumferences and skinfold thicknesses) were measured by post-graduate biokinetics students, standardised by a level III anthropometrist. Fasting blood samples were drawn by registered nursing sisters from the vena cephalica using a sterile butterfly infusion set (Johnson & Johnson; 21G, 19 mm) and sterile syringes. Serum and plasma were prepared immediately in the field using a Universal 16R™ Hettich centrifuge (Tuttlingen, Germany) with cooling facilities. Serum and plasma samples were stored at -20°C in the field for 2-4 days and later at -84°C in the laboratory. Liver enzymes (including serum gamma-glutamyl transferase (GGT) to verify reported alcohol intakes) and fasting glucose in serum were determined with the DAX system (discrete analyzer, Technicon DAX 48; Miles Inc. Diagnostic Division, Tarrytown, NY, USA).

Statistical analysis

The average daily intake of each food item was calculated in grams from the weight of the portion size and the frequency of consumption. Portion sizes reported in household measures were converted to weights. The FoodFinder 3 Dietary analysis programme of the MRC was used for the dietary analyses of energy and nutrient intakes and intakes of alcohol and specific foods. The contributions of carbohydrate, protein, fat and alcohol to total energy intakes were expressed as percentages of energy intakes. Alcohol consumption was divided into three levels of intake for men and women separately. Respondents who abstained from alcohol were in Group 1. Men who consumed up to two drinks per day (30g alcohol per day) and women consuming up to one drink per day (15g alcohol) were in Group 2. Those men drinking more than 30g and women consuming more than 15g alcohol per day were in Group 3. Differences between mean intakes of strata of urbanisation were tested using the analysis of variance (ANOVA) procedure.

Significant p-values were tested using the TUKEY test for honest significant differences (HSD) with the level of significance set at 0.05, using the Statistica programme (StatSoft Inc., Tulsa, OK, USA). The SPSS 15 package (SPSS Inc., Chicago, IL, USA) was used to analyse differences between the three levels of alcohol intakes using non-parametric multi-variate analyses. Non-parametric partial correlations between alcohol intake and GGT were performed, adjusted for age, BMI and serum glucose.

Results

Obtaining accurate information on alcohol consumption was extremely difficult. Many subjects reported drinking 'two or three' cases (12 bottles) of 'quarts' (750 mL bottles) of beer over a weekend. Usually men drink together in a group which makes it difficult to know exactly how many bottles or cans were consumed by an individual. The amount of 'home made' beer was also difficult to quantify. However, alcohol intake correlated weakly but statistically significantly ($r=0.08$, $p=0.029$) with GGT, adjusted for age, BMI and serum glucose. For the women a somewhat stronger correlation ($r=0.22$, $p=0.000$) was found. Furthermore, alcohol intake as measured by the QFFQ correlated (Spearman rank coefficient) relatively good ($r=0.53$, $p<0.05$) with intake as measured by a seven-day weighed record completed by a subsample of respondents (n=74).[15]

Sixty-one percent of men and 25% of women reported alcohol consumption. Alcohol intakes, expressed as intake in gram and as energy provided by alcoholic beverages (Tables I and II), varied considerably. Alcohol intakes of the women in all strata were low (mean of 11.4 g/day, standard deviation (SD) 18.8) for the drinkers and non-drinkers. Among the males, however, alcohol contributed between 6.1% and 7.9% of the total dietary energy (mean intake of drinkers as well as non-drinkers, 30.2g/day, SD 47.7). Intakes increased from rural to middle class urban, but people living in upper urban areas consumed the least alcohol. Men from the urban middle class had the highest mean intake of alcohol (33.7g/day) and the highest proportion of drinkers (73%). Women living on farms had the highest mean intake (15.2g/day) but a larger percentage of women from informal settlements reported alcohol consumption (35%).

Table I. Daily energy, macronutrient and alcohol intake of men by strata of urbanisation (mean, standard error of the mean)						
	Rural (R)	**Farm (F)**	**Informal settlement (IS)**	**Middle class urban (MC)**	**Upper class urban (UC)**	**Significant differences[a]**
	n = 194	**n = 109**	**n = 128**	**n = 229**	**n = 83**	
	Mean (SEM)	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**	
Energy (kJ)	9597(278)	8913(371)	9333 (342)	9897(256)	9818 (425)	R:UC
Carbohydrate (g)	360.5(11.0)	340 (14.7)	335.0(13.5)	343.4(10.2)	315(16.8)	R:UC
Energy %	67.4 (0.67)	67.2(0.89)	65.5 (0.82)	64.0 (0.62)	57.3 (1.02)	R,F,IS,MC:UC
Protein (g)	65.9 (1.8)	63.6 (2.4)	63.8 (2.2)	66.3 (1.7)	76.9 (2.7)	R,F,IS,MC:UC
Energy %	11.6 (0.15)	12.1 (0.2)	12.0 (0.18)	11.8 (0.14)	13.2 (0.23)	R,F,IS,MC:UC
Animal protein (g)	25.9 (1.1)	28.2 (1.5)	27.2 (1.4)	29.2 (1.0)	44.1 (1.7)	R,F,IS,MC:UC
Plant protein (g)	39.8 (1.2)	35.3 (1.6)	36.3 (1.5)	36.9 (1.1)	32.6 (1.9)	R:F:R:UC:MC:UC
Fat (g)	54.4 (1.9)	51.1 (2.5)	55.3 (2.3)	63.0 (1.7)	77.3 (2.8)	R,F,IS:MC,UC; MC:UC
Energy %	22.9 (0.51)	22.8(0.68)	24.3 (0.63)	26.0 (0.47)	30.6 (0.78)	R,F,IS:MC,UC; MC:UC
Alcohol (g)*	31.5(4.77)	20.1(6.16)	30.77(5.09)	33.7(3.68	25.0(7.36)	F:MC
Energy %*	7.5 (0.92)	6.1 (1.18)	7.6 (0.98)	7.9 (0.71)	6.5 (1.4)	
Fibre (g)	19.2 (0.67)	15.6 (0.9)	17.4 (0.82)	18.8 (0.61)	19.7 (1.02)	R:F,MC,UC:F

[a] Difference significant $p < 0.05$. Strata before colon differ significantly from strata after colon
n = number; SEM = standard error of the mean; * Data given for drinkers only (61% of men)

Table II. Daily energy, macronutrient and alcohol intake of women by strata of urbanisation (mean, standard error of the mean)						
	Rural (R)	**Farm (F)**	**Informal settlement (IS)**	**Middle class urban (MC)**	**Upper class urban (UC)**	**Significant differences[a]**
	n = 290	**n = 148**	**n = 172**	**n = 292**	**n = 106**	
	Mean(SE)	**Mean (SE)**	**Mean (SE)**	**Mean(SE)**	**Mean (SE)**	
Energy (KJ)	7906(180)	7973 (251)	7893 (233)	8010(179)	8523(297)	
Carbohydrate (g)	308.0(7.7)	313.0(10.7)	292.2 (9.9)	283.6(7.6)	276.0(12.7)	R,F:MC,UC
Energy %	67.0(0.54)	68.3 (0.75)	64.1 (0.70)	61.5(0.54)	55.6 (0.89)	R,F:IS,MC,UC; IS:MC,UC; MC:UC
Protein (g)	54.8 (1.3)	54.4 (1.8)	56.9 (1.6)	59.5 (1.3)	69.7 (2.1)	R,F,IS:MC,UC; MC:UC
Energy %	11.4(0.13)	11.3 (0.18)	11.8 (0.16)	12.1(0.12)	13.4 (0.21)	R,F,IS:MC,UC; MC:UC
Animal protein (g)	22.2(0.86)	22.1 (1.21)	25.9 (1.12)	29.1(0.86)	42.6 (1.43)	R,F,IS,MC:UC
Plant protein (g)	32.4(0.80)	32.2 (1.13)	30.9 (1.04)	30.2(O.80)	27.0 (1.33)	R,F,IS,MC:UC; R:MC
Fat (g)	48.7 (1.5)	47.0 (2.0)	52.8 (1.9)	58.8 (1.5)	72.7 (2.4)	R,F,IS:MC,UC; F:IS; MC:UC
Energy %	23.6(0.41)	22.6 (0.57)	25.6 (0.53)	27.7(0.40)	31.8 (0.67)	R,F,IS:MC,UC; R,F:IS; F:R; MC:UC
Alcohol (g)*	12.1(2.51)	15.2 (2.85)	10.8 (2.39)	11.6(2.16)	2.8 (3.98)	R,F,IS,MC:UC
Energy %*	4.6 (0.74)	4.9 (0.84)	4.0 (0.70)	3.4 (0.63)	0.80 (1.17)	R,F,IS,MC:UC
Fibre (g)	15.8(0.44)	15.4 (0.62)	16.3 (0.58)	17.1(0.44)	17.7 (0.73)	R,F:MC,UC

[a] Difference significant $p < 0.05$. *Strata before colon differ significantly from strata after colon*
n = number; SEM = standard error of the mean; * Data given for drinkers only (25% of women)

Commercial beer, sorghum beer and home brew were the most popular beverages, a finding which is in agreement with Ramphele and Heap[18] and Steyn *et al.*[19] With increased urbanisation, the type of beer shifted from sorghum based to commercial beer, as shown in Table III which depicts the ten foods consumed in the largest amounts per day.

Tables IV and V show alcohol and nutrient intake as percentage of energy and as absolute intakes for men and women respectively in the different alcohol intake categories. Results for the men show that energy, carbohydrate (% TE) and fibre intake increased as alcohol intake increased. Male respondents consuming more than 30g per day also had significantly higher mean intakes of most micronutrients (vitamin A, thiamin, riboflavin, niacin, vitamin B12, folate, pantothenic acid, calcium, iron, magnesium, phosphorus, zinc, copper, potassium and sodium) than non-drinkers and also more of these nutrients than light to moderate drinkers except for vitamin A which was not significantly different. Light to moderate drinkers consumed significantly more thiamin than heavy drinkers. Women consuming more than 15g alcohol per day had higher mean intakes of energy, protein, thiamin, riboflavin, niacin, folate, iron, magnesium, phosphorus, zinc and potassium than non-drinkers and more energy, riboflavin, niacin, magnesium, phosphorous and zinc than light to moderate drinkers. For both men and women only percentage energy from fat reduced significantly as alcohol intake increased. Although the total energy intake increased with increased alcohol intake, there was no significant difference between the mean BMI of the three groups of men and women. Heavy drinking men and women were significantly older than the non-drinkers. Mean intakes of vitamin B_{12}, vitamin E, folate, ascorbic acid and calcium were below the Dietary Reference Intake[22] (DRI, Estimated Average Requirements (EAR) for men at all levels of alcohol consumption. Pantothenic acid, biotin and zinc intakes reached the DRI in the group of men consuming more than 30g alcohol/day but not in the other groups. Women had intakes lower than the EAR for vitamin B_{12}, folate, pantothenic acid, biotin, vitamin D, vitamin E, ascorbic acid and calcium at all levels of alcohol intake.

Table III. Top ten food items consumed in largest amount per person by men and women in different strata (g/day)

Rural			Farm			Informal settlement (IS)			Middle class urban (MU)			Upper class urban (UC)		
N = 484			n = 257			n = 300			n = 521			n = 189		
Food item	Total (n)	Mean (g)	Food item	Total	Mean (g)	Food item	Total	Mean (g)	Food item	Total	Mean (g)	Food item	Total	Mean (g)
Beer, sorghum	74	782.2	Beer, sorghum	66	745.5	Beer, commercial	82	619	Beer, commercial	151	735.2	Beer, commercial	41	595.9
Beer, commercial	92	625.1	Maize porridge	257	558	Beer, sorghum	99	427.1	Maize porridge	514	423	Tea, brewed	136	308.5
Maize porridge	475	490	Tea, brewed	189	471.5	Tea, brewed	236	426.2	Tea, brewed	389	421.5	Maize porridge	95	240
Tea, brewed	349	467.3	Coffee, brewed instant	65	436	Maize porridge	300	411	Beer, sorghum	102	391.1	Coffee brewed instant	46	227.5
Coffee, brewed instant	126	430	Milk, whole fresh and UHT	204	274.6	Tea, rooibos brewed	3	342	Coffee, brewed instant	142	296	Milk, fresh whole and UHT	169	151.5
Tea, rooibos brewed	3	400	Mabella cornrice/ sorghum cooked	3	223.7	Coffee, brewed instant	74	315.7	Maltabella, cooked	16	174.5	Cold drink, squash, diluted	80	150.9
Mabella cornrice/sorghum cooked	15	238.1	Beer, commerc ial	56	212.9	Mabella cornrice/sorghum cooked	7	261.7	Brandy	22	132.5	Cold drink, carbonated	107	144.6
Milk, whole fresh and UHT	413	149.8	Cold drink, carbonat ed	149	184.6	Maltabella, cooked	18	187.2	Milk, whole fresh and UHT	436	129.3	Orange juice - Liquifruit/Ceres	15	126.1
Maize, whole kernel raw (white)	4	148.3	Amahew u*	90	115.4	Champagne	13	155.4	Cold drink, carbonated average	369	119.5	Cold drink, low cal/diet squash	25	113.2
Samp and Beans, 1:1	1	143	Coldrink, low-cal/diet squash	86	84.2	Milk, whole fresh and UHT	250	146.9	Cold drink, low cal/diet squash	129	96.2	Mabella cornrice/sorghum, cooked	3	81.7

* Amahewu (maheu, mageu, magou, aramrewu) is a traditional non alcoholic lactic-acid-fermented maize drink.[30]

Intake expressed as a proportion of energy (Tables VI and VII) showed a significant reduction of most micronutrients (vitamin A, thiamin, vitamin B6, folate, pantothenic acid, vitamin D, vitamin E, calcium, zinc) for heavy drinking men with the exception of niacin and magnesium. Expressed per energy unit (4.18kJ), women who were light to moderate drinkers consumed more vitamin A, vitamin B12 and vitamin D than the other two groups. Niacin, phosphorus and magnesium intake per energy unit increased in female heavy drinkers. The nutrient densities of vitamin B6, folate, pantothenic acid, vitamin E and calcium were significantly higher in abstainers than in heavy drinkers.

With regard to food group intakes, female heavy drinkers consumed significantly more chicken, fish, vegetables, potatoes, samp, fat and sugar than the non- drinkers and more chicken, fish, eggs, fat and sugar than the light to moderate drinkers (data not shown). The light to moderate drinkers consumed more red meat than the other two groups of women. Heavy drinking males consumed significantly more rice than the other two groups whilst the light to moderate drinkers consumed the most milk, cereals and fat. Significantly more sugar and cold drinks were consumed by the abstainers.

Table IV. Daily nutrient intake, BMI and age of men according to alcohol intake (g/day): mean, 95% confidence interval					
Nutrient	**DRI (EAR)**	**Total (n =747)**	**Group1:0g/day (n =286)**	**Group2:0.1-30g/day (n =319)**	**Group3:>30g/day (n 137)**
Alcohol (g)		18.5 (16.5-20.5)	0.4 (-2.8-3.5)[ab]	8.3 (5.3-11.3)[ac]	80.4 (75.7-84.9)[bc]
% E alcohol		4.5 (4.1-5.0)	0.1 (-0.5-0.7)[ab]	2.8 (2.3-3.4)[ac]	18.1 (17.3-18.9)[bc]
Total Energy (including alcohol)		9569.4 (9320.7-9818)	8662.4 (8248.9-9075.9)[a]	8986.1 (8597.1-9375.1)[b]	12849(12255-13444)[ab]
% E protein		12.0 (11.8-12.1)	12.0 (11.7-12.2)	12.0 (11.8-12.3)	11.8 (11.4-12.1)
% E fat		24.9 (24.4-25.5)	25.5 (24.7-26.4)[a]	25.3 (24.5-26.1)[b]	22.5 (21.3-23.7)[ab]
% E carbohydrates		64.9 (64.2-65.6)	64.4 (63.5-65.6)[a]	64.5 (63.5-65.6)[b]	65.1 (65.5-68.8)[ab]
Added sugar(g)		54.1 (50.7-57.6)	54.8 (49.3-60.2)	52.9 (47.8-58.1)	55.3 (47.5-63.2)
% E from sugar		9.5 (9.0-10.1)	11.9 (10.9-12.8)[ab]	10.5 (9.6-11.5)[ac]	8.4 (7.0-9.8)[bc]
Fibre g/d	30-38	18.3 (17.7-18.9)	15.2 (8.0)[a]	18.3 (10.0)[b]	21.1 (9.1)[ab]
Vitamin A (µg RE)	625	705.2 (656.5-753.9)	654.6 (582.2-727.1)[a]	710.8 (642.4-779.2)	799.7 (695.3-904.1)[a]
Thiamin (mg)	1	1.2 (1.1-1.2)	1.2 (1.1-1.2)[a]	1.6 (1.1-1.2)[b]	1.3 (1.2-1.4)[ab]
Riboflavin (mg)	1.1	1.5 (1.4-1.5)	1.4 (1.3-1.5)[a]	1.4 (1.3-1.5)[b]	2.0 (1.9-2.1)[ab]
Niacin (mg)	12	15.2 (14.7-15.7)	12.8 (12.0-13.7)[a]	13.8 (13.0-14.6)[b]	23.2 (21.9-24.4)[ab]
Vitamin B12 (µg)	2	1.1 (1.1-1.2)	1.0 (0.9-1.1)[a]	1.1 (1.4-1.6)[b]	1.5 (1.4-1.6)[ab]
Vitamin B6 (mg)	1.1-1.4	5.0 (4.7-5.4)	4.8 (4.2-5.4)	5.0 (4.4-5.5)	5.6 (4.7-6.4)
Folate (µg)	320	223.1 (216.4-229.7)	205.2 (193.7-216.8)[a]	208.1 (197.3-219.0)[b]	295.3 (278.7-311.9)[ab]
Pantothenic acid (mg)	5.0 (AI)	4.3 (4.1-4.4)	3.9 (3.7-4.1)[a]	4.0 (3.8-4.2)[b]	5.5 (5.2-5.8)[ab]
Biotin (µg)	30.0 (AI)	28.7 (27.7-29.7)	26.4 (24.7-28.1)[a]	26.9 (25.3-28.6)[b]	37.7 (35.2-40.2)[ab]
Vitamin D (µg)	5.0-10.0	5.4 (5.1-5.6)	5.6 (5.1-6.1)	5.3 (4.9-5.8)	4.9 (4.1-5.6)
Vitamin E (mg)	12	11.7 (11.2-12.1)	11.7 (10.9-12.5)	11.6 (10.9-12.4)	11.8 (10.6-12.9)
Ascorbic acid (mg)	75	34.9 (32.1-37.8)	34.1 (30.1-38.2)	34.6 (30.8-38.4)	37.5 (31.7-43.3)
Calcium (mg)	1000-1200(AI)	459.4 (441.1-477.6)	436.0 (405.4-466.7)[a]	443.7 (414.8-472.6)[b]	544.9 (500.7-589.0)[ab]
Iron (mg)	6	9.2 (8.9-9.5)	8.8 (8.3-9.3)[a]	8.8 (8.4-9.3)[b]	10.7 (9.9-11.4)[ab]
Magnesium (mg)	350	356.0 (345.0-367.1)	304.7 (285.8-323.6)[a]	322.7 (304.8-340.5)[b]	541.9 (514.7-569.1)[ab]
Phosphorus (mg)	580	1169.9 (1138.7-1201.0)	1043.0 (990.5-1095.5)[a]	1087.6 (1038.1-1137.2)[b]	1628.1 (1552.5-1703.7)[ab]
Zinc (mg)	9.4	8.9 (8.6-9.2)	8.6 (8.2-9.0)[a]	8.6 (8.2-9.0)[b]	10.2 (9.6-10.8)[ab]
Potassium (mg)		2263 (903.8)	2070.3 (1971.9-2168.7)[a]	2154.1 (2061.1-2246.9)[b]	2932.4 (2790.6-3074.1)[ab]
Sodium (mg)		1361.7 (805.7)	1304.6 (1214.5-1394.8)[a]	1333.6 (1248.6-1418.7)[b]	1561.5 (1431.6-1691.3)[ab]
BMI		21.1 (20.7-21.5)	21.3 (20.9-21.7)	20.9 (20.5-21.3)	21.0 (20.4-21.6)
Age		37.8 (36.8-38.7)	34.6 (32.8-36.5)[ab]	39.2 (37.4-40.9)[a]	40.6 (38.0-43.3)[b]

a,b,c = means with the same letter differ significantly, $p \leq 0.05$

n = number; CI = confidence interval; EAR = Estimated Average Requirement; AI = Adequate Intake

Table V. Daily nutrient intake, BMI and age of women according to alcohol intake (g/day): mean, 95% confidence interval					
Nutrient	**DRI (EAR)**	**Total (n =1015)**	**Group 1: (0g)(n =759)**	**Group 2:(0.1-5g)(n =196)**	**Group 3: (>15g)) (n =60)**
Alcohol (g)		2.9 (1.2-4.6)	0.0 (-0.5-0.5)[ab]	3.7 (2.8-4.6)[ac]	36.6 (34.9-38.2)[bc]
% E alcohol		1.0 (0.6-1.3)	0.0 (-0.1-0.1)[ab]	1.5 (1.2-1.7)[ac]	11.7 (11.2-12.2)[bc]
Total Energy (including alcohol)		8005.0 (7791.5-8218.6)	7867.7(7653.5-8082)[a]	7990.6(7569.3-8411.8)[b]	9582.4 (8818.9-10346.0)[ab]
% E protein		11.9 (11.7-12.0)	11.8 (11.7-12.0)	12.1 (11.8-12.4)	11.9 (11.4-12.5)
% E fat		25.8 (25.4-26.3)	25.9 (25.3-27.4)[a]	26.3 (25.3-27.4)[b]	23.8 (21.9-25.7)[ab]
% E carbohydrates		63.9 (63.3-64.6)	64.1 (63.3-64.8)	63.1 (61.7-64.5)	65.1 (62.5-67.6)
Added sugar(g)		52.5 (49.6-55.4)	53.3 (49.8-56.7)	50.6 (43.9-57.2)	43.6 (31.5-55.7)
% E from sugar		10.7 (10.2-11.1)	12.3 (11.7-13.0)[a]	11.7 (10.4-13.1)[b]	8.2 (5.9-10.6)[ab]
Fibre g/d	21-25	16.4 (15.9-16.9)	16.3 (15.8-16.8)	16.4 (15.3-17.4)	17.3 (15.4-19.2)
Vitamin A (µg RE)	625	761.2 (719.4-803.1)	739.0 (687.9-790.0)[a]	862.4 (761.9-962.9)[a]	712.4 (530.1-894.8)
Thiamin (mg)	1	1.1 (1.0-1.1)	1.1 (1.0-1.1)[a]	1.1 (1.0-1.1)	1.2 (1.1-1.3)[a]
Riboflavin (mg)	1.1	1.3 (1.3-1.4)	1.3 (1.3-1.4)[a]	1.3 (1.2-1.4)[b]	1.6 (1.4-1.8)[ab]
Niacin (mg)	12	12.4 (12.0-12.8)	12.1 (11.6-12.5)[a]	12.5 (11.7-13.3)[b]	16.5 (15.0-18.0)[ab]
Vitamin B12 (µg)	2	1.0 (0.9-1.0)	1.0 (0.9-1.0)	1.0 (1.0-1.1)	1.0 (0.9-1.2)
Vitamin B6 (mg)	1.1-1.4	4.8 (4.5-5.1)	4.8 (4.4-5.2)	4.8 (4.1-5.5)	4.4 (3.1-5.7)
Folate (µg)	320	193.2 (187.5-198.9)	190.9 (185.0-196.8)[a]	196.2 (184.7-207.8)	212.9 (191.9-233.8)[a]
Pantothenic acid (mg)	5.0 (AI)	3.5 (3.4-3.6)	3.5 (3.4-3.6)	3.5 (3.3-3.7)	3.8 (3.5-4.2)
Biotin (µg)	30 (AI)	21.7 (20.8-22.5)	21.7 (20.9-22.5)	20.9 (19.2-22.5)	24.0 (21.0-27.1)
Vitamin D (µg)	05-Oct	4.5 (4.0-4.5)	4.3 (4.1-4.6)	4.1 (3.6-4.6)	4.0 (3.1-5.0)
Vitamin E (mg)	12	10.2 (9.8-10.6)	10.2 (9.8-10.6)	10.2 (9.4-11.0)	11.1 (9.6-12.5)
Ascorbic acid (mg)	75	38.9 (36.5-41.4)	39.4 (36.3-42.4)	40.4 (34.5-46.4)	29.0 (18.2-39.8)
Calcium (mg)	1000-1200(AI)	409.8 (394.1-425.5)	407.9 (390.5-425.3)	409.9 (375.7-444.2)	433.8 (371.7-495.9)
Iron (mg)	6	8.6 (8.3-8.8)	8.4 (8.1-8.7)[a]	8.7 (8.1-9.3)	9.7 (8.7-10.7)[a]
Magnesium (mg)	350	290.3 (280.8-299.8)	280.2 (271.5-306.2)[a]	289.0 (271.8-306.2)[b]	423.0 (391.9-454.2)[ab]
Phosphorus (mg)	580	962.2 (935.4-989.0)	941.7 (915.5-968.0)[a]	961.0 (909.3-1012.7)[b]	1226.6 (1132.8-1320.4)[ab]
Zinc (mg)	9.4	8.0 (7.8-8.2)	7.9 (7.6-8.1)[a]	8.1 (7.6-8.6)[b]	9.2 (8.3-10.0)[ab]
Potassium (mg)		2263 (903.8)	1998.7(1942-2055.4)[a]	2089.7 (1978-2201.4)[b]	2355.0 (2152.2-2557.7)[ab]
Sodium (mg)		1361.7 (805.7)	1238.6 (1189-1288.2)	1242.0 (1144.3-1339.8)	1268.7 (1091.4-1446.0)
BMI		27.0 (26.6-27.3)	27.1 (26.6-27.5)	26.9 (26.0-27.9)	25.6 (23.8-27.3)
Age		37.8 (36.8-38.7)	37.3 (36.0-38.1)[a]	38.0 (36.0-40.0)	41.8 (38.1-45.5)[a]

a,b,c = means with the same letter differ significantly, $p \leq 0.05$; n = number; CI = confidence interval;
EAR = Estimated Average Requirement; AI= Adequate Intake

Table VI. Daily micronutrient intake of men (per 4.18MJ), according to alcohol intake as a proportion of energy (95% confidence interval)				
Nutrient	**Total (n =742)**	**Group 1: (0g) (n =286)**	**Group 2: (0.1- 30g) (n =319)**	**Group 3: (> 30g) (n =137)**
% energy from alcohol	4.6 (4.2-5.0)	0.1 (-0.5-0.7)	2.8 (2.3-3.4)	18.1 (17.3-18.9)
Vitamin A (µg/4.18MJ)	327.3 (303.6-351.1)	330.2 (0.5-0.6)	348.0 (315.9-380.1)[a]	273.4 (224.5-322.4)[a]
Thiamin (mg/4.18MJ)	0.5 (0.51-0.53)	0.6 (0.5-0.6)[a]	0.5 (0.5-0.6)[b]	0.4 (0.4-0.5)[ab]
Riboflavin (mg/4.18MJ))	0.7 (0.6-0.7)	0.7 (0.6-0.7)	0.7 (0.6-0.7)	0.7 (0.6-0.7)
Niacin (mg/4.18MJ)	6.6 (6.4-6.7)	6.3 (6.0-6.5)[a]	6.5 (6.3-6.7)[b]	7.5 (7.2-7.9)[ab]
Vitamin B12 (µg/4.18MJ)	0.5 (0.4-0.5)	0.5 (0.4-0.5)	0.5 (0.4-0.5)	0.5 (0.4-0.5)
Vitamin B6 (mg/4.18MJ)	2.4 (2.2-2.5)	2.5 (2.2-2.8)[a]	2.4 (2.2-2.7)[b]	1.9 (1.5-2.3)[ab]
Folate (µg/4.18MJ)	15.7 (14.3-17.0)	16.8 (15.2-18.4)[a]	16.0 (14.5-17.5)[b]	12.4 (10.1-14.7)[ab]
Pantothenic acid (mg/4.18MJ)	1.9 (1.9-2.0)	2.0 (2.0-2.1)[a]	2.0 (1.9-2.0)[b]	1.8 (1.7-1.9)[ab]
Biotin (µg/4.18MJ)	13.1 (12.7-13.6)	13.5 (12.8-14.3)[a]	13.2 (12.5-13.9)	12.1 (11.0-13.2)[a]
Vitamin D (µg/4.18MJ)	2.6 (2.5-2.8)	3.0 (2.7-3.3)[a]	2.7 (2.5-3.0)[b]	1.6 (1.2-2.0)[ab]
Vitamin E (mg/4.18MJ)	5.3 (5.1-5.6)	5.8 (5.5-6.1)[a]	5.5 (5.2-5.7)[b]	3.9 (3.5-4.3)[ab]
Calcium (mg/4.18MJ)	207.9 (200.1-215.7)	217.0 (205.1-228.9)[a]	210.3 (199.1-221.6)[b]	183.3 (166.1-200.4)[ab]
Iron (mg/4.18MJ)	4.1 (4.0-4.2)	4.3 (4.1-4.4)[a]	4.1 (4.0-4.3)[b]	3.5 (3.3-3.7)[ab]
Magnesium (mg/4.18MJ)	154.5 (152.1-157.0)	147.6 (143.6-151.4)[a]	151.7 (148.0-155.4)[b]	175.6 (169.9-181.3)[ab]
Phosphorus (mg/4.18MJ)	518.4 (511.6-525.2)	514.1 (503.0-525.2)	516.5 (515.6-547.7)	531.7 (515.7-547.7)
Zinc (mg/4.18MJ)	4.0 (3.9-4.1)	4.2 (4.1-4.3)[a]	4.1 (4.0-4.2)[b]	3.4 (3.2-3.6)[ab]

a,b,c = means with the same letter differ significantly, $p \leq 0.05$

n = number

Table VII. Daily micronutrient intake of women (per 4.18MJ), according to alcohol intake as a proportion of energy (mean, (95% confidence interval)				
Nutrient	**Total (n =1015)**	**Group 1:(0g) (n =759)**	**Group 2: (0.1 - 15g) (n =196)**	**Group 3: (> 15g) (n =60)**
% energy from alcohol	1.0 (0.6-1.3)	0.0 (-0.1-0.1)	1.5 (1.2-1.7)	11.7 (11.2-12.2)
Vitamin A (µg/4.18MJ)	409.6 (389.3-429.9)	403.5 (378.2-428.8)[ab]	463.4 (413.8-513.0)[ac]	310.8 (221.0-400.7)[bc]
Thiamin (mg/4.18MJ)	0.6 (0.5-0.6)	0.6 (0.5-0.6)[a]	0.6 (0.5-0.6)[b]	0.5 (0.4-0.5)[ab]
Riboflavin (mg/4.18MJ))	0.7 (0.65-0.7)	0.7 (0.6-0.7)	0.7 (0.6-0.7)	0.7 (0.6-0.8)
Niacin (mg/4.18MJ)	6.5 (6.4-6.6)	6.4 (6.3-6.6)[a]	6.6 (6.3-6.9)[b]	7.2 (6.7-7.7)[ab]
Vitamin B12 (µg/4.18MJ)	0.5 (0.5-0.6)	0.5 (0.5-0.6)[a]	0.6 (0.5-0.6)[b]	0.5 (0.4-0.5)[ab]
Vitamin B6 (mg/4.18MJ)	2.6 (2.4-2.7)	2.6 (2.5-2.8)[a]	2.6 (2.3-3.0)	1.9 (1.2-2.6)[a]
Folate (µg/4.18MJ)	20.9 (19.7-22.1)	21.5 (19.9-23.0)[a]	21.3 (18.3-24.3)[b]	12.5 (7.1-18.0)[ab]
Pantothenic acid (mg/4.18MJ)	1.9 (1.8-1.9)	1.9 (1.9-2.0)[a]	1.9 (1.8-2.0)[b]	1.6 (1.5-1.8)[ab]
Biotin (µg/4.18MJ)	11.7 (11.4-12.1)	12.0 (11.6-12.4)	11.2 (10.5-12.0)	10.1 (8.7-11.5)
Vitamin D (µg/4.18MJ)	2.4 (2.2-2.5)	2.4 (2.3-2.6)[a]	2.8 (2.0-2.6)[b]	1.6 (1.1-2.1)[ab]
Vitamin E (mg/4.18MJ)	5.5 (5.3-5.6)	5.5 (5.3-5.7)[a]	5.5 (5.2-5.8)[b]	4.6 (4.0-5.2)[ab]
Calcium (mg/4.18MJ)	219.4 (212.8-226.1)	222.5 (214.5-230.4)[a]	215.8 (200.2-231.4)	193.1 (164.8-221.4)[a]
Iron (mg/4.18MJ)	4.5 (4.4-4.6)	4.5 (4.4-4.6)	4.5 (4.3-4.7)	4.2 (3.9-4.5)
Magnesium (mg/4.18MJ)	152.3 (150.2-154.4)	150.1 (147.8-152.4)[a]	150.1 (145.7-154.6)[b]	187.5 (179.4-195.6)[ab]
Phosphorus (mg/4.18MJ)	510.0 (504.2-515.8)	508.9 (502.2-515.6)[a]	506.4 (493.3-519.6)[b]	535.4 (511.6-559.2)[ab]
Zinc (mg/4.18MJ)	4.3 (4.2-4.3)	4.3 (4.2-4.3)	4.3 (4.2-4.5)[a]	4.0 (3.7-4.3)[a]

a,b,c = means with the same letter differ significantly, $p \leq 0.05$

n = number

Discussion

The present study aimed to evaluate whether alcohol intake above 30g alcohol/day for men and 15g/day for women causes micronutrient dilution in a community in a country suffering from micronutrient deficiencies and presently in nutrition transition. Results from the SADHS (1998) showed alcohol consumption by 47% of men and 17% of women in the North West Province.[3] whilst the present study, conducted at the same time, demonstrated that 61% of men and 25% of women drank alcohol. Although the main problem with accurately surveying alcohol consumption has been reported to be due to the stigma connected with alcohol use and its associated behaviours,[20] the comparison between the SAHDS and THUSA data seems to indicate that underreporting was not a significant problem in the THUSA study, which was confirmed by the GGT correlation, a proxy for alcohol intake.

Alcohol intake (absolute intake and % TE) was the highest for men living in middle class urban areas and women living on farms. Beer was the most popular alcoholic drink with a shift from sorghum beer to commercial beer with urbanisation, a finding which is in agreement with Ramphele and Heap[18] and Steyn *et al.*[19] A major principle in managing diets is to obtain nutrient allowances within the appropriate energy intake needed to maintain or attain healthy body weight. As the proportion of energy from alcohol increases, it becomes more difficult to balance the diet in terms of nutrients. The mean intakes of alcohol of the three groups of women (non-drinkers, light to moderate drinkers and heavy drinkers) were 0.0g/day, 3.7g/day and 36.6g/day and for the men 0.4g/day, 8.3g/day and 80.4g/day. Recommendations in international food based dietary guidelines on alcohol intake vary in quantity as well as in quantification (for example, measured by % of daily energy intake, dL/day or g/day or units).

A number of countries including South Africa suggest a limited alcohol intake but do not quantify this recommendation.

In general, European countries recommend less than 5% of daily energy intake or 15g/day and 20g/day for women and men, respectively.[21] The UK recommends 3-4 units/day for men and 2-3 units /day for women (defining one unit as 8g alcohol).[22] In the THUSA population, the non-drinkers obtained no energy from alcohol, the light to moderate male drinkers 2.8% and heavy male drinkers 18.1%. For light to moderate female drinkers alcohol provided on average 1.5% E and for heavy drinkers 11.7%. Therefore, neither the women nor the men who drank heavily complied with the general guidelines for alcohol consumption. It seems, therefore, reasonable to conclude that alcohol consumption may be a problem in this population in transition.

Although the mean energy intake of heavy drinkers (men as well as women) was significantly higher than the other groups, the micronutrient density of their diets was not compromised to such an extent that the DRIs were not met. In fact, the diets of the heavy drinkers met the recommended intakes for pantothenic acid, biotin and zinc, which were inadequate in the other groups. Furthermore, the sorghum and commercial beers made some contribution to the diet with regard to the intake of not only energy but also some micronutrients, such as magnesium, zinc, manganese, riboflavin and niacin as illustrated in the MRC food composition tables.[23] According to Malenganisho[24] and Ahmed[25] it seems as if alcohol consumption is a positive predictor of iron status, however, in this THUSA population the opposite was found. Forty six percent of the men and 23% of the women drinkers had an iron balance exceeding 150µg/L[26]. The high levels of iron associated with alcohol intake may increase the risk of iron overload.[26] Some studies have shown that light to moderate alcohol consumers do not substitute alcoholic beverages for food items, but consume alcohol in addition to normal food intakes.[27, 28] According to Walmsley[28] light to moderate alcohol consumption in older people in the UK was associated with higher intakes of certain nutrients and higher blood concentrations (independent of intake) of some micronutrient status indices, including antioxidants. However, others have shown that substitution in those drinking alcohol does occur.[29]

In conclusion, the results of this study were unexpected. It seems as if economics play a major role in a population in transition. Those respondents, who could afford to buy alcoholic drinks, could probably also afford to buy foods which could provide sufficient amounts of micronutrients. This was illustrated in the higher consumption of protein rich foods and vegetables by the women who consumed the most alcohol.

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CHAPTER 4: ARTICLE

Sugar intake and micronutrient density in a population in transition: the THUSA study

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Abstract

Objective. To investigate the possibility of micronutrient dilution by sugar in the diets of an adult population in nutrition transition.

Design. A cross-sectional, comparative, population based study.

Setting. The African population of the North West Province, South Africa

Subjects. One thousand seven hundred and fifty seven participants (742 men, 1015 women) aged 15 years and older from 37 randomly selected sites from rural and urban areas.

Outcome measures. Respondents consuming sugar were divided into three tertiles, sugar intake < 6%, 6 – 11% and > 11% of total energy (TE). Outcome measures included macro and micronutrient intakes in different tertiles of sugar intake as well as body mass indices of men and women separately. Food intakes were also investigated in the different tertiles.

Results. Average added sugar intake of the male group was 9.5% (confidence interval 9.0 - 10.1%) of TE and 10.6% (10.2 – 11.8%) of TE for the women. Men and women in tertile 3 consumed ≥ 15% and ≥ 18% of TE respectively. Men and women consuming the most sugar had significantly higher mean intakes of energy, carbohydrates and most micronutrients. Percentage energy from fat and protein reduced significantly as sugar intake increased. Intake of vitamin B_{12}, folate, pantothenic acid, ascorbic acid and calcium did not meet the Dietary Reference Intake [DRI, Estimated Average Requirement (EAR)] at all levels of sugar consumption. However, the DRIs for vitamin E in men and women and biotin in men were only met in tertile 3. There was no significant difference in mean BMI across the tertiles of sugar intakes even though the energy intake increased with higher sugar intake. Men consuming the most sugar had higher intakes of red meat, bread, cereals, fat, sweets and cold drink.

Conclusion. One third of the population consumed more than 100g sugar/day, but this did not cause an overall micronutrient dilution effect. The diets of this population were not prudent, reflecting deficiencies of certain vitamins and minerals. In this population sample it seems that respondents living in urban areas buy more nutrient dense food including protein rich food, fruit and vegetables and possibly fortified breakfast cereals. Further research is needed to investigate the effect of fortification of staple food on this population in transition.

Introduction

African people living in South Africa are rapidly trying to change their lifestyles by moving to more urban areas.[1] Urban areas hold a promise to provide more jobs and higher incomes, resulting in improvements in some areas of living. One area of urbanisation that can impact on health negatively is the change in eating patterns.[2] Traditional diets high in fibre and complex carbohydrates are being substituted with foods higher in fat and refined carbohydrates[3] including food and drinks containing added sugar.[4] Some forms of sugar occur naturally and add nutrients to the diet like fructose in fruit and lactose in milk.[5] Added sugar, on the other hand, does not occur naturally and is defined as sugar being added to food during processing or preparation.[6] This type of sugar adds energy to the diet but does not provide the body with any micronutrients.[7] High intakes of added sugar have been shown to cause micronutrient dilution.[7-14] Studies done to investigate the diets of elderly people in South Africa, show an inverse relationship between high levels of added sugar and nutrient intake by displacing more nutrient dense foods.[15, 16] Consuming more than 18% of total energy as sugar can dilute micronutrient intake, especially thiamin, riboflavin, vitamin B_6, folate, vitamin C, calcium, iron, magnesium, zinc and selenium.[16] However, evidence to support the assumption that high sugar intake causes micronutrient dilution is inconclusive. In a recent systematic review published by Gibson,[17] the author stated that evidence supporting the negative impact of sugars on micronutrient intake was usually weak. It is important to consider that in a population with sufficient energy intake, the RDA of micronutrients can be achieved through a wide range of sugar intake.[17] It has been argued that low energy intakes are a better indicator of micronutrient adequacy than dietary sugars concentration.[18,19] In a South African study, elderly blacks had an inadequate dietary intake and suboptimal nutritional status.[16] High sugar intake worsened the diet quality of women, but energy intake was the most predictive factor of micronutrient intake.[16] Ruxton *et al.* concluded that added sugar intakes between 5% and 16% of dietary energy did not have a detrimental effect on micronutrient intakes of adults.[20]

There has never been a national dietary survey on adults in South Africa. However, data from studies from 1983 to 2000 were analysed to determine food items and portion sizes most consumed by South Africans.[21] Added sugar was consumed by 77% of the South African adult population.[21] There are differences in sugar intake between urban and rural areas. Walker *et al.* (1981)[22] reported that adolescents living in urban areas consumed almost double the amount of sugar (118g – 141g) than those living in rural areas (69g – 97g). This was shared by data from the "Nutrient intakes of South Africans" (SANSS),[4] reporting the highest intake of sugar amongst urban African men and women.

From a public health perspective it is important to investigate the levels of sugar intake and the possible micronutrient dilution effect it may have on a population in transition, suffering from nutrition deficiencies.[2] The National Food Consumption Survey (NFCS)[24] showed that children in South Africa, especially those living in rural areas, had deficient intakes of energy, calcium, iron, zinc, selenium, vitamins A, D, C and E, riboflavin, niacin, vitamin B6 and folate. Studies on adults in South Africa support these findings.[25,26] Kruger *et al.* [27] reported that urban dwellers participating in the THUSA survey had higher intakes of most vitamins and iron compared to respondents living in rural areas. Even though a higher intake of vitamins and iron were reported in urban areas, 50% still had intakes of iron, zinc, calcium, ascorbic acid and folate below 67% of the Recommended Dietary Allowance (RDA).[27] It can be argued that people living in urban areas have a more varied diet with more access to healthier food higher in micronutrients, but dietary intakes in South Africa are still not prudent.[27] Sugar may not only cause micronutrient dilution but also add energy to the diet, resulting in weight gain and obesity.[28] Overweight and obesity rates in South Africa are alarmingly high with more than half of the women in South Africa being overweight.[29] It is recommended that sugar intake in South Africa should not exceed 55g per day or 6 – 10% of total energy intake.[30]

The THUSA survey was undertaken between 1996 and 1998 (see Vorster *et al.*[31]). The objective of this project was to gather data on the impact that urbanisation has on the health and wellbeing of the African population at different levels of transition. In the present study dietary intake from this population was analysed to determine the effect of sugar intake on intakes of nutrients and food groups.

Methods

Study design, subject selection and organisational procedures

A statistical model was used to recruit 1854 "apparently healthy" volunteers, aged 15 years and older from 37 randomly selected sites from rural and urban areas. They were excluded from the study if they had any diseases, used chronic medication, were inebriated or had an oral temperature above 37°C. Pregnant and lactating women were also excluded. Participants who did not meet the inclusion criteria were screened for hypertension, diabetes mellitus, anaemia or other abnormalities, referred to local clinics, hospitals or their physician and excluded from the study. The study was approved by the Ethics Committee of the Potchefstroom University (Ethics number 4M5-95) and all participants signed an informed consent form after the procedures were explained to them in their native tongue.

Demographic information, health histories and dietary intake data were obtained during individual interviews by specially trained, multilingual fieldworkers in the language of the subject's choice, using questionnaires specially designed or adapted and validated for this population. Dietary intakes were measured with a culture sensitive quantitative food frequency questionnaire (QFFQ), which was validated against a seven-day weighed food record and biomarkers[32] as well as a combination of statistical methods.[33] Books with photographs of different foods in three portion sizes were used to establish the portion sizes of foods eaten. Food models, household utensils and food packaging were also used to assess the portion sizes. Reproducibility of the questionnaire was tested on a subsample of 144 respondents.[34]

Anthropometric measurements (height, weight, body circumferences and skinfold thicknesses) were measured by post-graduate biokinetics students, standardised by a level III anthropometrist. The participants wore only their underwear and measurements were taken in triplicate. Calibrated instruments (Precision Health Scale, A&D Company, Japan; Invicta Stadiometer, IP 1465, UK; Holtain® unstretchable metal tape; John Bull® calipers) were used.

Statistical analysis

The average daily intake of each food item was calculated in grams from the weight of the portion size and the frequency of consumption. Portion sizes reported in household measures were converted to weights. The FoodFinder 3 Dietary analysis programme of the MRC was used for the dietary analyses. The contributions of carbohydrate, sugar, protein and fat to total energy intakes were expressed as percentages of energy intakes. The SPSS 15 package (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. Sugar was divided into tertiles of intake for men and women separately. Those who had daily sugar intakes of less than 6% of TE (< 26g sugar/day) were in tertile 1. Those consuming between 6% of TE to 11% (26g – 60g sugar per day) of TE were grouped in tertile 2. People with an intake of more than 11% sugar as TE per day (> 60g) were in the highest tertile, tertile 3, representing the highest intake of sugar. Descriptive statistics were calculated for continuous variables. Significant differences were calculated using multi-variate non-parametric tests.

Results

Average added sugar intake of the male group was 9.5% of TE (confidence interval 9.0 - 10.1%) and 10.6% of TE (10.2 – 11.8%) for the women. Added sugar intake was 3.8, 8.4 and 15.7% and 4.5, 9.3 and 17.8% for the men and women in the three tertiles, respectively. A third of the participants had sugar intakes higher than 15.8% of TE, consuming more than a 100g sugar per day. On average women used more sugar than men. Male farm workers consumed significantly more sugar compared to upper class urban respondents, consuming the least sugar. There was no significant difference in sugar intake between the females in the different strata[35] (data not shown here).

Mean intakes of energy and macro and micronutrients of men and women respectively across tertiles of absolute sugar intake are given in Tables I and II. For both men and women total energy and carbohydrate intake increased with higher sugar intake. There was a significant reduction in intake of protein and fat expressed as percentage of TE between tertile 1 and tertile 3. Dietary fibre intake was low for all the groups. Men had a mean fibre intake between 50 – 66% of the dietary reference intakes [DRI, Estimated Average Requirements (EAR)].[36] BMI did not differ between subjects with the highest and lowest sugar intake, and no association was found between BMI and sugar intake.

For men and women, mean vitamin B_{12}, folate, pantothenic acid, ascorbic acid and calcium intakes were lower than the DRI. Mean vitamin E intakes for men and women were lower than the DRI in tertile 1 and 2 but reached the DRI in the group consuming the most sugar. Both men and women with the highest sugar intake per day ($\geq$ 100g/day) had significantly higher mean intakes of all micronutrients except vitamin D.

Table I. Daily nutrient intake, BMI and age of men, according to tertiles of sugar intake (g/day): mean, 95% confidence interval (CI)					
Nutrient	**DRI (EAR)**	**Total (n = 747)**	**Tertile 1 (n = 246)**	**Tertile 2 (n = 221)**	**Tertile 3 (n = 271)**
Added sugar (g)		54.1 (50.7-57.6)	15.1 (11.3 - 18.9)[ab]	40.8 (36.7 - 44.8)[ac]	100.1 (96.4 - 103.7)[bc]
% E from sugar		9.5 (9.0-10.1)	3.8 (3.3-4.4)	8.4 (7.8-9.0)	15.7 (15.1-16.2)
Alcohol (g)		18.4 (16.5-20.5))	20.0 (16.1 - 23.9)	17.0 (12.9 - 21.2)	21.0 (17.3 - 24.8)
% alcohol		4.5 (4.1-5.0)	4.8 (3.8-5.8)	5.0 (3.9-6.1)	4.0 (3.0-4.9)
Total energy (including alcohol)		9563.1 (9320.7-9818)	7596 (7043.3 – 8148.6)[ab]	9327.3 (8856.2 - 9798.4)[ac]	11354.6 (10927.2 - 11782.1)[bc]
Protein (g)		66.5 (64.8-68.2)	57.5 (54.5-60.5)	67.0 (63.8-70.2)	74.2 (71.3-77.1)
% E protein		12.0 (11.8-12.1)	12.9 (12.6-13.1)[ab]	12.1 (11.8 - 12.4)[ac]	10.9 (10.6 - 11.1)[bc]
Fat (g)		59.1 (57.2-61.0)	48.1 (44.9-51.3)	59.1 (55.7-62.5)	69.3 (66.2-72.3)
% E fat		24.9 (24.4-25.5)	25.9 (24.9-26.8)[a]	25.3 (24.3 - 26.3)[b]	23.3 (22.3 - 24.2)[ab]
Carbohydrate (g)		343.2 (333.0-353.3)	269.3 (251.9-286.7)	325.9 (307.5-344.3)	424.9 (408.3-441.5)
% E carbohydrates		64.9 (64.2-65.6)	62.7 (61.5-63.9)[a]	64.2 (62.9 - 65.5)[b]	68.1 (66.9 - 69.3)[ab]
Fibre g/d	30-38	18.3 (17.7-18.9)	15.2 (8.0)	18.3 (10.0)	21.1 (9.1)
Vitamin A (µg RE)	625	704.8 (656.5-753.9)	536.1 (455 - 612.4)[ab]	755.1 (674.9 – 835.3)[a]	818 (745.2 - 890.8)[b]
Thiamin (mg)	1	1.2 (1.1-1.2)	1 (0.9 - 1.1)[ab]	1.2 (1 - 1.3)[ac]	1.3 (1.3 - 1.4)[bc]
Riboflavin (mg)	1.1	1.5 (1.4-1.5)	1.3 (1.2 - 1.4)[a]	1.5 (1.4 - 1.6)[b]	1.6 (1.5 - 1.7)[ab]
Niacin (mg)	12	15.1 (14.7-15.7)	13.1 (12.1 - 14.1)[ab]	15.7 (14.7 - 16.8)[a]	16.6 (15.7 - 17.6)[b]
Vitamin B12 (µg)	2	1.1 (1.1-1.2)	0.9 (0.9 - 1)[ab]	1.2 (1.1 - 1.2)[ac]	1.2 (1.2 - 1.3)[bc]
Vitamin B6 (mg)	1.1-1.4	5.0 (4.7-5.4)	4.2 (3.6 - 4.9)[ab]	5.2 (4.5 - 5.9)[a]	5.8 (5.1 - 6.4)[b]
Folate (µg)	320	222.9 (216.4-229.7)	188.8 (176.1 - 201.5)[ab]	227.5 (176.1 – 240.8)[ac]	250.6 (238.5 - 262.7)[bc]
Pantothenic acid (mg)	5.0 (AI)	4.2 (4.1-4.4)	3.8 (3.6 - 4)[ab]	4.2 (4 - 4.5)[ac]	4.7 (4.5 - 4.9)[bc]
Biotin (µg)	30 (AI)	28.7 (27.7-29.7)	26.7 (24.8 - 28.6)[a]	28.2 (26.2 - 30.2)[b]	30.9 (29 - 32.7)[ab]
Vitamin D (µg)	5.0-10.0	5.4 (5.1-5.6)	5.1 (4.5 - 5.6)	5.4 (4.8 - 6)	5.6 (5.1 - 6.1)
Vitamin E (mg)	12	11.6 (11.2-12.1)	9.8 (9 - 10.7)[ab]	11.5 (10.6 - 12.4)[ac]	13.5 (12.7 - 14.3)[bc]
Ascorbic acid (mg)	75	34.8 (32.1-37.8)	25.9 (21.7 - 30.2)[ab]	36.8 (32.3 - 41.3)[a]	41.6 (37.6 - 45.7)[b]
Calcium (mg)	1000-1200 (AI)	460.6 (441.1-477.6)	393.6 (361.3 - 426)[a]	441 (406.9 - 474.9)[b]	534.1 (503.2 - 564.9)[ab]
Iron (mg)	6	9.2 (8.9-9.5)	7.3 (6.8 - 7.8)[ab]	9.6 (9.0 - 10.2)[ac]	10.6 (10 - 11.1)[bc]
Magnesium (mg)	350	356.1 (345.0-367.1)	321.9 (301 - 342.9)[ab]	353.6 (331.2 – 376)[ac]	400.6 (380.2 - 420.9)[bc]
Zinc (mg)	9.4	8.9 (8.6-9.2)	7.5 (7 - 7.5)[ab]	9.3 (8.8 - 9.8)[a]	9.9 (9.5 - 10.3)[b]
BMI		21.1 (20.7-21.5)	20.7 (20.3 – 21.2)	21.4 (20.8 – 21.9)	20.9 (20.4 – 21.4)
Age		37.2(36.8-38.7)	39.7 (37.8-41.6)	37.4 (35.4-39.5)	34.7 (32.9-36.6)

a,b,c = means with the same letter differ significantly, $p \leq 0.05$; n = number; CI = confidence interval;
EAR = Estimated Average Requirement; AI= Adequate Intake

Table II. Daily nutrient intake, BMI and age of women, according to tertiles of sugar intake (g/day): means, 95% confidence interval (CI)					
Nutrient	**DRI (EAR)**	**Total (n= 1015)**	**Tertile 1 (n = 324)**	**Tertile 2 (n = 336)**	**Tertile 3 (n = 341)**
Added sugar (g)		52.2 (49.6-55.4)	14.1 (9.8 - 18.5)[ab]	38.7 (34.4 – 43.0)[ac]	100.3 (95.9 - 104.7)[bc]
% E from sugar		10.6 (10.2-11.1)	4.5 (4.0-5.0)	9.3 (8.8-9.8)	17.8 (17.2-18.3)
Alcohol (g)		2.9 (1.2-4.6)	13.8 (13-14.6)	13.4 (12.6-14.2)	13.6 (12.8-14.5)
% alcohol		1.0 (0.6-1.3)	1.3 (0.9-1.6)	1.0 (0.7-1.4)	0.6 (0.2-0.9)
Total energy (including alcohol)		8005.0 (7791.5-8218.6)	6902.3 (6539.7-7264.8)[ab]	8434.6 (8072.5 - 8796.6)[ac]	10620.9 (10252.2 - 10989.7)[bc]
Protein (g)		57.9 (56.5-59.4)	48.8 (46.6-51.1)	58.7 (56.5-60.9)	65.9 (63.7-68.2)
% E protein		11.9 (11.7-12.0)	13 (12.7 - 13.3)[ab]	12.2 (12 - 12.4)[ac]	10.6 (10.4 - 10.8)[bc]
Fat (g)		54.5 (52.8-56.1)	42.5 (39.9-45.1)	55.6 (53.1-58.2)	64.8 (62.3-67.4)
% E fat		25.8 (25.4-26.3)	25.5 (24.5-26.5)[a]	26.2 (25.2 – 27.2)[b]	23.2 (22.2 - 24.3)[ab]
Carbohydrates (g)		295.0 (286.3-303.7)	221.8 (209.6-233.9)	277.4 (265.5-289.3)	383.3 (371.4-395.2)
% E carbohydrates		63.9 (63.3-64.6)	62.5 (61.1 - 63.8)[a]	62.3 (61.2 – 63.8)[b]	67.3 (66.3 - 68.3)[ab]
Fibre (g/d)	21-25	16.4 (15.9-16.9)	13.5 (6.2)	16.2 (6.8)	19.3 (8.4)
Vitamin A (µg RE)	625	762.1 (719.4-803.1)	594.3 (517.6 - 671.1)[ab]	776.1 (701 - 851.3)[ac]	905.1 (830.3 - 979.8)[bc]
Thiamin (mg)	1	1.1 (1.0-1.1)	0.9 (0.9 - 1)[ab]	1.1 (1 - 1.1)[ac]	1.2 (1.2 - 1.3)[bc]
Riboflavin (mg)	1.1	1.3 (1.3-1.4)	1.1 (1 - 1.2)[ab]	1.4 (1.3 - 1.5)[ac]	1.5 (1.4 - 1.6)[bc]
Niacin (mg)	12	12.4 (12.0-12.8)	10.2 (9.5 - 10.8)[ab]	12.7 (12.1 - 13.3)[ac]	14.2 (13.6 - 14.8)[bc]
Vitamin B12 (µg)	2	1.0 (0.9-1.0)	0.8 (0.7 - 0.9)[ab]	1.1 (1 - 1.1)[ac]	1.2 (1.1 - 1.2)[bc]
Vitamin B6 (mg)	1.1-1.4	4.8 (4.5-5.1)	3.8 (3.3 - 4.4)[ab]	5 (4.5 - 5.6)[a]	5.4 (4.9 - 6)[b]
Folate (µg)	320	192.9 (187.5-198.9)	164.4 (155.8 - 173.1)[ab]	195.6 (187.2 – 204.1)[ac]	218.2 (209.7 - 226.6)[bc]
Pantothenic acid (mg)	5.0 (AI)	3.5 (3.4-3.6)	3 (2.9 - 3.2)[ab]	3.6 (3.4 - 3.7)[ac]	3.9 (3.8 - 4.1)[bc]
Biotin (µg)	30.0 (AI)	21.6 (20.8-22.5)	19.8 (18.5 - 21.1)[a]	21..2 (20 - 22.5)[b]	23.9 (22.6 - 25.1)[ab]
Vitamin D (µg)	5.0-10.0 (AI)	4.5 (4.0-4.5)	4.1 (3.7 - 4.5)	4.1 (3.7 - 4.5)	4.6 (22.6 - 25.1)
Vitamin E (mg)	12	10.2 (9.8-10.6)	8.4 (7.8 - 9)[ab]	10.2 (9.6 - 10.8)[ac]	12 (11.4 - 12.6)[bc]
Ascorbic acid (mg)	75	38.9 (36.5-41.4)	29.8 (25.2 - 34.4)[ab]	42.1 (37.6 – 46.5)[a]	44.6 (40.1 - 40.0)[b]
Calcium (mg)	1000-1200 (AI)	409.8 (394.1-425.5)	329 .9 (304.2 - 355.5)[ab]	417.1 (392 - 442.2)[ac]	478.6 (453.6 - 503.6)[bc]
Iron (mg)	6	8.6 (8.3-8.8)	6.8 (6.3 - 7.2)[ab]	8.6 (8.2 - 9)[ac]	10.3 (9.9 - 10.7)[bc]
Magnesium (mg)	350	290.3 (280.8-299.8)	244.6 (231.4 - 257.8)[ab]	289.6 (276.3 - 302.6)[ac]	334.4 (321.6 - 347.3)[bc]
Zinc (mg)	9.4	8.0 (7.8-8.2)	6.6 (6.3 - 7)[ab]	8.2 (7.9 - 8.6)[ac]	9.2 (8.8 - 9.5)[bc]
BMI		27.0 (26.6 – 27.3)	26.5 (25.5 – 27.4)	26.8 (25.8 – 27.7)	27 (26.0 – 28.0)
Age		37.8 (36.8-38.7)	39.6 (38.1-41.2)	37.6 (36.1-39.1)	36.2 (34.7-37.7)

a,b,c = means with the same letter differ significantly, $p \leq 0.05$; n = number; CI = confidence interval;
EAR = Estimated Average Requirement; AI= Adequate Intake

Micronutrient density was investigated as shown in Tables III and IV. A negative trend was observed when micronutrient intake was expressed per 4.18 MJ. The mean intake of thiamin, riboflavin, niacin, vitamin B_6, magnesium, phosphorus and zinc was slightly but significantly less in the men consuming the most sugar. For women consuming the most sugar, the mean intake of niacin, magnesium and phosphorus was also slightly but significantly less than women consuming the least sugar in tertile one.

Table III: Mean daily micronutrient intakes of men (per 4.18 MJ), according to tertiles of sugar intake as a proportion of energy (%E): ***mean, 95% confidence interval***

Micronutrient	Tertile 1 (n = 33)	Tertile 2 (n = 53)	Tertile 3 (n = 652)
% E from sugar	3.8 (3.3-4.4)	8.4 (7.8-9.0)	15.7 (15.1-16.2)
Vitamin A (µg/4.18MJ)	364.2 (266.2-462.1)	270.9 (193.6-348.2)	327.4 (304.9-349.9)
Thiamin (mg/4.18MJ)	0.6 (0.6-0.6)[a]	0.6 (0.6-0.6)[b]	0.5 (0.5-0.5)[ab]
Riboflavin (mg/4.18MJ)	0.8 (0.7-0.9)[a]	0.7 (0.7-0.8)	0.7 (0.6-0.7)[a]
Niacin (mg/4.18MJ)	7.6 (6.9-8.4)[a]	7.1 (6.6-7.7)[b]	6.5 (6.4-6.7)[ab]
Vitamin B12 (µg/4.18MJ)	0.5 (0.5-0.6)	0.5 (0.4-0.5)	0.5 (0.5-0.5)
Vitamin B6 (mg/4.18MJ)	3.2 (2.4-4.0)[a]	1.8 (1.2-2.5)[a]	2.4 (2.2-2.6)
Folate (µg/4.18MJ)	12.4 (7.7-17.1)	14.3 (10.6-18.0)	15.9 (14.8-17)
Pantothenic acid (mg/4.18MJ)	2.1 (1.9-2.3)	2.0 (1.9-2.2)	2.0 (1.9-2)
Biotin (µg/4.18MJ)	13.3 (11.1-15.4)	14.3 (12.6-16.0)	13.5 (13-14)
Vitamin D (µg/4.18MJ)	2.3 (1.5-3.1)	3.0 (2.4-3.7)	2.7 (2.6-2.9)
Vitamin E (mg/4.18MJ)	5.1 (4.3-5.9)	5.5 (4.8-6.1)	5.4 (5.2-5.6)
Calcium (mg/4.18MJ)	241.1 (206.3-275.8)	223.1 (195.6-250.5)	205.6 (197.6-213.6)
Iron (mg/4.18MJ)	4.2 (3.7-4.6)	4.0 (3.7-4.3)	4.1 (4.0-4.2)
Magnesium (mg/4.18MJ)	169 (157.2-180.8)[a]	165.2 (155.9-174.5)[b]	154.1 (151.4-156.8)[ab]
Phosphorus (mg/4.18MJ)	582.5 (551.8-613.2)[a]	559.2 (535-583.4)[b]	517.6 (510.5-524.6)[ab]
Zinc (mg/4.18MJ)	4.6 (4.3-5)[a]	4.2 (3.9-4.5)	4.0 (3.9-4.1)[a]
Copper (µg/4.18MJ)	0.5 (0.5-0.6)	0.5 (0.5-0.6)	0.6 (0.5-0.6)
Potassium (mg/4.18MJ)	1078.1 (1012.1-1144.2)	1051.5 (999.4-1103.6)	1012.8 (997.6-1028)
Sodium (mg/4.18MJ)	646.7 (561.3-732.1)	550.6 (483.2-618)	606.2 (586.6-625.9)

a,b,c = means with the same letter differ significantly ($p \leq 0.05$)

n = number

Table IV: Mean daily micronutrient intakes of women (per 4.18 MJ), according to tertiles of sugar intake as a proportion of energy (%E), 95% confidence interval			
Micronutrient	**Tertile 1 (n = 40)**	**Tertile 2 (n = 68)**	**Tertile 3 (n = 893)**
% E from sugar	4.5 (4.0-5.0)	9.3 (8.8-9.8)	17.8 (17.3-18.3)
Vitamin A (µg/4.18MJ)	349.6 (239.8-459.4)	363.2 (279.0-447.4)	417.2 (393.5-441)
Thiamin (mg/4.18MJ)	0.7 (0.6-0.7)[ab]	0.6 (0.6-0.6)[ac]	0.6 (0.5-0.6)[bc]
Riboflavin (mg/4.18MJ)	0.7 (0.7-0.8)	0.7 (0.7-0.8)	0.7 (0.7-0.7)
Niacin (mg/4.18MJ)	7.5 (6.9-8.1)[ab]	6.4 (6-6.9)[a]	6.5 (6.4-6.6)[b]
Vitamin B12 (µg/4.18MJ)	0.6 (0.5-0.7)[a]	0.5 (0.5-0.6)[a]	0.5 (0.5-0.6)
Vitamin B6 (mg/4.18MJ)	1.9 (1.1-2.7)	2.5 (1.9-3.1)	2.6 (2.5-2.8)
Folate (µg/4.18MJ)	18.7 (12-25.4)	18.4 (13.3-23.5)	21.2 (19.8-22.7)
Pantothenic acid (mg/4.18MJ)	2.0 (1.9-2.2)	2.1 (2-2.3)[a]	1.9 (1.9-1.9)[a]
Biotin (µg/4.18MJ)	12.1 (10.4-13.8)[a]	14.9 (13.6-16.2)[ab]	11.7 (11.3-12.1)[b]
Vitamin D (µg/4.18MJ)	2.2 (1.5-2.8)[a]	3.4 (2.9-3.9)[ab]	2.4 (2.2-2.5)[b]
Vitamin E (mg/4.18MJ)	5.3 (4.6-6.0)	6.0 (5.5-6.6)[a]	5.5 (5.3-5.6)[a]
Calcium (mg/4.18MJ)	253.1 (218.5-287.7)	227.3 (200.8-253.8)	218.4 (210.9-225.9)
Iron (mg/4.18MJ)	4.4 (4-4.8)	4.3 (4.0-4.6)	4.5 (4.4-4.6)
Magnesium (mg/4.18MJ)	173 (163.1-182.8)[a]	161.1 (153.6-168.7)[b]	152.2 (150.1-154.3)[ab]
Phosphorus (mg/4.18MJ)	569.7 (542.6-596.7)[a]	551.3 (503.6-572.0)[b]	508.8 (503-514.7)[ab]
Zinc (mg/4.18MJ)	4.5 (4.1-4.8)	4.2 (3.9-4.5)	4.3 (4.2-4.4)
Copper (µg/4.18MJ)	0.5 (0.5-0.6)	0.5 (0.5-0.6)[c]	0.6 (0.6-0.6)[c]
Potassium (mg/4.18MJ)	1180.3 (1108-1252.6)[a]	1100.8 (1045.3-1156.2)	1086.5 (1070.8-1102.1)[a]
Sodium (mg/4.18MJ)	581.3 (501.8-660.8)	574.1 (513.1-635)[a]	656.8 (639.7-647.0)[a]

a,b,c = means with the same letter differ significantly ($p \leq 0.05$)

n = number

To understand how intake of micronutrients can be different across different tertiles of sugar intake, food consumption for different levels of sugar intake were compared (Tables V and VI). Men consuming higher levels of sugar also consumed significantly more red meat, bread, cereals, fat and cold drink. The women consuming higher levels of sugar only had a significantly higher intake of potatoes and fat. There was no significant increase in the intake of sweets or cold drink with higher intake of sugar in the female group, which was rather unexpected.

Table V: Dietary intake of men according to tertiles of added sugar intake (g/day): 95% confidence interval (n = 747)			
Food group	**Tertile 1 (n = 249)**	**Tertile 2 (n = 221)**	**Tertile 3 (n = 271)**
Milk	0.7 (0.4-1)	0.8 (0.5-1.0)	0.9 (0.6-1.1)
Red meat	0.3 (0.1-0.5)[a]	0.5 (0.3-0.7)	0.6 (.4-0.8)[a]
Chicken	0.1 (0.02-0.2)	0.1 (0.1-0.2)	0.2 (0.1-0.2)
Fish	0.1 (0.03-0.1)	0.1 (0.06-0.1)	0.1 (0.7-0.1)
Legumes	0.1 (0.7-1.1)	0.7 (0.5-1)	0.9 (0.7-1.1)
Egg	1.1 (0.8-1.5)	1.0 (0.7-1.5)	1.4 (1.1-1.7)
Fruit	0.9 (0.3-1.5)	1.4 (0.9-1.9)	1.4 (1.1-1.9)
Vegetables	1.1 (0.6-1.7)	1.6 (1.2-2.1)	1.5 (1.1-1.9)
Potatoes	0.6 (0.4-0.8)	0.6 (0.4-0.8)[a]	0.9 (0.7-1.0)[a]
Mealie meal	9.9 (7.3-12.5)	8.1 (5.8-10.3)	8.3 (6.4-10.2)
Rice	0.9 (0.6-1.2)	1.0 (0.8-1.3)	0.8 (0.6-1.0)
Samp	1.0 (0.7-1.3)	0.8 (0.6-1.1)	0.6 (0.4-0.8)
Bread	2.5 (1.1-3.9)[a]	3.2 (2.0-4.3)[b]	5.3 (4.3-6.3)[ab]
Cereal	0.5 (-0.2-1.1)[a]	0.8 (0.3-1.4)[a]	2.3 (1.8-2.8)[ab]
Fat	1.5 (1.0-2.1)[a]	2.1 (1.6-2.6)	2.7 (2.3-3.2)[a]
Sweets	40.7 (23.8-57.6)	24.1 (10.0-38.5)	33.4 (21.0-45.7)
Sugar	5.1 (-2.8-13.1)[ab]	22.1 (15.4-29.0)[ac]	47.0 (41.1-52.8)[bc]
Soup	0.1 (0.02-0.2)[a]	0.1 (0.04-0.2)[ab]	0.2 (0.1-0.2[b]
Cold drink	0.1 (-0.2-0.5)[ab]	0.2 (-0.07-0.5[ac]	1.0 (0.8-1.3)[bc]

a,b,c = means with the same letter differ significantly ($p \leq 0.05$)

n = number

Table VI: Dietary intake of women according to tertiles of sugar intake (g/day): 95% confidence interval (n = 1015)			
Food group	**Tertile 1 (n = 324)**	**Tertile 2 (n = 336)**	**Tertile 3 (n = 341)**
Milk	0.5 (0.05-0.9)	0.5 (0.2-0.8)	0.8 (0.6-1.0)
Red meat	0.5 (0.4-0.8)	0.6 (0.4-0.8)	0.7 (0.5-0.9)
Chicken	0.3 (0.1-0.5)	0.2 (0.1-0.4)	0.3 (0.2-0.5)
Fish	0.1 (0.04-0.2)	0.1 (0.07-0.2)	0.2 (0.1-0.2)
Legumes	0.7 (0.3-1.1)	0.7 (0.4-0.9)	0.5 (0.3-0.7)
Egg	1.1 (0.4-1.8)	0.7 (0.3-1.2)	1.2 (0.8-1.6)
Fruit	1.0 (-0.06-2.0)	1.0 (0.3-1.6)	1.4 (0.9-2.7)
Vegetables	1.8 (0.9-2.7)	1.5 (1.0-2.1)	1.8 (1.4-2.3)
Potatoes	0.3 (0.9-2.7)[a]	0.6 (0.3-0.9)[ab]	1.1 (0.9-1.4)[b]
Mealie meal	4.7 (0.6-8.8)	5.3 (2.7-8.0)	6.7 (4.6-8.8)
Rice	1.2 (0.7-1.8)	0.8 (0.4-1.1)	1.0 (0.7-1.3)
Samp	0.8 (0.02-0.9)	0.7 (0.4-1.0)	0.7 (0.4-0.9)
Bread	2.3 (0.3-4.3)	3.8 (2.6-5.1)	4.2 (3.1-5.2)
Cereal	0.6 (-0.06-1.7)	0.8 (0.02-1.5)	1.1 (0.5-1.7)
Fat	1.0 (-0.06-2.0)[a]	2.0 (1.4-2.7)[b]	3.2 (2.7-3.7)[ab]
Sweets	23.8 (-16.7-64.3)	22.0 (-3.6-47.6)	33.2 (12.3-54.1)
Sugar	4.1 (-16.9-25.0)[ab]	17.9 (4.7-31.2)[ac]	63.4 (52.2-74.2)[bc]
Soup	0.07 (-0.01-0.2)[a]	0.1 (0.04-0.1)[b]	0.2 (0.1-0.2)[ab]
Cold drink	0.3 (-0.3-0.9)	0.3 (-0.1-0.6)	0.6 (0.3-0.9)

a,b,c = means with the same letter differ significantly ($p \leq 0.05$)

n = number

Discussion

High sugar intakes have been shown in some studies to cause micronutrient dilution.[7-16] However, from the systematic review of 47 papers on the results of observational studies as well as interventions,[17] it appeared that results were not necessarily linear or consistent across nutrients, populations and age groups and quantification was hampered by different cut-off criteria in each study. According to Bourne *et al.*, it is unclear whether the current literature provides sufficient evidence of nutrient dilution by added sugar for future public health guidelines.[37]

The present study included respondents in different stages of urbanisation between the ages of 15 years and 80 years with different dietary intakes. The aim of the present study was to evaluate the dietary intake from this population and determine the effect of intake of added sugars on intakes of nutrients and food groups.

Findings in the present study illustrated higher mean energy intakes for men and women than energy intakes from other South African surveys of rural [25] and urban areas.[37] There may have been underreporting by the respondents on the QFFQ, however, there was no evidence of proportional bias or of the extent of underreporting differing among gender and strata.[27] However, micronutrient intake was still not optimal in this population and dietary intake reflected deficiencies of vitamin B_{12}, folate, pantothenic acid, ascorbic acid and calcium across all levels of sugar intake. These results are consistent with findings from other South African studies.[24,37] Some alleviation from micronutrient deficiencies was observed after it became compulsory to fortify South African staple food, maize meal and wheat flour with vitamin A, iron, zinc, folic acid, thiamin, niacin, vitamin B6 and riboflavin in October 2003.[38] Fortification of maize meal and wheat flour improved mean intakes of vitamin B6, thiamin, riboflavin, niacin and folate.[38] However, fortification does not solve all micronutrient deficiencies and deficiencies of calcium and iron were still common in both adults and children in South Africa.[38] The present study was conducted before the mandatory fortification of staple food in 2003. It is important to note that only one of the micronutrients, folate, which was deficient in this group, is currently part of the fortification mixture.

The mean sugar intake of the men was 9.5% TE (54g) and that of the women was 10.6% TE (52.2g), which correlates with the WHO/FAO recommendation of <10% of TE consumed[38] and also with the South African recommended intake of <55g/day to prevent dental caries.[30] The American Institute of Medicine concluded in the 2002 Dietary Reference Intakes that there was insufficient evidence to set an upper intake level for added sugars. However, they suggested a maximum intake level of 25% of TE because of growing concerns about inadequate micronutrient intakes.[36]

Two approaches were used to determine a dilution effect by sugar. The first approach used sugar as absolute intake (g/day). Using this approach the results showed that respondents consuming more sugar had higher intakes of most micronutrients. This correlates with other studies also investigating absolute intakes.[8, 15, 16] It seems that people consuming higher amounts of sugar (g/day) tend to have higher total nutrient intakes as a consequence of higher total energy intake.[8] In a review published by Rennie and Livingstone[39] the authors stated that reported energy intake is an important indicator of micronutrient intake and, in general, is significantly positively associated with micronutrient intakes. In this review, men and women who consumed the most sugar had the highest intake of energy and carbohydrates.[39] Fat and protein intakes as percentages of total energy were less in the group consuming the most sugar. This is in agreement with findings from other studies.[7, 13] This may suggest that more refined carbohydrates were eaten and less protein and fat. However, energy intake was the highest in the highest tertiles of sugar intake for men and women. Absolute intakes of protein and fat also increased as more sugar was consumed. There was no difference in BMI between tertiles of sugar intake, however, the mean BMI reflected a pattern of overweight and risk of obesity in the female group.

Using the second approach to determine the dilution effect of sugar (micronutrient intake per 4.18MJ), slight but significant nutrient dilution was found for thiamin, riboflavin, niacin, vitamin B6, magnesium, phosphorus and zinc in the men consuming the most sugar. For women consuming the most sugar, mean intake of riboflavin, niacin, magnesium and phosphorus was also slightly but significantly less than women consuming the least sugar in tertile one. These results correlate well with another South African study[16] reporting that women with the highest intake of sugar had the lower intakes of thiamin, riboflavin, niacin, vitamin B_6, folate, pantothenic acid, biotin, vitamin C, calcium, magnesium, phosphorus, zinc, copper and magnesium.

The impact of added sugars has been shown to be very small and it would require very large changes in sugar consumption to have any positive or negative effect on the quality of the diet.[40] On the other hand, Overby[14] reported a 30 - 40% reduction in fruit and vegetable consumption in children consuming the most sugar. Children consuming the least sugar seemed to consume one extra serving of grain, fruit and dairy products compared to children consuming >25% added sugar.[7] These food groups are of great importance in young children that need certain micronutrients for optimal health and growth.[7]

With regard to food intake, men who consumed the most sugar also consumed the most red meat, bread, cereals and fat and women who consumed the most sugar also consumed significantly more potatoes and fat.

Sugar intake amongst the participants living in different strata[35] showed that those living in farm areas had the highest intake of sugar added during preparation or at the table compared to upper class urban areas. This is in contrast to other studies reporting higher intakes of sugar in urban areas. However, although not significant, the intake of miscellaneous sweets including candy, chocolate, cookies, cakes and sweetened cold drinks was the highest in people living in upper class urban areas.[35] These data highlight the affordability and accessibility of refined sugary products in urban areas.

The effect of added sugar on the micronutrient status depends on the foods that were consumed as part of the daily diet and may be one of the reasons why different results were obtained for micronutrient intake between the different epidemiological studies.[39] Frary *et al.*[41] examined associations between the five major dietary sources of sugar in the diets of children and adolescents in the United States and calcium, folate and iron intakes. They found very different patterns depending on the source of the added sugars. Alexy[42] investigated the consumption of fortified foods by participants in the DONALD study. They reported that 32% of the food items were fortified and 56% of the food items were fortified and sweetened with sugar. They concluded that fortification may mask micronutrient dilution.[42] The form in which sugars are consumed, therefore, appears to be an important modifier of the impact of dilution. Soft drinks, sugar and sweets are more likely to have a negative impact on diet quality whereas dairy foods, milk drinks and pre-sweetened cereals may have a positive impact.[17]

The authors of a recent systematic review of 15 observational studies reported that intakes of added sugars and micronutrient density are inconclusive, and that there is currently insufficient data to draw firm conclusions.[39] Overall, the studies suggest that micronutrient intakes are optimal at moderate levels of sugars in the diet, provided energy needs are met. Very high intakes of added sugars in excess of 20% of energy are associated with lower intakes of several micronutrients.[39] It has been argued that low energy intakes are a better indicator of micronutrient inadequacy than dietary sugar concentration.[18,19]

Further research is needed on the dietary intake of South African adults representing all ethnic groups from all areas of living to determine nutrient deficiencies after the recently implemented fortification of staple food and the effect of fortified sweetened products such as breakfast cereals on micronutrient status. It seems as if generalisations such as "sugars compromise nutrient intakes" (or conversely "micronutrient intakes are adequate irrespective of sugars intake") are unhelpful in resolving current public health issues.

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CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Food intake in South Africa is changing, especially because of movement of people from rural areas to urban areas. In the rural areas people eat more traditional diets which are more nutrient dense, higher in fibre and lower in refined carbohydrates (Nel & Steyn, 2002). People living in urban areas have access to more shops, food vendors, take away stores, liquor stores, restaurants and pubs. There is a higher availability of food and drink containing higher levels of added sugar (Popkin, 1994) and stronger alcoholic beverages (Parry *et al.*, 2004) that are available almost every day. Traditional low alcohol home brewed sorghum beer is being substituted with commercial beer, spirits and wine (Parry *et al.*, 2004). This suggests that the promise of improvements in socio-economic status associated with urban areas does not necessarily lead to improved nutritional status, but may add to the burden of disease in South Africa (Bourne *et al.,* 2002).

The overall mean intake of certain vitamins and minerals by South Africans reflected a nutritionally depleted diet (Bourne *et al.*, 1993). Children had a deficient intake of calcium, iron, zinc, selenium, vitamin A, D, C and E, riboflavin, niacin, vitamin B6 and folic acid (Labadarios *et al.,* 1999). In the present study people living in urban areas seemed to eat healthier foods showing higher micronutrient intakes than people living in rural areas, however 50% still had intakes of iron, zinc, calcium, ascorbic acid and folate below 67% of the RDA (Kruger *et al.,* 2005). From October 2003, it became compulsory to fortify bread flour and maize flour with certain micronutrients. The present study was conducted before this legislation, thus future studies are needed to establish the effect fortification will have on micronutrient status of South Africans. However, from a public health perspective it is important to educate South Africans on relatively cheap food sources of vitamins and minerals that will increase the health of the population.

High levels of alcohol intake and added sugar intake have been studied to determine the effect they have on micronutrient intake. Results from epidemiological studies are not conclusive with some studies showing strong dilution effect and some studies reporting no association (Gibson, 2007; Rennie & Livingstone, 2007). It is important to look at the levels of alcohol as well as sugar in the diets of South Africans to determine if they are causing nutrient dilution that may lead to a deficiency of a certain nutrient.

5.2 Summary of findings

Alcohol intake was consumed by 61% and 25% of men and women respectively. Eighteen percent of the men consumed more than two drinks per day (30g/day) and 11.7% of women more than one drink per day (15g/day). Consumption increased from rural to middle class urban, but people living in the upper urban areas consumed the least alcohol. Sorghum and commercial beer were the most commonly consumed alcoholic beverage. The beer might have made a contribution to their diets with regard to intake of energy, magnesium, zinc, manganese, riboflavin and niacin. With regard to micronutrient dilution, men and women consuming the most alcohol had the highest intake of most micronutrients. However, the intake of vitamin B_{12}, B_6, folate, vitamin E, ascorbic acid and calcium was lower than the RDA at all levels of alcohol intake reflecting the poor overall nutrient intake of the population. The current fortification of staple food with vitamin B_6 and folate may improve the situation with regard to these two vitamins. Interestingly, abstainers consumed significantly more sugar and cold drinks than the heavy drinkers.

A third of the participants in the THUSA survey consumed 100g sugar or more per day. This is much higher than the recommended intake of no more than 55g/day (Steyn *et al.*, 2003a). The sugar intake of this population was mostly from sugar that was added during preparation or at the table, cookies, cake, sweets, candy and sugar sweetened beverages. The intake of sugar as such was the highest in the rural areas compared to upper urban areas, however, the intake of cookies, cakes, sweets, candy and drinks was the highest in the urban areas, reflecting easier access to unhealthy foods in urban areas. Participants consuming the most sugar also had higher intakes of energy and carbohydrates, and lower intakes of fat and protein. Participants consuming the most sugar had higher intakes of most micronutrients. The mean intakes of thiamin, riboflavin, niacin, vitamin B_6, magnesium, phosphorus and zinc in men and riboflavin, niacin, magnesium and phosphorus in the female participants increased with increased consumption of sugar, however, the intake of vitamin B_{12}, folate, ascorbic acid and calcium did not meet the RDA across all levels of sugar intake.

The intake of chicken, fish, vegetables, potatoes, samp, fat and sugar was the highest in the female heavy drinkers compared to non-drinkers. Male heavy drinkers consumed significantly more rice. Light to moderate female drinkers consumed the most red meat and the intake of milk, fat and cereals was the highest for the light to moderate male drinkers. The intake of potatoes and fat were the highest in females consuming the most sugar and the intake of red meat, bread, cereals and fat was highest for the men consuming the most sugar.

Alcohol intake was the highest in people staying in the middle class urban areas, and farm dwellers consumed the most sugar. It seems that people living in urban areas have more money to buy alcohol but also healthier food such as fruit and vegetables contributing to their overall health status.

Low energy intakes are a better indicator of micronutrient adequacy than the intake of one single food item like sugar and alcohol that may cause dilution (Department of Health, 1989; Gibson, 2001). It seems reasonable to conclude from the results of this study that this was indeed the case in the THUSA population and that the absolute intakes of micronutrients were not reduced with higher intakes of alcohol or sugar.

From a public health perspective it is more important to look at the proportion of people failing to achieve the recommended level of intake of a certain nutrient (Rennie & Livingston, 2007). Energy intake is a more reliable measure of nutrient intake than the concentration of one food item in the diet (Charlton *et al.*, 2005). Future research should focus on the reasons for inadequate micronutrient intake in populations in transition and ways to improve micronutrient intakes.

5.3 Recommended upper limit for alcohol and sugar intake

Alcohol intake has not only been linked with micronutrient dilution but also more than 60 medical conditions (Rhem *et al.*, 2003) and mortality due to accidents (Schneider *et al*,. 2007). South Africa does not quantify a safe limit for alcohol intake but suggests a limited alcohol intake. In light of the negative effects of high levels of alcohol intake, men should not consume more than 30g alcohol/day and women 15g/day, meaning two drinks per day for men and one drink per day for women.

Further studies on sugar intake are needed to determine an upper limit. The National Academy of Sciences recommends a DRI of 25% or less of total energy from added sugar, based on evidence of potentially adverse consequences on outcomes including biomarkers (e.g., blood lipids), behaviour, dental caries, obesity, coronary heart disease and nutrient intakes (Institute of Medicine, 2002).

Dental caries were not studied in the THUSA population. Improved physical (micronutrient intakes and status) and mental health were observed in urban respondents. However, obesity and serum total cholesterol and low-density lipoprotein cholesterol, accepted risk factors of cardiovascular disease, increased significantly with urbanisation (Vorster *et al.*, 2005). Kruger *et al.* (2002) found that physical inactivity was the major determinant of obesity in the women in the THUSA study and that total energy and fat intake correlated positively with BMI. In South Africa where undernutrition often goes hand in hand with overnutrition, sugar may be an important energy source for the very poor.

5.4 Limitations of this study

There might have been underreporting by the respondents on the QFFQ. The validation study (MacIntyre *et al.*, 2000) showed that the QFFQ tended to underreport energy intakes relative to a seven day weighed record. There was, however, no evidence of proportional bias, or of the extent of underreporting differing among genders and strata.

5.5 Conclusions

The intake of nutrient dense foods high in vitamins and minerals in this population was not optimal. The diets reflected deficiencies of vitamin B_{12}, folate, ascorbic acid and calcium across all levels of alcohol and sugar intake. Added sugar and alcohol are energy dense, and it has been argued that higher consumption of added sugar or alcohol may displace other more nutritious foods from the diet resulting in nutrient dilution. Results from this population show that as energy intake increased so did the intake of most micronutrients.

However, some nutrients were still below the RDA. For future research focus must be placed on the reasons for low intake of most micronutrients and education must be given to increase the intake of more nutrient dense foods.

Recently, the Directors of the National Food Consumption Survey Fortification Baseline (NFCS-FB-1, Labadarios *et al.*, 2008) recommended that in order to achieve a sustainable solution in the reduction of micronutrient deficiencies, a comprehensive strategy should be developed to improve the socio-economic status of South Africans, because of the intimate link to dietary intake. Furthermore, consumer awareness of adequate micronutrient intake should be increased and the Food Based Dietary Guidelines be used for nutrition education (Labadarios *et al.*, 2008). From the results of the current study it can be concluded that it may be useful if nutrition educators can quantify the guidelines on alcohol and sugar intakes.

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