The association between black tea consumption and iron status of African women in the North West Province: THUSA study

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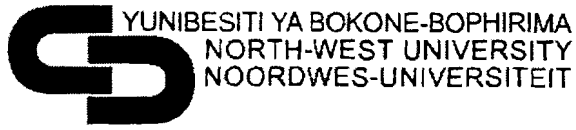

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Afrikaanse titel en opsomming

Die verband tussen swart tee inname en ysterstatus van Swart vroue in die Noordwes Provinsie: THUSA studie

OPSOMMING

Motivering: 'n Verskeidenheid van faktore insluitend voedseltekorte, swak higiëne en 'n lae opleidingsvlak dra by om die voedingstatus van swart vroue te beïnvloed. Vroue het verder 'n hoë risiko vir die ontwikkeling van ystertekorte aangesien hulle baie yster verloor deur menstruasie, die geboorteproses en 'n algemene lae inname van ysterbevattende voedsel. Al hierdie faktore dra by om die risiko vir die ontwikkeling van ystertekort anemie in vroue te verhoog.

Doelwitte: Die primêre doel van hierdie studie was om die assosiasie tussen tee inname en die ysterstatus van swart vroue in die Noordwes provinsie te ondersoek. Die meer spesifieke doelwitte om die primêre doel te bereik was om (1) die ysterstatus van vroue te bepaal (2) die tee inname te bepaal en (3) die verhouding tussen tee inname en yster status te bepaal terwyl die inhiberende en bevorderende faktore in gedagte gehou word.

Metodes: 'n Kruis steekproef van klaarblyklike gesonde vrouens uit 5 verskillende stratums van verstedeliking is geneem. Die populasie is verder verdeel in 2 groepe naamlik jonger vroue (jonger as 45.9 jaar) of ouer vroue (ouer as 46 jaar). Die steekproefgrootte was 920. Data is verkry van dieet, demografiese en bykomende vraelyste sowel as deur die insameling van bloedmonsters. Die studie is gedoen as deel van die THUSA studie.

Resultate: 'n Totaal van 920 proefpersone is ingesluit in die studie, waarvan 69.24% jonger vroue was en 30.76% ouer vroue. As gevolg van verlore data, het die hoeveelheid proefpersone vir elke parameter verskil. Die gemiddelde serum ferritien en hemoglobien waardes was binne normale grense vir beide groepe. Die gemiddelde dieetysterinname was minder as die dieetaanbevelings vir beide groepe. Geen betekenisvolle korrelasies is gevind tussen serum ferritien of hemoglobien en totale tee-inname sowel as 'n verskeidenheid van ander dieetfaktore nie. Die lae hemoglobienkonsentrasie groep van die jonger en ouer vroue het 'n effense hoër inname van dierlike proteiene en askorbiensuur gehad as die hoë hemoglobien konsentrasie groep. Die hoë serum ferritien konsentrasie groep het egter merkbare hoër inname van dierlike proteien gehad.

Gevolgtrekking: Die resultate van hierdie studie dui aan dat tee nie 'n inhiberende effek op die yster status van die vroulike populasie van die Noord Wes provinsie het nie. Daar is egter gevind dat ander studies wat op dieselfde onderwerp gedoen is, gemengde resultate het. Twee van die sewe studies wat ondersoek is, het aangedui dat tee geen inhiberende effek op ysterabsorpie het nie. Hierdie twee studies, net soos die THUSA studie is nie uitgevoer in 'n gekontrolleerde omgewing nie, met ander woorde faktore soos tyd van tee inname en gelyktydige inname van melk is nie gekontrolleer nie. Die ander vyf studies is uitgevoer in 'n omgewing waar proefpersone maaltye ontvang het, die tyd van tee inname gekontrolleer en melkinname aangedui is. Die gevolgtrekking kan dus gemaak word dat verdere studies in die Suid-Afrikaanse populasie, in 'n gekontrolleerde omgewing, nodig is om betroubare aanbevelings aan die populasie te verskaf.

Sleutelterme: Absorpsie, biobeskikbaarheid, polyfenole, swart tee, ysterstatus, ystertekort, ystertekortanemie.

English title and summary

The association between black tea intake and iron status of African women in the North West Province: THUSA study

Summary

Motivation: A variety of factors including food shortage, poor hygiene and low education levels affects the nutritional status of black women. Women also have a high risk for the development of iron deficiency because they lose iron through menstruation, the birth process and a low intake of iron containing foods. All of these factors contribute to an increased risk for the development of iron deficiency anaemia in women.

Objectives: The primary purpose of the study was to investigate the association between tea consumption and iron status of African females in the North West Province. To reach this purpose the specific aims were to (1) assess the iron status of women, (2) determine tea intake, and (3) determine the relationship between tea consumption and iron status, taking into account inhibiting and enhancing factors of iron absorption.

Methods: A cross-sectional sample of apparently healthy females was taken from five different strata of urbanisation. The subjects were then further divided into two groups, namely younger women (younger than 45.9 years) and older women (older than 46 years). A sample of 920 subjects was used. Data were obtained from dietary, demographic and additional questionnaires, as well as from the taking of blood samples. This study was a sub-study of the THUSA study.

Results: A total of 920 subjects participated of which 69.24% were younger women and 30.76% were older women. Due to missing data, the number of subjects for each parameter differed. The mean serum ferritin as well as haemoglobin concentrations were within normal ranges for both groups. The mean dietary iron intake for both groups was below recommendations. No significant correlations were found between serum ferritin or haemoglobin and total tea intake as well as a variety of other dietary factors. The low haemoglobin concentration group of the younger and older women combined had a slightly higher intake of animal protein and ascorbic acid than the high haemoglobin concentration group. On the other hand, the high serum ferritin concentration group had a significantly higher intake of animal protein than the low serum ferritin concentration group.

Conclusion: The results of this study indicated that tea does not have an inhibitory effect on the iron status of the female population of the North West Province. However, the investigation of other studies conducted on the same topic had mixed results. Two of seven studies investigated and this study indicated that tea had no inhibitory effect on iron absorption. These two studies, as well as this study were not done in a controlled environment where certain factors can be controlled for, for example, time of tea intake and milk consumption with tea. The other five studies were, however, conducted in an environment where subjects were given test meals, time of tea consumption was regulated and milk consumption with tea was recorded. The conclusion can, therefore, be made that further studies on the South African population in a controlled environment are necessary to give accurate recommendations to the population.

Keywords: Absorption, black tea, bioavailability, iron status, iron deficiency, iron deficiency anaemia, polyphenols.

CONTENTS

CHAPTER 4: GENERAL SUMMARY, RECOMMENDATIONS AND CONCLUSIONS.

Addendum 1:

The impact of urbanization on physical, physiological and mental health of Africans in the North West Province of South Africa: the THUSA study (Vorster *et al.*, 2000)

Addendum 2:

Authors instructions for the South African journal of clinical nutrition

Abbreviations

DNA	deoxyribonucleic acid
DRI	dietary reference intake
Fe	iron
IDA	iron deficiency anaemia
NCD's	non-communicable diseases
QFFQ	quantitative food frequency questionnaire
RDA	recommended daily allowance
THUSA	transition, health and urbanisation in South Africa
UNICEF	United Nations Children's fund
VIGHOR	Vanderbijlpark information project on health, obesity and risk factors

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Chapter 1:

Background and motivation

Chapter 1: Background and motivation

1.1 Introduction

In every living cell in the human body there is iron (Bruner, 1999:3). Iron plays a role in a variety of metabolic processes. Haemoglobin is responsible for oxygen transport from the lungs to the tissues and myoglobin for the transport and storage of oxygen in the muscles (Anderson, 2000:129). Iron also plays an important role in cellular respiration because of its oxidation/reduction capabilities (Conrad et al., 1999:213; Wessling-Resnick, 2000:130). Other functions of iron include electron transport, oxidative degradation of drugs, conversion of hydrogen peroxide to oxygen and water, and involvement in cognitive performance and immune function (Anderson, 2000:130; MacPhail, 1998:137; Yip, 2001:330).

Iron deficiency not only causes anaemia but can also affect work capacity, neurotransmitter function and immunologic and inflammatory defenses (Ross, 2002:220, Wessling-Resnick, 2000:130). Some of the signs and symptoms of iron deficiency include glossitis (glistening appearance of tongue), angular stomatitis, spoon shaped nails and a pale conjunctiva (Beard et al., 1996:306; Ross, 2002:222). Behavioural changes can occur, which include pica (compulsive eating of non food items) and pagophagia (compulsive eating of ice) (Andrews, 1999:1990; Ross, 2002:222). Iron deficiency can also affect cognition and lead to possible neuropsychological impairments (Tapiero et al., 2001:325).

Iron deficiency is the most prevalent nutritional disorder in the world (Youdim, 2000:504). Two thirds of children and women of childbearing age in most developing countries are estimated to suffer from iron deficiency (MacPhail et al., 2004:13). According to an overview compiled by MacPhail (2004:2) on the 29 studies done on anaemia and iron deficiency in South Africa, the prevalence of anaemia in the black female population is 31% and the prevalence of anaemia in the pregnant population is 28%. The prevalence of anaemia in children 6-71 months was 20% and the prevalence of children with depleted iron stores 10% (MacPhail, 2004:2).

The next figure (Figure 1.1) shows how the risk for iron deficiency increases with multiple risk factors.

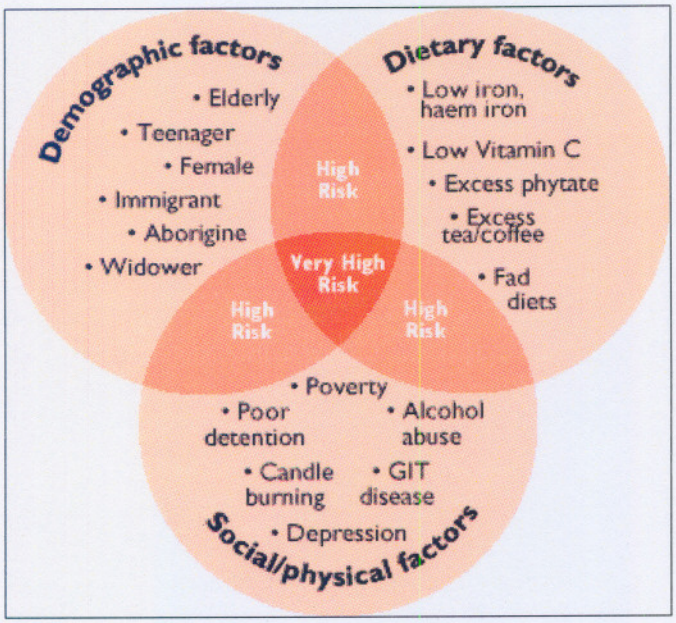


Figure 1.1: Consider dietary iron deficiency in the patient with multiple risk factors (http://healthpsych.psy.vanderbilt.edu/index.htm) (16 September 2005)

Iron deficiency will result from iron intake that does not meet the body's demands (Andrews, 1999:1990). Iron deficiency can be caused by (1) low intake of food rich in bioavailable iron, such as meat or (2) high intake of food that has an inhibitory effect on iron such as phytates or calcium (Tapiero et al., 2001:325). Other factors that may lead to iron deficiency include excessive blood loss due to hookworm infestations and malaria and in females, iron losses due to menses and childbirth; and in children and adolescents, increased needs for growth (Hoffbrand & Herbert, 1999:19). Linked to these factors, black tea appears to have an inhibitory effect on the bioavailability of non heme iron (Hurrell et al., 1999:293; McKay & Blumberg, 2002:8; Rossander Hulthen & Hallberg, 1996:110). Simultaneous intake of black tea and iron containing foods inhibit iron absorption by 60-70%, while between meal tea intake only has an inhibitory effect of about 20% (Zijp et al., 2000:379).

Care must be taken with studies done on a single meal intake basis as it can lead to false negative results if subjects were already iron replete. According to the overview by Rossander-Hulthen & Hallberg (1996:107), studies have shown that iron replete subjects absorb more or less the same amount of iron from meals with different bioavailabilities.

It is, therefore, important to choose subjects that are not fully iron replete (Rossander-Hulthen & Hallberg, 1996:107). It is also important to note that some of the studies were done on animal (rat) models. These data are not representative of human beings because (1) rats absorb more iron than humans and (2) the effects of inhibiting and enhancing factors cannot be seen in a rat's diet.

1.2 Problem formulation

Poor iron status can affect the health and wellbeing of different populations. It is known that polyphenol containing beverages have an inhibitory effect on iron absorption, but the practical significance thereof on iron status is not known. Iron absorption is affected by a variety of factors. Some of these factors can include the individuals iron status, the intake of high or low bioavailable iron and the presence of inhibiting and enhancing factors in the diet. The effect of one of these inhibiting factors (tea), as mentioned earlier, can be ascribed to simultaneous intake of iron and tea. It is also important to investigate the effect of tea on iron status in respondents with different iron status. A review done by MacPhail et al. (2004:3) on studies of iron deficiency and iron deficiency anaemia (IDA) indicates that at least one third of black and Indian adult women in South Africa have IDA.

As mentioned in the introduction, a variety of factors can influence iron status to such an extent that it can lead to iron deficiency, which is associated with weakness, impaired effort tolerance and eventually heart failure (MacPhail et al., 2004:12). It is, therefore, important to determine the association between tea consumption and iron status and the possible recommendations that can be made.

1.3 Hypothesis

The hypothesis for this study is as follows:

Tea consumption is associated with low iron status in the African female population of the North West Province, South Africa.

In order to test this hypothesis it was necessary to state certain objectives that would eventually lead to a clear answer to the hypothesis. The objectives are stipulated in 1.4.

1.4 Objectives

The primary purpose of the study was to investigate the association between tea consumption and iron status of African females in the North West Province.

The specific aims were:

- ✓ To describe the iron status of younger (< 45.9 years) and older (> 46 years) women using haemoglobin and serum ferritin as markers of iron status
- ✓ To describe the tea intake of younger (< 45.9 years) and older (> 46 years) women
- ✓ To determine the relationship between tea consumption and iron status, taking into account inhibiting and enhancing factors of iron absorption

1.5 Definitions

Low iron status: According to WHO standards the cut off points for a low iron status are haemoglobin < 120g/L and serum ferritin < 15µg/L (FAO/WHO, 2001:205).

1.6 Outline of the study

Chapter 1: Background and motivation

The motivation for the study of the association of tea consumption and iron status of African women that took part in the THUSA study, as well as the effects of iron deficiency, is given in the first chapter.

Chapter 2: Literature review: Iron metabolism, black tea intake and iron status, and health effects

The literature study will give a concise explanation of the latest research findings on the role of iron in the body, the effects of iron deficiency and people affected and how a deficiency develops (factors that plays a role for example tea drinking or calcium intake).

Chapter 3: The association between black tea consumption and iron status of African women in the North West Province: THUSA study

This chapter will include a complete discussion of the research methodology, results, discussion and recommendations in the form of a publishable article.

Chapter 4: General summary, recommendations and conclusion

A concise overview to draw final conclusions and summarize the results will be included in this chapter.

Chapter 2

The metabolism of iron, the association between black tea intake and iron status, and its health effects.

Chapter 2: The metabolism of iron, the association between black tea intake and iron status, and its health effects

2.1 Introduction

Iron deficiency is a highly prevalent nutritional disorder in developing countries (Ross, 2002:220; Tapiero et al., 2001:324; Youdim, 2000:504). Iron deficiency is not only a problem of developing countries; this deficiency affects billions of people worldwide, including 370 million women of childbearing age (West, 1996:1).

The prevalence of anaemia in South Africa according to ethnic origin is as follows: 31% of adult black females, 28% of adult Indian females, no data available for coloured and white adult females (MacPhail, 2004:3). In a review done by Vorster et al. (1997:17) of studies done on nutritional status in South Africa, it was found that vulnerable groups for iron deficiency, with an iron intake less than 67% of RDA, were rural black children and women aged 16 – 65 years.

In the VIGHOR study done by Vorster et al. (1995:124) on the white population, aged 35 - 44 from Vanderbijlpark and Witbank, the mean intake of dietary iron compared to British data and other South African studies showed that iron intake was more or less the same in the different populations, even if the populations used in the studies differed in size. The study also further showed that over and under nutrition can exist in the same community. In the THUSA study done by MacIntyre et al. (2002:11) on an African population in transition in the North West Province, low mineral intakes of iron and calcium, especially among females were found.

Iron plays a vital role in a variety of metabolic processes which include oxygen uptake and transport as well as electron transport (Conrad & Umbreit, 2000:287). Aside from this, iron also serves as a cofactor for many physiologically important enzymes including those involved in oxidative metabolism, dopamine and DNA synthesis as well as free radical formation in neutrophils (Ross, 2002:220; Youdim, 2000:504). Iron plays an important functional role in brain development, muscle contraction and energy metabolism (Yip, 2001:331; Zijp et al., 2000:372).

Iron deficiency (with or without anaemia) can be diagnosed by a serum ferritin concentration of less than 15g/L (Nelson & Poulter, 2004:44). The other causes of iron deficiency have already been mentioned in chapter 1, which include the presence of inhibitors, for example calcium and polyphenol compounds in food products (Hurrell et al., 1999:289). Solutions for the causes of iron deficiency as well as other deficiencies can be managed by adapting the UNICEF framework. The UNICEF framework was developed to recognise the causes of a deficiency and effective ways to manage the problem. The basic UNICEF framework as well as the adaptation for iron deficiency will be discussed under section 2.2.

2.2 UNICEF conceptual framework

According to Herbert (1973:77), all nutrient deficiencies have five causes. The five causes are three inadequacies, namely, inadequate ingestion, absorption and utilization and two increases, namely, increased excretion and requirements.

The UNICEF framework helps identify process and outcome indicators on three levels of causation, namely: immediate, underlying and basic. The basic causes of malnutrition include political and ideological superstructure, economic structure and potential resources (Worldbank & UNICEF, 2002:2). Other factors that play a role in basic causes are the role of the women in the family (see Figure 2.1), knowledge and discriminatory attitudes (UNICEF, 1998). All of these factors combine to affect the amount as well as the quality of food available to communities.

The underlying causes are household food insecurity, inadequate maternal and child care and inadequate health services (see Figure 2.1) (Worldbank & UNICEF, 2002:2). Household food insecurity depends on access to food and this in turn depends on financial, physical and social circumstances (UNICEF, 1998). The immediate causes of malnutrition can be seen in Figure 2.1 and include inadequate intake as well as infectious disease (Worldbank & UNICEF, 2002:2; UNICEF, 1998).

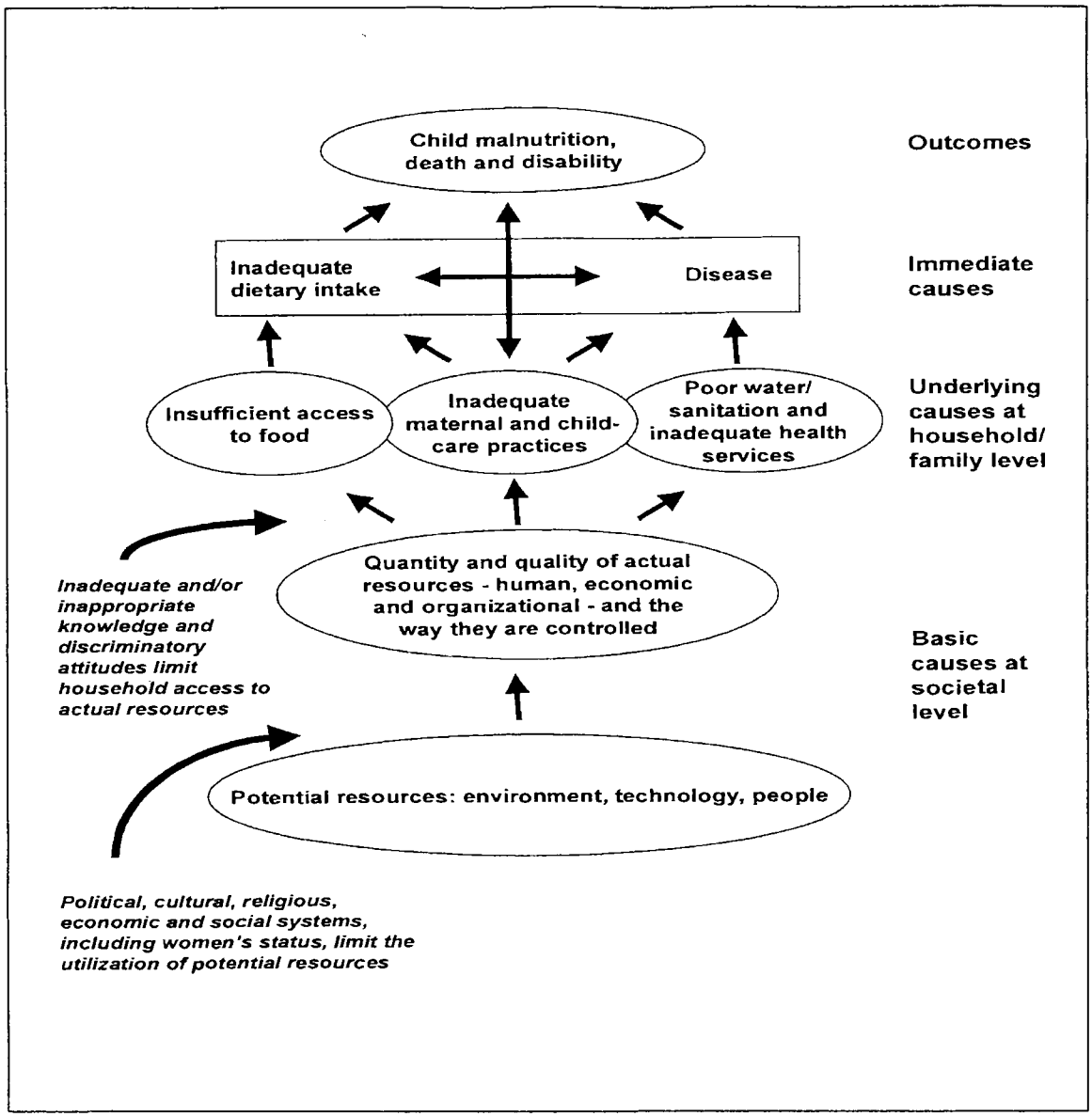
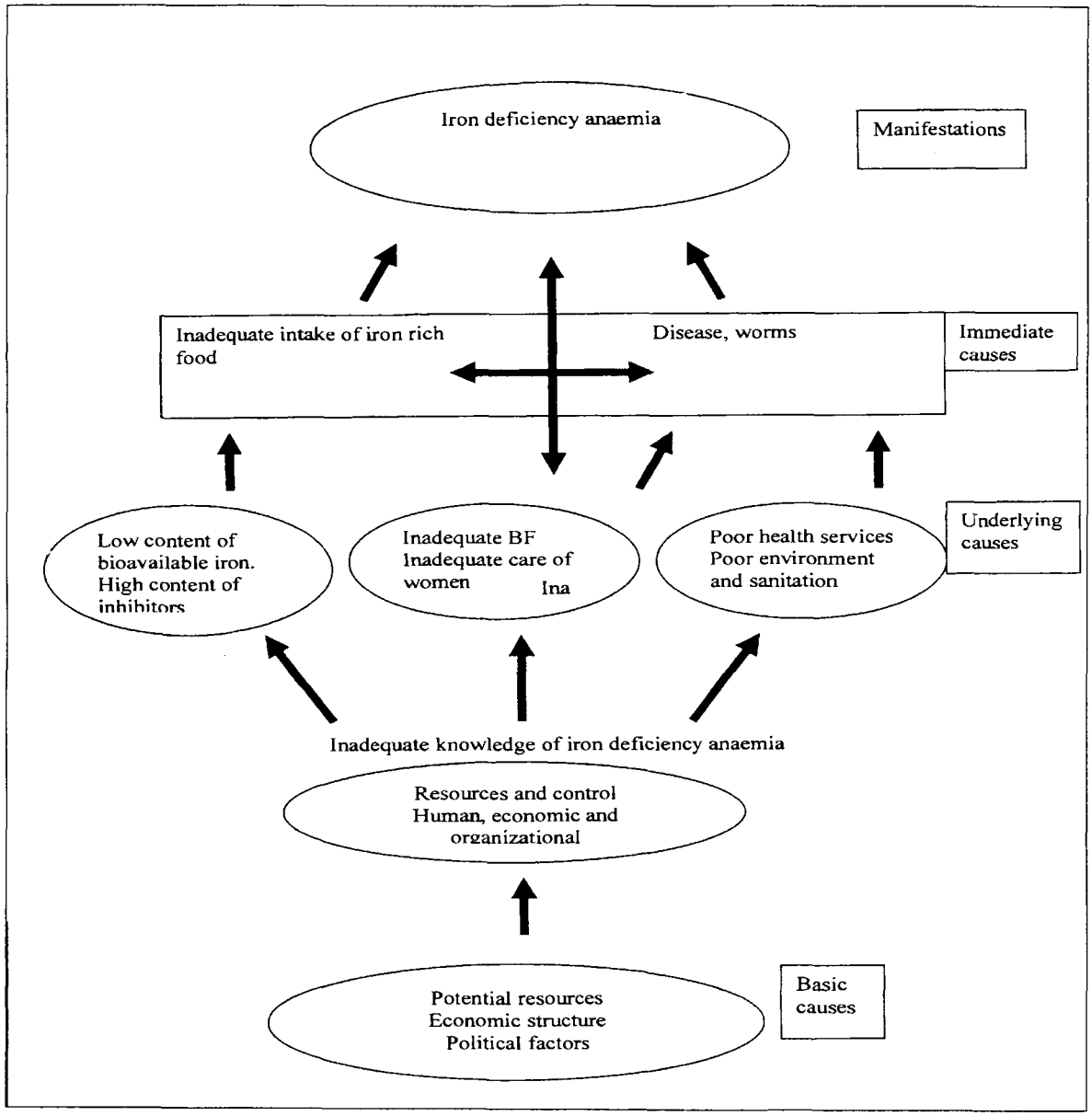


Figure 2.1: Conceptual framework for development of malnutrition (UNICEF, 1998)

The framework in Figure 2.1 can be used and adapted for IDA (see Figure 2.2) to help with effective solutions to improve nutrition, for example to improve the iron status of women at risk. The basic causes will remain the same, starting with availability of resources which is affected by the economic and political structure of a country.

An inadequate knowledge of the causes of IDA can lead to the underlying causes of IDA. The underlying causes will also stay more or less the same as the basic framework, but it is important to investigate factors such as inadequate breastfeeding, intake of food with low bioavailable iron and high content of inhibitors

of iron absorption in the diet. The immediate causes of iron deficiency also remain the same as the basic framework.



*BF = breastfeeding

Figure 2.2: Conceptual framework of causes of IDA (Van Lieshout et al., 2004:7)

2.3 *Iron in the body*

Iron contributes a vital role to processes by which cells generate energy. Iron can occur in different ionic states. In the reduced state iron has lost two electrons and, therefore, has a net positive charge of two (ferrous iron) and in the oxidized state iron has a net positive charge of three (ferric iron) (Whitney et al., 1998:451). This ability

to exist in different ionic states helps iron to serve as a cofactor for enzymes involved in oxidation-reduction reactions, enzymes such as cytochromes that are critical for energy production and enzymes involved in the immune system (Whitney et al., 1998:451; Zijp et al., 2000:371).

Iron is packed in the heme molecule which is the non-protein conjugate of haemoglobin in the red blood cells (Sempos et al., 1996:76). Haemoglobin in the red blood cells and myoglobin in the muscle cells contain the majority of iron in the body. In both, iron helps receive, carry and release oxygen (Conrad & Umbreit, 2000:287; Whitney et al., 1998:451). Iron also plays a vital role in DNA synthesis since ribonucleotide reductase, the rate-limiting enzyme involved in DNA synthesis, is an iron containing enzyme (Conrad & Umbreit, 2000:287).

2.4 Absorption of iron

According to Beard et al. (1996:296), the process of iron absorption takes place in three stages namely (1) iron uptake, (2) intraenterocyte transport, and (3) storage and extraenterocyte transfer. No absorption of iron occurs in the mouth. Iron absorption mostly occurs in the duodenum and jejunum - collectively known as the proximal small intestine (Conrad et al., 1999:214; Conrad & Umbreit, 2000:288; Wessling-Resnick, 2000:131).

In the body a protein called mucosal ferritin receives iron from the lumen of the gastrointestinal tract and stores it in the mucosal cell (Conrad et al., 1999:214; MacPhail, 1998:138; Whitney et al., 1998:452). When the body needs iron, mucosal ferritin take up the iron and transfers it to a carrier in the blood called blood transferrin, which then transfers the iron to the rest of the body (Conrad et al., 1999:214; Whitney et al., 1998:452). This process of iron absorption is illustrated in the routes of iron in the body (see Figure 2.3). The absorption of heme and non heme iron will be discussed in sections 2.4.1 and 2.4.2

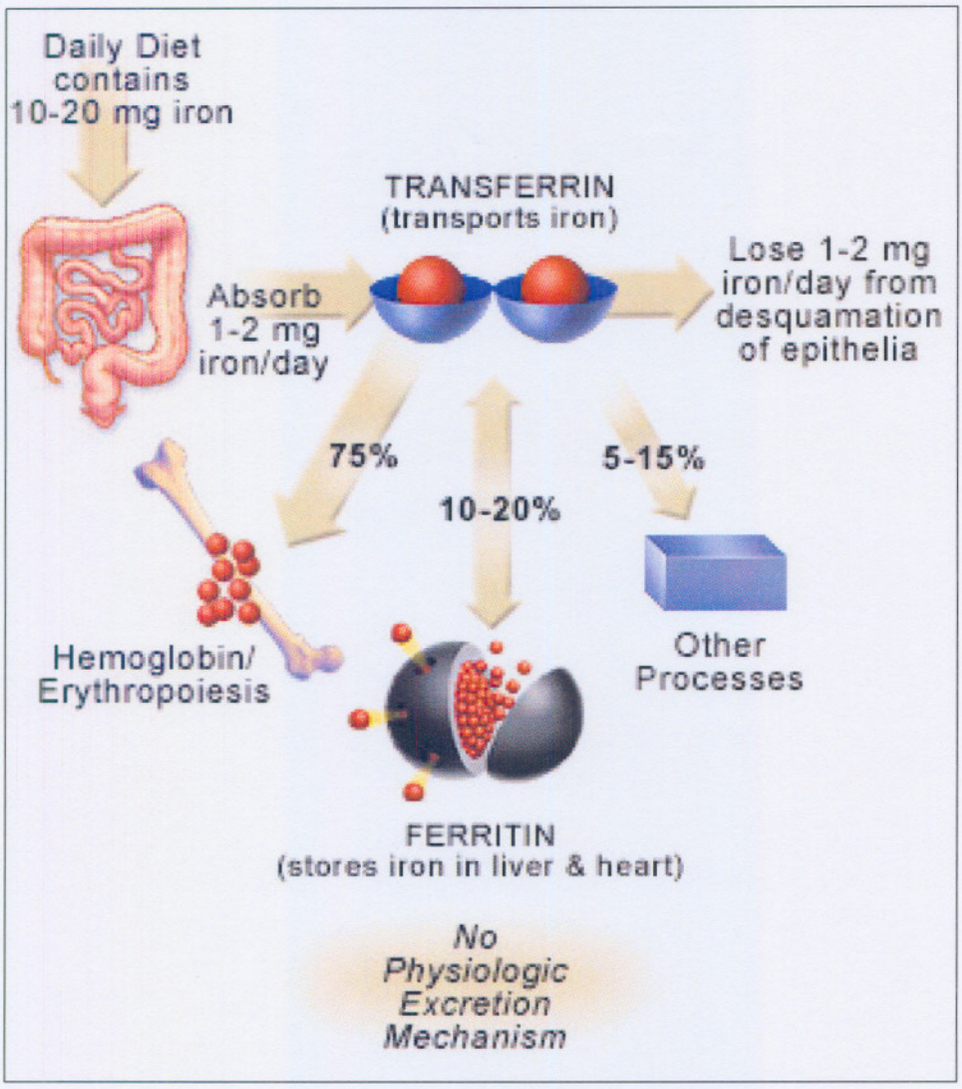


Figure 2.3: Normal iron absorption and metabolism (http://www.cdc.gov/hemochromatosis/training/pathophysiology/iron_cycle pop up.htm)(16 September 2005; 16:00)

2.4.1 Absorption of non heme iron

Non heme iron is found in a wide variety of foods of both plant and animal origin, for example, cereals, vegetables, fruits, roots, beans, eggs, meat, fish and poultry (MacPhail et al., 2004:4; Rossander-Hulten & Hallberg, 1996:106; Whitney et al., 1998:453). The factors that influence iron absorption are summarized in Table 2.1. The balance between enhancing and inhibiting factors will be discussed under section 2.6.

Table 2.1: Factors influencing dietary iron absorption (Hallberg, 2001:6)

Heme iron absorption	Iron status of subject Amount of heme iron especially in meat Content of calcium in meat Food preparation, time and temperature
Non heme iron absorption	Iron status of subject Amount of potentially available non heme iron
Balance between enhancing and inhibiting factors	
Enhancing factors	Ascorbic acid Meat, chicken, fish and other seafood
Inhibiting factors	Phytate and other inositol phosphates Tannin – iron binding phenolic compounds Calcium Soy proteins

The bioavailability of non heme iron, unlike heme iron, is influenced by other constituents in the diet. Non heme iron, for example, is digested early in the duodenum at low pH. Further down the formation of insoluble ferric complexes will reduce the bioavailability of non heme iron (MacPhail et al., 2004:5; Miret et al., 2003:284). It is also important to note that solubilised iron enhances absorption and iron absorption is decreased by factors that polymerize or precipitate iron (Conrad et al., 1999:215).

For optimal absorption two physiological factors are needed, (1) gastric hydrochloric acid secretion, and (2) the retention and mixing of food in the stomach (Lynch, 1997:103). For non heme iron to be transferred across the brush border (mucosa) for absorption, the iron must be digested free from plant sources and enter the duodenum and upper jejunum in a soluble form. The acid of gastric secretions

enhances both the solubility and the change of iron to the ionic state (either as ferric or ferrous iron). Further down the duodenum the pH will increase due to addition of pancreatic and duodenal secretions, where most ferric iron will be precipitated unless it has been chelated. Ferrous iron, however, will remain available for absorption because it is significantly more soluble at a pH of 7 (Anderson, 2000:128).

Iron absorption of both heme and non heme iron are lowered in iron replete conditions. In iron deficiency non heme iron becomes more absorbable, thus leading to the assumption that non heme iron absorption is most influenced by iron status and, therefore, an important determinant of non heme iron absorption (Lynch, 1997:102; Rossander-Hulthen & Hallberg, 1996:106; Tapiero et al., 2001:325).

2.4.2 Absorption of heme iron

Heme iron is only found in food derived from animal origin, for example meat, poultry and fish. Heme iron is relatively well absorbed and even if there is only a small amount of intake, heme iron contributes significantly to body iron stores (Lynch, 1997:106; Whitney et al., 1998:453;).

After heme iron (intact ferroporphyrin ring) has been digested from animal sources it is absorbed across the brush border (mucosa) of intestinal absorbing cells. Ferrous iron is removed from the ferroporphyrin complex once heme enters the cell. Ferrous iron then immediately binds with apoferritin to form ferritin.

The ferritin molecule, as also discussed in paragraph 2.3 then serves as both a storage place and transporter of absorbed iron to the basolateral membrane of the absorbing cell. There the final step of absorption occurs, which is the same as for non heme iron, by means of an active transport mechanism which moves the iron into the blood (Anderson, 2000:127; Wessling-Resnick, 2000:131; Yip, 2001:329).

Heme absorption is independent of meal composition and not drastically affected by enhancers and inhibitors that alter non heme iron absorption (see Table 2.1) (Lynch, 1997:106). Different opinions exist on whether heme iron absorption is regulated by iron status to the same extent as non heme iron absorption (Miret et al., 2003:285).

According to Hallberg (2001:13), iron deficiency can be defined as a state

(a) when an otherwise healthy individual's haemoglobin is below normal values

(b) when no infection or other disorder is present

(c) when no other nutrients are lacking

(d) when laboratory results are compatible with iron deficiency.

The most obvious and severe consequence of iron deficiency is anaemia. IDA can be defined by a haemoglobin concentration below -2 standard deviations for age and sex specific normal reference value. IDA represents the severe spectrum of iron deficiency and, therefore, requires fulfilment of the definitions for iron deficiency and anaemia (Yip, 2001:327).

Some of the consequences of iron deficiency include weakness which will lower work capacity. IDA can eventually lead to heart failure while other consequences include mental changes due to lowered neurotransmitter function as well as immunologic and inflammatory defences (Hallberg, 2001:13; Ross, 2002:220;). Iron deficiency in pregnancy can lead to prematurity, low birth weight and increased perinatal mortality (MacPhail, 2004:12). Some signs and symptoms of IDA include pallor, listlessness, fatigue, poor exercise tolerance, pica and pagophagia. These symptoms as well as a variety of other symptoms have already been mentioned in the introduction of Chapter 2.

2.6 Factors leading to iron deficiency

Iron deficiency will occur when the amount of iron absorbed is not sufficient to cover physiological losses and requirements of iron. This can be caused by a (1) low intake of food rich in bioavailable iron, such as meat or (2) high intake of food that has an inhibitory effect on iron such as phytates or calcium (Tapiero et al., 2001;325; Hallberg, 2001:2). A variety of factors influence iron absorption. Examples of such factors are iron status of the individual and composition of the diet (Hallberg, 2002:S13). Other factors include excessive blood loss due to hookworm infestations

and malaria and in females, iron losses due to menses and childbirth; and in children and adolescents, increased needs for growth (Hoffbrand & Herbert, 1999:19). These factors are summed up in Table 2.1 (section 2.4.1).

Other factors that may lead to iron deficiency include It is important to also take into account the balance between enhancing and inhibiting factors. Enhancing and inhibiting factors will be discussed under section 2.6.2 and 2.6.3.

2.6.1 Common causes of Fe-deficiency

In societies where dietary iron of high bioavailability is ingested, theoretically no iron deficiency should be found. However, there are still certain groups that are at risk, for example growing children, women in their childbearing years and people with decreased absorption (Gibson, 1999:521). Vegetarians, due to a lack of the stimulatory effect of meat and fish on iron absorption, will have reduced absorption of non heme iron (Hallberg, 2002:S16).

To compensate for their decreased meat intake, vegetarians usually eat large amounts of beans, peas and lentils, which contain phytates – a strong inhibitor of iron absorption (Hallberg, 2002:S16). Iron from plant sources is not readily available and binding by tea can further reduce the amount of available iron. Therefore, vegetarians especially, should be advised to drink tea between meals (Dufresne & Farnworth, 2001:407).

The iron status of the individual also plays an important role in the determination of iron requirements. During infancy, early childhood, adolescence and pregnancy, rapid growth and development occur, leading to much higher iron requirements. Women are at an increased risk due to iron losses related to monthly menstrual blood loss and iron transfer to the foetus during pregnancy (Yip, 2001:331). More than 70% of women emerge with IDA due to rapid expansion of maternal blood volume and placental growth during pregnancy (Beard et al., 1996:308).

Some of the causes of iron deficiency can include factors such as injury, haemorrhage or illness (Anderson, 2000:130; Yip, 2001:332). This can be further aggravated by insufficient dietary intake combined with the presence of inhibiting

factors such as phytate, calcium or polyphenols (Tapiero et al., 2001:325). These dietary insufficiencies are usually secondary to intestinal blood loss resulting from parasitosis (Andrews, 1999:1990). Iron deficiency can further be caused by insufficient access and poor quality of food resources. Food sources may be available but not accessible due to lack of resources to purchase food and the burden of women's work (caring for family, taking care of the household and agricultural work) (Worldbank & UNICEF, 2002: 4).

South Africa is a developing country with a great variety of cultural and socio-economic factors influencing eating patterns. Large parts of the population are currently in the process of nutrition transition, a change from a traditional African diet, low in fat and high in fibre and micronutrients, to a more westernized diet, which is high in fat and refined carbohydrates and low in fibre and micronutrients (MacIntyre et al., 2002:2; Vorster et al., 1995:119).

A review done by Steyn et al. (2003:643) revealed that foods most frequently consumed by the adult black South African population (Table 2.2) are maize porridge, white sugar, tea, brown bread, white bread, non-dairy creamer, brick margarine, chicken meat, full cream milk and green leaves. If one considers this diet, it is easy to conclude that it is a contributing factor in the development of iron deficiency, whether it be a low intake of highly bioavailable iron or high intake of poor bioavailable iron and/or intake of inhibiting factors such as tea and calcium.

Table 2.2: Foods most frequently consumed by South Africans (Steyn et al., 2003:643)

Ranking	Food / drink item	Amount (g/mℓ) per day	% Frequency of usage
1	Maize porridge	848 g	78%
2	White sugar	27 g	77%
3	Tea	456 g	68%
4	Brown bread	165 g	55%
5	White bread	163 g	28%
6	Non-dairy creamer	6 g	25%
7	Brick margarine	19 g	21%
8	Chicken meat	111 g	19%
9	Full cream milk	204 g	19%
10	Green leaves	182 g	17%

2.6.2 Inhibiting factors in iron absorption

Tea

Tea at an intake of 120ml/day is, besides water, the most popular consumed beverage worldwide (McKay & Blumberg, 2002:2). Tea is obtained from the leaves of a plant named *Camellia sinensis*. Black tea, which contains multimeric polyphenols is produced by fermentation of tea leaves (Dufresne & Farnworth, 2001:404; Luczaj & Skrzydlewska, 2004:1).

Tea is rich in polyphenolics, especially catechins (a group of very active flavonoids) (Dufresne & Farnworth, 2001:405; McKay & Blumberg, 2002:2). Fresh black tea leaves contain upon average, 10-12% catechins, 15% carbohydrates, 1% proteins and a variety of other substances (Luczaj & Skrzydlewska, 2004:2). The contents of the catechins in the tea leaves depend on the age of the leaves, this catechin content is normally higher in black tea production (Luczaj & Skrydlewska. 2004:2). A cup of black tea brewed with 2.5g tea leaves contains about 200mg tea flavonoids (Zijp et al., 2000:377).

Flavonoids are polyphenols containing two aromatic rings as a functional group with two or more hydroxyl groups (catechol) or three hydroxyl groups (galloyl) positioned at adjacent carbon atoms (Zijp, 2000:377). The most abundant polyphenols are monomers (catechins), dimers (theaflavin) and polymers (thearubigin) (Luczaj & Skrzydlewska, 2004:2; Zijp et al., 2000:377).

The polyphenols, because of their strong interaction with transition metals, form an insoluble complex with iron in the gastrointestinal tract which strongly inhibits iron absorption (Dufresne & Farnworth, 2001:406; Luczaj & Skrzydlewska, 2004:6). Black tea inhibits the bioavailability of non heme iron by 79% to 94% when they are ingested concomitantly (Hurrell et al., 1999:293). The main inhibitor in the black tea composition seems to be the galloyl group (Rossander-Hulthen & Hallberg, 1996:110; Zijp et al., 2000:377).

It is, however, important to note that some of the studies done on the effect of tea consumption on iron status have a number of limitations. In a study done by Hulthen et al. (1995:800) to measure total amount of iron absorbed from two common types of diet, it was found that more iron was absorbed from the diet with high bioavailable

iron. All subjects in this study had a free initial choice between coffee, black tea, herb tea or honey-water with breakfast and evening meals. This study did not investigate the effect of inhibitors and enhancers on iron absorption and, since the choice of beverage was not controlled, this could have affected the results negatively. Table 2.3 gives a summary of studies done on the effect of tea consumption on iron status as well as the intake of inhibiting or enhancing factors on iron absorption.

Temme and Van Hoydonck (2002:383) reviewed six studies on the effect of tea on iron status and found that, in three of the studies, other foods that might affect iron bioavailability were not taken into account. The study done by Hurrell et al. (1999:292) showed a definite inhibitory effect of tea intake on iron status even at low concentrations of black tea. A black tea concentration of 5% inhibited iron absorption by 70%. This inhibitory effect of tea on iron absorption can be counteracted by ascorbic acid, because ascorbic acid has an enhancing effect on non heme iron absorption (Dufresne & Farnworth, 2001:407; Heath & Fairweather-Tait, 2002:228).

Five of the seven studies summarised in Table 2.3 showed a definite inhibitory effect of tea consumption on iron status. The study by Root et al. (1999) showed no association between tea consumption and iron status and had a relatively low incidence of subjects with iron deficiency. The study by Doyle et al. (1999) also showed no association between tea consumption and iron status for women. This can be attributed to the positive correlation between tea drinking and energy intake (suggesting that more food was consumed by those who drank more tea) (Doyle et al., 1999:558).

Table 2.3: Summary of studies which investigated the effect of regular tea drinking on iron status

Reference and study design	Subjects	Iron status of subjects	Dietary assessment method	Tea intake	Inhibiting/ enhancing factor intake	Effect of tea intake on iron status	Factors controlled for in analysis
Brune et al., 1989	125 Subjects (57 men and 68 women). Aged 19 -51 years	Not described	Food samples	150ml black tea (contain 3 g dry tea)	Not described	Inhibitory effect of tea on iron status was 68%	Ascorbic acid
Disler et al., 1975	Indian housewives. Aged 26 – 60 years.	Not described	Not described	200 ml black tea (contain 5 g dry tea)	Inhibiting effect the same whether tea contained milk or not	Tea inhibits absorption of non heme iron to a significant effect. Tea no inhibitory effect if haemoglobin is cooked.	Meat, haemoglobin, milk
Doyle et al., 1999 Cross sectional	1268 Subjects (651 men and 617 women) Aged > 65 years	Anaemia in 11% and 9% of free living men and women respectively and 52% and 39% of men and women respectively in institutions	4 d weighed dietary record	Black tea (volume not described)	Calcium negative association with haemoglobin and positive correlation with meat	Negative association with haemoglobin in men ($p \leq 0.01$) No significant association with serum ferritin.	Not indicated
Galan et al., 1985 Cross sectional	476 females Aged 17 – 42 years	1.3% anaemic and 16% iron deficient	Diet history for random sample of 157 women	172 +/- 22ml/day	Intake of meat, vegetable, fruits and diary products which can affect results	Significant inhibitory effect of tea	None

Reference and study design	Subjects	Iron status of subjects	Dietary assessment method	Tea intake	Inhibiting/ enhancing factor intake	Effect of tea intake on iron status	Factors controlled for in analysis
Hurrell et al., 1999 8 separate studies	77 subjects of which were 23 males and 44 females. Aged 19 - 40 years.	No anaemic subjects 5 female subjects were iron deficient	-	275 ml black tea or a variety of other beverages	Addition of milk in one study which had little or no effect on inhibition	Black tea very inhibitory even at low concentrations. Black tea at 5% concentration reduced Fe absorption by almost 70%.	Milk
Razagui et al., 1991 Longitudinal study	15 long stay mentally handicapped, menstruating women Aged 19 – 43	6 subjects were considered iron deplete of which 1 was considered anaemic	7 day dietary survey	486 +/- 333 ml/day	Vitamin C intake 46 +/- 17 mg/day	Significant inverse relationship between serum ferritin and meal-time tea intake.	None
Root et al., 1999 Cross sectional	80 randomly selected subjects per country (5 countries) aged 32 – 66 years	Incidence of iron deficiency relative low	3 day dietary survey	9 – 38 g dry black tea	21 – 154 mg Vitamin C intake	Tea intake not associated with iron status.	Country, vitamin C intake and heme iron

Calcium

Both heme and non heme iron absorption is inhibited by calcium intake in a dose-dependent manner (Harris, 2002:232; MacPhail, 1998:141; Tapiero et al., 2001:328). Unlike the inhibitory effect of tea that can be reversed by ascorbic acid intake, the inhibitory effect of calcium cannot be reversed in the same way (West, 1996:5). The effect occurs with calcium intakes of approximately 300mg/meal. Although the mechanism is not clearly understood, the following explanation might give an indication of the effect (Lynch, 1997:105; MacPhail, 1998:141).

The addition of 150mg of calcium to bread or a hamburger meal decreased iron absorption by 50% in a study done by Hallberg et al. (1991:116). Available evidence suggests that inhibition takes place in the mucosal cell during the final step of transfer of heme and non heme iron. A condition for inhibition seems to be the presence of iron and calcium in the same meal (Harris, 2002:232; Rossander-Hulthen & Hallberg, 1996:111).

The applicability of the results of short term studies to long term iron absorption is limited by the variety and self selected food consumed regularly, as well as the ability of the respondents to adapt to low iron intake (Harris, 2002:232). It, therefore, seems that calcium interferes with iron absorption when taken together with tea, but it does not appear to affect iron absorption and status in healthy people that eat a varied diet over the long term adversely (Harris, 2002:232).

Phytate

Phytates, of which 90% originate from cereals in the western-type diet, are recognised as an important inhibitor of non heme iron absorption (Heath & Fairweather-Tait, 2002:228; Zijp et al., 2000:376). Wholegrain cereals, bran, oats, legumes, seeds and nuts are especially high in phytates.

The mechanism behind the inhibitory effect of phytates on iron absorption is still unclear. Monoferric phytate is not inhibitory, while diferric and tetraferric complexes in the gastrointestinal tract will have a definite inhibitory effect (Lynch, 1997:104; Rossander-Hulthen & Hallberg, 1996:105).

This inhibitory effect of phytates takes place in a dose dependent fashion, with even the smallest amount of phytate having a significant effect (Zijp et al., 2000:376). This effect by phytates can be counteracted by the simultaneous addition of ascorbic acid, meat, fish and poultry to the diet. To overcome the effect of 25mg phytate (equivalent to one teaspoonful of peanut butter), at least 80mg of vitamin C is required (Heath & Fairweather-Tait, 2002:228).

2.6.3 Enhancing factors in iron absorption

Ascorbic acid

The most potent enhancer of iron absorption is ascorbic acid (MacPhail, 1998:141; Zijp et al., 2000:377). The enhancing effect presumably takes place in the lumen of the gut where ferric iron is converted to ferrous iron. This keeps the iron in a soluble and absorbable form, thus preventing binding to inhibitory compounds.

Another mechanism that also plays a role in the enhancement of iron absorption is the prevention of precipitation of ferric complexes such as ferric hydroxide (MacPhail, 1998:141; Rossander-Hulthen & Hallberg, 1996:108; West, 1996:5).

This mechanism can be explained as follows – ascorbic acid maintains iron in a soluble form as the luminal pH rises. Iron in the ferric form is only soluble at an acidic pH. In an aqueous solution metal ions are bound through water bridges. If the pH rises, metallic hydroxides are formed. Above a pH of four all iron is precipitated from a solution of ferric chloride. However, if ascorbic acid is added to this soluble ferric chloride in an acid solution, a complex is formed that remains soluble over a wide pH range (Lynch, 1997:103).

When tea and ascorbic acid intakes occur simultaneously, ascorbic acid can counteract the inhibiting effect of tea by preventing the formation of an iron-tannin complex (Zijp et al., 2000:377). It is important to note that the promoting effect of ascorbic acid on iron absorption is only effective if taken together with iron (Lynch, 1997:103).

The beneficial effect of ascorbic acid can be completely erased by cooking at high temperatures or prolonged warming, because it may lead to the oxidation of the vitamin – the extent of destruction will be determined by the time and method of food preparation (Lynch, 1997:103; Rossander-Hulthen & Hallberg, 1996:108). Even with prolonged warming of food at a low temperature there is destruction of ascorbic acid (Rossander-Hulthen & Hallberg, 1996:108).

Cook and Reddy (2001) examined the importance of dietary ascorbic acid in iron balance. This was done by measuring non heme iron absorption from a complete diet. The results found that the effect of ascorbic acid on iron absorption has been exaggerated by measuring absorption from single meals only. The mechanism for this occurrence is unknown. One explanation can be that residual gastric contents from meals throughout the day dampen the influence of dietary factors compared to fasting subjects. Another possibility can be that the biochemical composition of the diet consumed over a five day period is much greater and more varied than with an isolated meal (Cook & Reddy, 2001:96-97).

Animal protein

Meat, fish and poultry have an enhancing effect on non heme iron absorption (Zijp et al., 2000:377). The specific factor in animal protein sources responsible for this enhancement has not been identified. This effect is not shared by proteins derived from plant material, eggs, milk or cheese (MacPhail, 1998:141). Individual amino acids may play a role in the enhancing effect (West, 1996:5).

It has been further suggested that peptides rich in the amino acid, cysteine, may play an important role (MacPhail, 1998:141).

Meat promotes iron nutrition in two ways:

(1) it stimulates non heme iron absorption

(2) it provides the well absorbed heme iron (Zijp et al., 2000:377).

It seems that further work is needed on this subject to form a clear picture.

Fermented products and organic acids

According to Rossander-Hulthen and Hallberg (1996:108), lactic acids as well as other organic acids are produced during the fermentation process of the cabbage, with a lowered pH and activated phytase as a result. All vegetables associated with good iron bioavailability contain one or more of the following organic acids: citric, malic or ascorbic acids (Lynch, 1997:103).

2.7 Summary

Consistent evidence from test meal studies suggests that tea drinking inhibits the absorption of non heme iron (Nelson & Poulter, 2004:52). There is a variety of factors that should be considered when investigating these results, for example, the iron status of the individual at the time of the experiment. It is known that iron deficient subjects absorb more iron from food than subjects with sufficient iron stores (Zijp et al., 2000:374). It is, therefore, important to stipulate the number of iron deficient subjects to be able to control the study for iron deficient subjects.

In the summary of studies done on the effect of tea consumption on iron status (Table 2.3), five of the six studies indicated a definite inhibitory effect of tea on iron absorption. The study by Root et al. (1999:204) shows no significant

association between tea consumption and iron status, before or after adjusting for survey count. This result can possibly be ascribed to the fact that statistically significant correlates (such as very high tea intake or the dietary form of iron) were not included in the analysis of data. This study also had a low incidence of iron deficient subjects.

The study by Razagui et al. (1991:337) examined the iron status of 15 mentally handicapped, menstruating women by evaluating the relationship between tea consumption and iron status. The subjects with depleted iron stores had a significantly lower vitamin C intake and a higher tea intake during meals (563ml/meal/day). It is also noted that in all of the studies examined the amount of tea ingested differed, suggesting that the strength of the tea does not have an impact on the degree of inhibition.

It can be deduced from these studies that a possible association between tea consumption and iron status exists. Further, when investigating the results of a study by Razagui et al. (1991:338) and the fact that iron deficient subjects absorb more iron from food than subjects with sufficient iron, the conclusion can be made that in populations with inadequate diets, iron bioavailability can be reduced by (1) inadequate content of iron in the diet and (2) an inadequate amount of ascorbic acid (or inadequate intake of any other enhancer of iron absorption) in the diet.

It is, however, important to keep in mind that these studies (Table 2.3) were done in a controlled environment, where factors affecting iron status could be controlled.

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Chapter 3

The association between black tea consumption and iron status of African women in the North West Province: THUSA study

Chapter 3: The association between black tea consumption and iron status of African women in the North West Province: THUSA study

3.1 Abstract

Objectives. To investigate the association between black tea consumption and iron status of African women in the North West Province: THUSA study.

Design. A sub-study done as part of the cross sectional THUSA study. Subjects were grouped into five levels of urbanisation namely (1) rural people living in traditional African villages with a tribal head, (2) farm workers, (3) subjects living in informal housing areas, (4) volunteers from established urban townships, (5) upper class urban subjects consisting of professional people.

Setting. North-West province.

Subjects. A sample of 920 women was used which were further divided into younger women (< 45.9 years) and older women (> 46 years).

Outcome measures. Haemoglobin and serum ferritin.

Results. The results of this study suggest that tea and a variety of other dietary factors have no association with iron status. It was, however, found that the population had an intake below the AI for fibre, animal protein, calcium and below the RDA for iron and ascorbic acid. There were also a variety of factors which were not controlled in the study, for example, time of tea intake.

Conclusion. No association exist between tea consumption and iron status.

3.2 Introduction

Iron deficiency is a highly prevalent nutritional disorder in developing countries.[1,2,3] Iron deficiency is not only a problem of developing countries, but this deficiency affects billions of people worldwide, including 370 million women of childbearing age.[4] Women of menstruating age are especially at risk due to

menstrual losses leading to increased iron requirements. In a review done by Vorster et al.[5] of studies done on nutritional status in South Africa, it was found that vulnerable groups for iron deficiency, with an iron intake less than 67% of RDA, were rural black children and women aged 16 – 65 years.

A variety of factors can play a role in iron status such as low intake of food rich in bioavailable iron, for example, meat. Low intake of food with an enhancing effect on iron absorption such as ascorbic acid can also aggravate iron deficiency.[2,6]

The human diet contains a variety of polyphenol containing compounds for example tea, coffee, red wine and cocoa. Besides water, tea at an intake of 120ml/day is the most popular consumed beverage worldwide.[7] These polyphenol containing compounds are released during digestion and form complexes with iron in the lumen, reducing non heme iron bioavailability by forming insoluble complexes.[8,9,10]

The purpose of this study was, therefore, to investigate the association between tea consumption and iron status of African females in the North West Province. The main study – THUSA (which means 'help' in setswana and is an acronym for Transition and Health during Urbanization of South Africans) investigated the known risk factors for non-communicable diseases (NCD's) and the determinants which affect these risk factors at different stages of urbanization. The THUSA study was a cross-sectional study conducted from 1996 – 1998 in apparently healthy male and female volunteers.[11] The volunteers were stratified for age, gender and stratum.

Detailed information about the THUSA study has been published by Vorster et al.[11]– see addendum 1.

To investigate the association between tea consumption and iron status, more specific aims were formulated, namely:

- ✓ To describe the iron status of younger (< 45.9 years) and older (> 46 years) women using haemoglobin and serum ferritin as markers of iron status
- ✓ To describe the tea intake of younger (< 45.9 years) and older (> 46 years) women
- ✓ To determine the relationship between tea consumption and iron status, taking into account inhibiting and enhancing factors of iron absorption

3.3 Methods

3.3.1 Subjects

A cross-sectional sample of apparently healthy females was taken from five different strata of urbanisation. The subjects were then further divided into two age groups, namely younger women (younger than 45.9 years) and older women (older than 46 years). A sample of 920 subjects was used. The following exclusion criteria were used in the study:

- ✓ Pregnant and lactating women
- ✓ Subjects known to suffer from any disease (infectious or NCD's)
- ✓ Subjects using any form of chronic medication (many hypertensive subjects were excluded because of this criterion)
- ✓ Subjects younger than 15 and older than 65 years
- ✓ Inebriated subjects

- ✓ Subjects suffering from epilepsy and mental diseases or defects.[11]
- ✓ HIV+ subjects (for this part of the study).

3.3.2 Organizational procedure

For the complete procedure of the THUSA study see Addendum 1.[11] During the procedure each subject had to visit eight stations where information on socio-economic status, dietary intake and other data were collected. All questionnaires were completed by a trained fieldworker *via* the interview method. Interviews were conducted in the respondents' mother tongue and then completed on the relevant questionnaire. Data were gathered using the following questionnaires and used in the study:

Demographic Questionnaire:

During individual interviews using the demographic questionnaire, information on age, home language, medical history, prevalence of NCD's in other family members, smoking habits, alcohol intake, household income, type of housing, education level and occupation were obtained. Information on source of water, electricity and sanitation was also obtained.

Dietary questionnaire

A standardised quantitative food frequency questionnaire (QFFQ) was used to determine usual food intake of the subjects as well as the amount consumed. The level of acculturation, meal frequency and where meals were eaten, alcohol intake and snacking habits were also evaluated. Quantities eaten were assessed by showing actual food items of different sizes, the use of food photographs of different portions and showing actual food utensils. The reported nutrient intakes were then coded and analysed by an experienced dietician using a computer programme (Food Finder®) based on the South African Food Composition Tables.[11,12]

Additional questionnaires

A questionnaire assessing food insecurity was completed by the subjects.[11] Additional information relating to reproductivity such as type of contraceptive used, age of menarche and number of children was obtained in an additional questionnaire, completed by women only.[11]

Blood samples

Samples of blood were drawn from the *vena cephalica* using a sterile butterfly infusion set (Johnson & Johnson, 21G, 19 mm) and syringes. For the preparation of serum 50 ml of blood was allowed to clot in glass tubes, centrifuged at 3000 rpm for 15 minutes and transferred to 30 x 1 ml *Eppendorf* tubes. Hematocrit was determined by using a capillary tube and centrifuge and haemoglobin was determined by using the cyanmethaemoglobin method. Iron, ferritin, transferrin saturation and total iron binding capacity were determined by standard methods described by Vorster et al.[11]

3.3.3 Statistical analysis

- ✓ Descriptive statistics were calculated namely means, standard deviations and median values for the younger and older women.
- ✓ Spearman correlation coefficient were calculated between haemoglobin and serum ferritin for the following dietary intake variables:
    - Dietary fibre
    - Animal protein
    - Calcium
    - Ascorbic acid
    - Iron

- Total milk intake
- Bread (brown and white)
- Other cereal
- Tea

✓ Difference in frequency distributions of

- Younger and older women
- High and low haemoglobin
- High and low serum ferritin

✓ Test for significant differences between haemoglobin or serum ferritin and a variety of dietary intake variables

3.3.4 Ethical considerations

The Ethics Committee of the Potchefstroom University (PU) approved the study (Project number: HH4M5/95). Subjects had to sign an informed consent form, giving permission to draw blood samples. In many instances subjects were illiterate and signed with a cross.[11]

3.4 Results

A total of 920 subjects were interviewed. The distribution of the 920 subjects between younger and older women can clearly be seen in Figure 3.1. Due to missing data (unavailable blood samples and questionnaires), the number of subjects for each parameter differed. Table 3.1 shows that the mean haemoglobin and serum ferritin values for younger and older women as a group fall within the normal ranges. The median value for haemoglobin was also within normal ranges, but the median value for serum ferritin was lower than the mean.

The median value for dietary iron intake of the group as a whole was low (7.90mg/day) when compared with the RDA of 18mg.

Table 3.1 Dietary intakes and characteristics of the study population

Variable	RDA and normal values	N*	Mean	Median	Lower Quartile	Upper Quartile	Standard deviation
Age (years)	-	920	38.19	37.00	27.00	49.00	14.34
Dietary fibre (g)	-	896	16.25	15.10	10.65	20.70	7.51
Animal protein (g)	-	896	26.95	23.60	15.30	34.85	16.05
Dietary calcium (mg)	-	896	407.63	357.50	237.00	516.00	245.81
Dietary iron (mg)	Range 8 – 18mg/day	896	8.51	7.90	5.60	10.60	4.08
Dietary ascorbic acid (mg)	-	894	38.76	25.00	15.00	46.00	41.97
Milk (portion)	-	879	0.71	0.49	0.22	0.96	0.72
Bread (portion)	-	879	2.73	2.10	1.14	3.68	2.35
Other cereals (portion)	-	879	0.96	0.43	0.14	1.02	2.02
Tea (g)	-	630	436.74	300.00	220.00	600.00	297.21
Haemoglobin (mg/L)	Normal ≥ 12mg/L (FAO/WHO, 2001:204)[13]	899	12.22	12.10	11.00	13.20	2.12
Serum ferritin (ug/L)	Normal 40 – 160 ug/L (FAO/WHO, 2001:204)[13]	894	87.81	42.42	18.47	96.50	166.53

N*: Due to missing data the number of subjects for each parameter tested differed. RDA of iron for different age groups 14-18 years = 15mg/day, 19-30 years = 18mg/day, 31-50 years = 18mg/day, 51-70 years = 8mg/day, >70 years = 8mg/day. (RDA = recommended daily allowance)

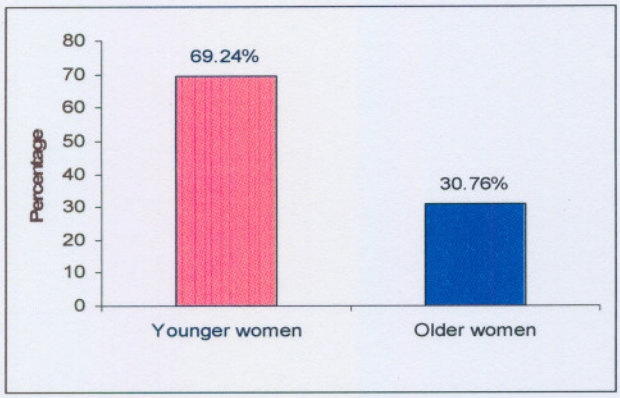

Figure 3.1 Percentage women in younger and older groups

Table 3.2 Dietary intakes and characteristics of younger and older women

		Older women (> 46 years)			Younger women (< 45.9 years)		
Variable	**RDA and normal values**	**N***	**Mean**	**Standard deviation**	**N***	**Mean**	**Standard deviation**
Age (years)	-	283	55.75	7.95	637	30.39	8.43
Dietary fibre (g)	-	275	14.95	7.16	621	16.82	7.60
Animal protein (g)	-	275	23.43	14.10	621	28.51	16.62
Dietary calcium (mg)	-	275	391.10	246.77	621	414.96	245.22
Dietary iron (mg)	Range 15 – 18mg/day	275	7.92	4.12	621	8.77	4.04
Dietary ascorbic acid (mg)	-	274	31.56	34.97	620	41.94	44.38
Milk (portion)	-	272	0.73	0.77	607	0.70	0.69
Bread (portion)	-	272	2.62	2.14	607	2.78	2.44
Other cereals (portion)	-	272	0.99	2.45	607	0.95	1.80
Tea (g)	-	210	453.45	312.68	420	428.39	289.18
Haemoglobin (mg/L)	Normal ≥ 12mg/L	273	12.48	2.59	626	12.10	1.87
Serum ferritin (µg/L)	Normal 40 – 160µg/L	276	151.67	254.95	618	59.28	92.35

N*: Due to missing data the number of subjects for each parameter tested differed. RDA of iron for different age groups 14-18 years = 15mg/day, 19-30 years = 18mg/day, 31-50 years = 18mg/day, 51-70 years = 8mg/day, >70 years = 8mg/day. (RDA = recommended daily allowance)

Clear comparisons between the younger and older groups (Tables 3.2) were found. The haemoglobin and serum ferritin values were within the normal ranges for both groups although haemoglobin was very near the cut off point of 12 mg/L for both groups. The mean serum ferritin concentrations for the younger group (59.28 +/- 92.35µg/L) were lower compared with the older group (151.67 +/- 254.95µg/L), but this is not significant due to the high standard deviation of the older group. The mean dietary intake of iron for older women was slightly below the dietary recommendations at 7.92 +/- 4.12mg/day for the age group. For this study, older women were classified as being older than 46 years, four years younger than the RDA used in Table 3.2.

The mean dietary iron intake of the younger women was also below the dietary recommendations at 8.77 +/- 4.04mg/day for the age group. Although the older women were significantly less than the younger women the mean dietary intake for both groups did not significantly differ. The mean dietary intake of other nutrients for both the younger and older women will be discussed later. For both the younger and older women the subjects with available data for tea intake were fewer than the other dietary factors. This can possibly be attributed to subjects' not consuming tea.

Table 3.3 Spearman correlation coefficients between haemoglobin and serum ferritin respectively and dietary variables for the study population

	Total group (n = 580)		Older women (n = 190)		Younger women (n = 390)	
Variable	**Haemoglobin (mg/L)**	**Serum ferritin (µg/L)**	**Haemoglobin (mg/L)**	**Serum ferritin (µg/L)**	**Haemoglobin (mg/L)**	**Serum ferritin (µg/L)**
Dietary fibre (g)	-0.00	-0.01	-0.08	0.06	0.06	-0.02
Animal protein (g)	-0.07	-0.01	-0.09	-0.03	-0.03	0.08
Dietary calcium (mg)	0.03	0.04	0.00	-0.02	0.06	0.12
Dietary iron (mg)	-0.01	0.02	-0.12	0.11	0.08	-0.03
Dietary ascorbic acid (mg)	-0.01	-0.05	-0.08	-0.06	0.04	-0.00
Milk (portion)	0.03	0.05	0.03	-0.04	0.02	0.15
Bread (portion)	-0.04	0.03	-0.10	0.12	-0.02	-0.05
Other cereals (portion)	0.04	-0.07	0.03	-0.13	0.05	-0.04
Tea (g)	-0.01	0.02	-0.06	-0.04	0.02	0.07

(Results were considered to be significant at $p<0.05$)

Table 3.3 shows no significant correlation between a variety of dietary variables and haemoglobin or serum ferritin for both the younger and older women. Specifically no correlation was seen between total tea intake and either haemoglobin or serum ferritin. When divided into groups there was no significant correlation between the dietary variables and haemoglobin or serum ferritin for the older group (Table 3.3).

In the younger group there was also no significant correlation between the variables and haemoglobin or serum ferritin. For both the younger and older groups, total tea intake was not associated with haemoglobin or serum ferritin.

Table 3.4 Comparison of mean dietary intakes and standard deviations for the study population (younger and older women) with haemoglobin ≥ 12 or < 12 as well as a comparison of dietary intakes with RDA and AI

			Group 1 (high = HB ≥ 12mg/L)			Group 2 (low = HB < 12mg/L)			
Variable	**RDA**	**AI**	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**P-values**
Dietary fibre (g)	-	Range 21 – 26g/day	448	16.04	7.42	429	16.46	7.67	NS
Animal protein (g)	14 – 18 years = 0.85g/kg/day 19+ years = 0.80g/kg/day	-	448	25.97	15.29	429	28.10	16.84	0.05
Dietary calcium (mg)		Range 1000 - 1300mg/day	448	406.24	243.11	429	409.56	249.63	NS
Dietary iron (mg)	Range 8 – 18mg/day	-	448	8.44	4.27	429	8.57	3.91	NS
Dietary ascorbic acid (mg)	Range 65 – 75mg/day	-	447	35.93	34.21	428	42.00	49.15	0.03
Milk (portion)	-	-	438	0.72	0.72	424	0.70	0.72	NS
Bread (portion)	-	-	438	2.58	2.08	424	2.86	2.62	NS
Other cereals (portion)	-	-	438	0.99	2.34	424	0.89	1.37	NS
Tea (g)	-	-	322	436.25	290.68	294	439.43	307.20	NS

NS = non significant ($p < 0.05$ is significant) (older > 46 years and younger < 45.9 years). AI of dietary fibre for different age groups 14-18 years = 26g/day, 19-30 years = 25g/day, 31-50 years = 25g/day, 51-70 years = 21g/day, >70 years = 21g/day. AI of dietary calcium for different age groups 14-18 years = 1300mg/day, 19-30 years = 1000mg/day, 31-50 years = 1000mg/day, 51-70 years = 1200mg/day, >70 years = 1200mg/day. RDA of iron for different age groups 14-18 years = 15mg/day, 19-30 years = 18mg/day, 31-50 years = 18mg/day, 51-70 years = 8mg/day, >70 years = 8mg/day. RDA of dietary ascorbic acid for different age groups 14-18 years = 65mg/day, 19-30 years = 75mg/day, 31-50 years = 75mg/day, 51-70 years = 75mg/day, >70 years = 75mg/day. (RDA = recommended daily allowance and AI = adequate intake)

In Table 3.4 the group with a low haemoglobin concentration (Group 2) showed a slightly higher animal protein intake (p = 0.05) than the group with a high haemoglobin concentration (Group 1). A significant difference was seen for ascorbic acid intake between the two groups (35,9mg for the group 1 versus 42mg for group 2), but this difference is not clinically important. For both groups the ascorbic acid intake was below the RDA (65 – 75mg/day). Furthermore, it can be seen that both groups had a medium to low intake of all the nutrients – the mean intakes of nutrients for both groups were well below the RDA.

Table 3.5 Comparison of mean dietary intakes and standard deviations for older women (between HB ≥ 12 or HB < 12)

	Group 1 (high = HB ≥ 12mg/L)			Group 2 (low = HB < 12mg/L)			
Variable	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**P-value**
Dietary fibre (g)	149	14.41	7.05	116	15.50	7.51	NS
Animal protein (g)	149	22.00	13.02	116	25.13	15.46	0.075
Dietary calcium (mg)	149	385.46	246.82	116	400.64	252.53	NS
Dietary iron (mg)	149	7.62	4.40	116	8.20	3.81	NS
Dietary ascorbic acid (mg)	148	27.82	27.84	116	36.64	43.11	0.045
Milk (portion)	147	0.75	0.77	116	0.73	0.80	NS
Bread (portion)	147	2.39	2.04	116	2.83	2.27	0.096
Other cereals (portion)	147	0.97	2.75	116	0.81	1.05	NS
Tea (g)	116	436.93	291.26	86	487.37	344.17	NS

*NS = non significant (p < 0.05 is significant) (older > 46 years)

In Table 3.5 the data for older women was divided into high (Group 1) and low (Group 2) haemoglobin concentration groups. As in Table 3.4, the group with a low haemoglobin concentration showed a significantly different ascorbic acid intake (p = 0.045), from the group with a high haemoglobin concentration. But this is not clinically important, because both groups had mean intakes below the RDA of 65 – 75mg/day.

The group with a low haemoglobin concentration showed a tendency of a higher animal protein intake than the group with high haemoglobin values (p = 0.075). A tendency of a difference can be seen between bread intake (p = 0.096) of the low haemoglobin concentration (p > 0.05 but < 0.1) compared with the high haemoglobin concentration group.

Table 3.6 Comparison of mean dietary intakes and standard deviations for younger women (between HB ≥ 12 or HB < 12)

	Group 1 (high = HB ≥ 12mg/L)			Group 2 (low = HB < 12mg/L			
Variable	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**P-value**
Dietary fibre (g)	299	16.86	7.48	313	16.81	7.72	NS
Animal protein (g)	299	27.94	15.96	313	29.19	17.22	NS
Dietary calcium (mg)	299	416.60	240.98	313	412.86	248.87	NS
Dietary iron (mg)	299	8.85	4.15	313	8.71	3.94	NS
Dietary ascorbic acid (mg)	299	39.94	36.34	312	43.99	51.14	NS
Milk (portion)	291	0.70	0.69	308	0.69	0.70	NS
Bread (portion)	291	2.67	2.10	308	2.87	2.73	NS
Other cereals (portion)	291	1.00	2.11	308	0.92	1.48	NS
Tea (g)	206	435.87	291.06	208	419.61	289.12	NS

NS = non significant (p < 0.05 is significant) (younger < 45.9 years)

In Table 3.6 the data for younger women was divided into high and low haemoglobin concentration groups. In this group no statistically significant differences were seen between the different nutrient intakes for the high or low haemoglobin concentration groups. Tea was not significantly associated with haemoglobin concentrations in the younger and older women (Tables 3.5 and 3.6).

Table 3.7 Comparison of mean dietary intakes and standard deviations for the study population (younger and older women) with serum ferritin > 12 or < 12 as well as a comparison of dietary intakes with RDA and AI

			Group 1 (high = S ferritin > 12µg/L)			Group 2 (low = S ferritin < 12µg/L)			
Variable	**RDA**	**AI**	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**P-values**
Dietary fibre (g)	-	Range 21 – 26g/day	736	16.23	7.57	136	16.37	7.41	NS
Animal protein (g)	14 – 18 years = 0.85g/kg/day 19+ years = 0.80g/kg/day	-	736	27.00	16.02	136	24.92	14.20	NS
Dietary calcium (mg)	-	Range 1000 – 1300mg/day	736	405.98	245.70	136	400.10	216.33	NS
Dietary iron (mg)	Range 8 – 18mg/day	-	736	8.45	4.10	136	8.64	3.96	NS
Dietary ascorbic acid (mg)	Range 65 – 75mg/day	-	734	38.41	42.14	136	39.35	42.50	NS
Milk (portion)	-	-	722	0.71	0.73	135	0.69	0.64	NS
Bread (portion)	-	-	722	2.71	2.20	135	2.94	3.14	NS
Other cereals (portion)	-	-	722	0.98	2.15	135	1.00	1.36	NS
Tea (g)	-	-	514	436.27	291.03	100	449.27	329.56	NS

NS = non significant ($p < 0.05$ is significant) (Older > 46 years and younger < 45.9 years). AI of dietary fibre for different age groups 14-18 years = 26g/day, 19-30 years = 25g/day, 31-50 years = 25g/day, 51-70 years = 21g/day, >70 years = 21g/day. AI of dietary calcium for different age groups 14-18 years = 1300mg/day, 19-30 years = 1000mg/day, 31-50 years = 1000mg/day, 51-70 years = 1200mg/day, >70 years = 1200mg/day. RDA of iron for different age groups 14-18 years = 15mg/day, 19-30 years = 18mg/day, 31-50 years = 18mg/day, 51-70 years = 8mg/day, >70 years = 8mg/day. RDA of dietary ascorbic acid for different age groups 14-18 years = 65mg/day, 19+ = 75mg/day (RDA = recommended daily allowance and AI = adequate intake)

Table 3.7 shows no statistically significant difference between the intake of different nutrients of women with high or low serum ferritin concentration. As in Table 3.4, there are low intakes of all nutrients, when compared to the RDA and AI's. When divided into younger and older groups (Tables 3.8 and 3.9) no statistical significant differences can be seen between the different nutrients of women with a high or low serum ferritin concentration.

Table 3.8 Comparison of mean dietary intakes and standard deviations for older women (between women with serum ferritin > 12 or serum ferritin < 12)

	Group 1 (high = S ferritin ≥ 12µg/L)			Group 2 (low = S ferritin < 12µg/L)			
Variable	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**P-value**
Dietary fibre (g)	250	14.97	7.29	18	15.06	6.54	NS
Animal protein (g)	250	23.43	13.88	18	23.72	17.79	NS
Dietary calcium (mg)	250	389.46	252.62	18	448.78	185.45	NS
Dietary iron (mg)	250	7.88	4.22	18	8.34	3.30	NS
Dietary ascorbic acid (mg)	249	30.84	33.49	18	43.22	55.39	NS
Milk (portion)	247	0.73	0.79	18	0.89	0.68	NS
Bread (portion)	247	2.64	2.20	18	2.28	1.52	NS
Other cereals (portion)	247	0.98	2.55	18	1.34	1.17	NS
Tea (g)	190	447.49	312.94	14	588.57	298.69	NS

NS = non significant ($p < 0.05$ is significant) (older women > 46 years)

The older group with low serum ferritin was considerably smaller (N = 18) than the group (N = 250) with higher serum ferritin levels. The group with low serum ferritin values (Group 2) had fewer subjects than the group with high serum ferritin values (Group 1) for tea intake. This can possibly be explained by less people in group 2 drinking tea than in group 1. There was, however, no significant difference between tea intake of low and high serum ferritin groups. In Table 3.9 the group with high serum ferritin concentration had a statistically significant higher animal protein intake than the group with low serum ferritin concentration ($p = 0.03$). No other statistically significant differences were found.

Table 3.9 Comparison of mean dietary intakes and standard deviations for younger women (between women with serum ferritin ≥12 or serum ferritin < 12)

	Group 1 (high = S ferritin ≥ 12µg/L)			Group 2 (low = S ferritin < 12µg/L)			
Variable	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**P-value**
Dietary fibre (g)	486	16.89	7.64	118	16.57	7.54	NS
Animal protein (g)	486	28.83	16.73	118	25.10	13.65	0.03
Dietary calcium (mg)	486	414.48	241.89	118	392.67	220.41	NS
Dietary iron (mg)	486	8.74	4.02	118	8.68	4.06	NS
Dietary ascorbic acid (mg)	485	42.30	45.50	118	38.76	40.44	NS
Milk (portion)	475	0.70	0.70	117	0.66	0.63	NS
Bread (portion)	475	2.74	2.20	117	3.04	3.32	NS
Other cereals (portion)	475	0.98	1.91	117	0.94	1.38	NS
Tea (g)	324	429.69	277.66	86	426.59	330.36	NS

NS = non significant (p < 0.05 is significant) (Younger women < 45.9 years)

3.5 Discussion

The 920 subjects included in the study were all human immunodeficiency virus (HIV) negative. The reason for the exclusion of HIV+ subjects is that the haemoglobin concentration does not give an accurate view of these subjects' iron status. This is due to the fact that iron excretion will increase because of the HIV infection altering iron metabolism and thus leading to false results.[14] The mean dietary iron intake for the group as a whole was below recommendations for the younger women but within recommendations for the older women, but the median dietary iron intake was below recommended values for both groups.

The results for the study were obtained by dietary questionnaires, blood samples, demographic and other questionnaires. It is, however, important to remember that information from the dietary questionnaires as well as the other questionnaires is not sufficient to determine the proportion of the population at risk for iron deficiency. Individuals will adapt to poor dietary intakes by increasing their rate of absorption and by using body stores.[15] Therefore blood samples

were taken to obtain biochemical measures. The cut off point used to determine low concentrations for serum ferritin was < 12µg/L and for haemoglobin 12mg/L.[13]

Haemoglobin measurements are the most commonly used method to determine iron status. The measurement is, however, affected by a variety of factors, for example, smoking.[16] Serum ferritin on the other hand is a very sensitive indicator. A low serum ferritin level will reflect low iron stores in the body almost immediately, increasing drastically with a variety of factors, for example, alcohol intake. The serum ferritin concentrations are also relatively stable in healthy persons.[16] For these reasons it was necessary to use both the haemoglobin and serum ferritin concentrations of the population. In some circumstances where the serum ferritin value was unavailable, haemoglobin would be used and vice versa.

Furthermore, the mean serum ferritin and haemoglobin concentrations of both the younger and older women were within normal ranges (Table 3.1), indicating an acceptable iron status. However, the median serum ferritin value of both the younger and older women as a group was significantly lower than the mean serum ferritin value, although it still fell within the normal ranges. This gives an indication that although the group as a whole had an adequate mean serum ferritin concentration, the values of certain individuals were lower than that achieved by the rest of the group. This lower value obtained by individuals can be attributed to a long term diet low in non-heme iron which will then lead to adaptation to maintain body iron stores.[17]

In a study by Galan et al.[18] it was seen that serum ferritin will decrease with an increasing duration of menses. In older women menses do not occur and that can affect the mean serum ferritin value. This is also further supported when looking at the mean serum ferritin for the individual groups (Tables 3.2). The mean concentration for both groups fall within the normal ranges. However the mean serum ferritin value for the younger group (59.28 +/- 92.35µg/L) was lower than the older group (151.67 +/- 254.95µg/L), but this is not significant due to the high standard deviation in the older group.

No significant correlations were seen between a variety of dietary factors and either haemoglobin or serum ferritin concentrations for the women as a group or for the younger and older women separately. According to these results, it may seem that tea and the other dietary factors are not important determinants of iron status. The studies by Doyle et al.[19] and Root et al.[20] also found that tea intake was not associated with iron status. In the present study as well as both of the previously mentioned studies, the subjects were free living, information was obtained by using dietary questionnaires and blood samples and factors like the time of consumption of tea was not controlled. In the present study, the iron status of the women as well as the consumption of milk with tea and time of tea consumption was not controlled.

Some studies that showed an inhibitory effect of tea on iron absorption were also found. In these studies, however, subjects received test meals or dietary factors were controlled. In the study by Brune et al.[8] subjects received a test meal to which the phenolic compounds were added. Subjects in the study by Disler et al.[9] drank either a solution of iron compound or ate a test meal after an overnight fast. The study by Hurrell et al.[10] also gave a test meal to subjects. When comparing these results it is clear that, studies done in a controlled environment showed a definite inhibitory effect between tea drinking and iron status. This is contrary to studies done in a non-controlled environment such as the present study as well as the studies by Doyle et al.[19] and Root et al.[20] Therefore the conclusion can be made that an association between regular tea drinking and iron status may exist, but this effect may not be that important to subjects that are free living and consuming a diet of their own choice. It seems that the association may only exist if subjects consume a test meal at certain times; therefore, further studies seem necessary.

The mean dietary intakes of the population (for low and high haemoglobin concentrations) of fibre, animal protein, calcium, dietary iron and ascorbic acid were below recommended values. As in the study by Mehta et al.[21] where demographic factors like sex, race and education level played an important role in iron status, these factors as well as poverty and lack of food might have played

a role in the present study. The low intake of ascorbic acid can possibly be attributed to lack of knowledge and socioeconomic status.[11]

The group with a low haemoglobin concentration showed a slightly higher intake of animal protein ($p = 0.05$) than the group with a high haemoglobin concentration (Table 3.4). A significant difference was seen for ascorbic acid intake ($p = 0.03$), but this was not clinically important and for both groups far below the RDA. A possible explanation for this might be that the QFFQ is not sensitive enough to accurately measure differences between the two groups.

When dividing the group into younger and older women, a statistically significant difference can be seen between ascorbic acid intake of the low and high haemoglobin groups for older women. The animal protein and bread intake tended to show statistically significant differences. This is however not clinically important, due to the fact that the intake of ascorbic acid as well as the animal protein were below the RDA.

No statistically significant differences were found between either low or high haemoglobin concentration or a variety of dietary factors for the younger women. There were also no statistically significant differences between either high or low serum ferritin concentration group for a variety of dietary factors for younger and older women as a group or the older women. The group with a high serum ferritin concentration showed a significantly higher intake of animal protein ($p = 0.03$) than the group with a low serum ferritin concentration (Table 3.9). Therefore, the group with high serum ferritin concentration had a higher animal protein intake than the group with a low serum ferritin concentration. This can be an indication that in younger women animal protein is important for iron status, because of blood loss due to menstruation and giving birth. Thus making younger women more susceptible to iron deficiency.

3.6 Conclusion

The results of this study indicated that the iron status of both the younger and older women was generally satisfactory, although the intake of a variety of dietary factors was below recommended values. The results also further indicated that total tea intake was not associated with iron status. Investigation of other studies done on the effect of tea consumption on iron status showed mixed results but had different methods. Most studies were done in a controlled environment, giving subjects test meals, timing tea intake, etc. This study had a few shortcomings, for example, (1) the time of tea intake in relation to meal intake was not determined, and (2) the data did not provide information on the intake of milk with tea (as well as other enhancers and inhibitors of iron status). When keeping the shortcomings of this study in mind, as well as the different methods used for other studies, the conclusion can be made that no association exist between tea consumption and iron status. Other factors for example animal protein intake seemed to play a more important role than tea consumption on iron status. Therefore, it seems important that further studies (in a controlled environment) on this topic, especially in the South African population are necessary.

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Chapter 4

General summary, recommendations and conclusions

Chapter 4: General summary, recommendations and conclusions

4.1 Introduction

Poor absorption of iron is one of the most important causes of iron deficiency, a major nutritional problem worldwide. This deficiency mostly affects children and women of childbearing age. An estimated one third of the two thirds of children and women thought to suffer from iron deficiency will also suffer from iron deficiency anaemia (MacPhail et al., 2004:13). As shown in Chapter 2, this deficiency has multiple and severe consequences which include lowered work capacity, heart failure, mental changes and pregnancy prematurity, low birth weight and increased perinatal mortality (Ross, 2002:220; Hallberg, 2001:13; MacPhail, 2004:12).

Furthermore, iron deficiency can also be caused by (1) low intake of food rich in bioavailable iron, or (2) high intake of food with an inhibitory effect on iron absorption (Tapiero et al., 2001:325). This study specifically looked at one of these inhibitory substances, namely black tea. According to Zijp et al. (2000:379), black tea will have a 60 – 70% inhibitory effect when taken with a meal. In the study by MacIntyre (which was also a sub study of the THUSA study), tea was one of the most popular consumed beverages (MacIntyre 1998:359). From the seven studies investigated in Chapter 2 only two studies showed no inhibitory effect of regular tea drinking and iron status. These studies as well as the present study, however, had a few shortcomings.

4.2 Summary of main findings

In the present study no significant correlations were found between serum ferritin or haemoglobin and tea as well as a variety of other dietary factors. Indicating, therefore that no association were found between tea consumption and iron status. A possible explanation for this can be that the inhibitory effect of the tea was not strong enough to influence the iron status. It was also found that the studied population had a below recommended intake of a variety of dietary factors, for example, iron. Furthermore, for the younger and older women as a group as well as

the postmenopausal women, a slightly higher intake of animal protein for the low haemoglobin concentration was seen. The same was seen for ascorbic acid, but this is not clinically significant. When looking at the other indicator used, namely serum ferritin, it was seen that the high serum ferritin concentration group had a significantly higher animal protein intake ($p = 0.03$)

4.3 Limitations

The first significant potential shortcoming is that the time of tea consumption in relation to meal consumption could not be measured by the QFFQ in this study. According to Zijp et al. (2000:379) simultaneous consumption of black tea and iron containing food will have a 60 – 70% inhibitory effect. However other studies done on the effect of tea consumption on iron status had mixed results and different methods (Doyle et al., 1999:557; Root et al., 1999:204). In the present study only the mean amount of tea consumed by the population (436.74g) was investigated and not the time when the tea was ingested.

A second potential significant shortcoming is that in the present study there was no indication if tea was consumed with or without milk. Calcium has a dose dependent inhibitory effect on both heme and non heme iron absorption (MacPhail, 1998:141; Harris, 2002:232; Tapiero et al., 2001:328). It is suggested that the polyphenols in tea has a strong binding capacity to the proteins in milk which will then prevent the polyphenols from binding with iron (Hurrell et al., 1999:294). Calcium seems to have an inhibitory effect only in people who do not eat a varied diet. Seeing that the population as a whole had low intakes (below RDA) of a variety of dietary factors, it is possible that if milk was taken with tea, the results could have been affected.

4.4 Recommendations

It is recommended that more studies on the effect of tea consumption on iron status of the South African female population, in a controlled environment is needed. A controlled environment would include:

1. Test meals given to subjects to control their dietary intake

2. The time of tea intake in relation to meal consumption should be recorded, this is important seeing that the inhibitory effect of tea seems to be bigger when taken with food
3. It is also important to note whether tea was consumed with milk or not. Calcium is reported to have an inhibitory effect on iron absorption. If there is no indication whether tea was taken with milk or not, the conclusion cannot be made whether the tea or the calcium is responsible for the inhibitory effect
4. The time of ascorbic acid intake also needs to be mentioned. It is known that consumption of ascorbic acid with a meal will increase iron absorption. Therefore the amount of ascorbic acid consumed by the population is not good enough to draw the conclusion that the iron absorption will increase with ascorbic acid intake. It is necessary to know whether the ascorbic acid was taken with a meal.

Recommendations that can be made to the population to improve iron absorption:

1. Increase ascorbic acid intake with meals – this will improve iron absorption drastically
2. Drink tea between meals
3. Alternatively, when tea is consumed with a meal, also consume ascorbic acid and meat at the same time.

4.5 Conclusions

A variety of studies of the effect of tea consumption on iron status for other countries were found, but information about the South African female population was scarce. In Chapter 2, seven studies on the effect of regular tea drinking on iron status for other countries were investigated. Of these seven studies, only two studies showed no inhibitory effect of regular tea drinking on iron status. These two studies and the present study showed similarities. In all three studies the subjects did not receive a test meal and the time of tea intake was not controlled. The other five studies all gave subjects a test meal to create a homogenous study design and tea was administered to the diet at specific periods.

All of these factors contribute to affect the results of the study, for example studies have shown that simultaneous tea and iron consumption will have a greater inhibitory effect than between meal consumption, but these studies had very specific designs. Other studies had different outcomes and showed no effect of tea consumption on iron status. All of these studies were done in other countries. It, therefore, seems necessary to make the conclusion firstly that a study on the effect of tea consumption on iron status in a controlled environment is necessary and secondly in South Africa.

In the present study a decreased amount of a variety of dietary factors was observed. The decreased intake of these factors can lead to the deficiency of a variety of vitamins and minerals. The studies investigated in Chapter 2 more or less gave an indication of the number of iron deficient or anaemic subjects. In this study the younger and older women had sufficient dietary iron intake, however 429 subjects had a haemoglobin value < 12mg/L and 136 subjects had a serum ferritin concentration < 12µg/L. The iron status of the subjects could also affect the results seeing that iron deficient subjects will absorb more iron than healthy subjects.

Another study if done in a controlled environment can provide valuable information to the population concerning their nutritional status. An example would be to advise the population to drink tea between meals, increase their intake of ascorbic acid and if possible to increase their intake of meat, fish and poultry. To make these recommendations, scientific evidence is necessary and, therefore, further studies are needed.

Addendum 1

The impact of urbanization on physical, physiological and mental health of Africans in the North West Province of South Africa: the THUSA study

The impact of urbanization on physical, physiological and mental health of Africans in the North West Province of South Africa: the THUSA study

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We studied the impact of urbanization and the resultant demographic transition on the physical, physiological and mental health of Africans in the North West Province of South Africa in order to inform health policies and programmes. Thirty-seven randomly selected sites were investigated in rural and urban areas covering all the districts of the province. A cross-sectional comparison was made of a sample in terms of gender, age (15 years and older) and five levels of urbanization (deep rural tribal areas, farms, informal housing areas or squatter camps, established urban townships and 'upper' urban areas). A total of 1854 'apparently healthy' men, and non-pregnant and non-lactating African women without identified diseases and not taking chronic medication, were recruited. Demographic information, health history and behaviour, psychological profiles and dietary intakes were obtained during individual interviews in the language of the subject's choice, using culturally sensitive and validated questionnaires. Anthropometric and blood pressure measurements and a 2-hour glucose tolerance test with a 75-g glucose load were taken. Serum, citrated and EDTA plasma and blood cell samples were analysed for biochemical variables with enzymatic, colorimetric and immunological methods. Anonymous HIV testing was also done. The improved socioeconomic circumstances observed in the wealthiest urban areas were accompanied by superior nutritional status, lower mean blood pressure, better health behaviours (lower smoking, drinking and HIV infection rates), lower measures of all indices of psychological pathology and higher scores of psychological well-being. These subjects also had the highest fat intake and serum cholesterol levels. Farm workers were identified as the most vulnerable group, having inadequate diets, highest scores for psychological symptomatology and the lowest scores for psychological well-being. Subjects in the transitional groups had the highest blood pressures, greatest HIV infection rates, and smoked and drank more than other subjects. Obesity in women, hypertension and impaired glucose tolerance were observed in both rural and urban subjects. The data suggest that urbanization of Africans is associated with improved mental, physiological and physical health in the more affluent groups but that those in transition living in poverty on farms and in densely populated areas are experiencing a high risk of the double burden of diseases associated with undernutrition on the one hand and overnutrition on the other.

It is necessary to develop appropriate policies and strategies for the promotion of health and prevention and treatment of ill-health. Data on the health status of target populations, protective factors, and risk exposure amenable to intervention are needed.[1,2] South Africa is experiencing rapid urbanization, especially of Africans leaving underdeveloped rural areas to seek a better life in transition. In 1993, 48.3% of the South African population was urbanized, compared to 53.7% in 1996.[3] During this period the percentage of urbanized Africans increased from 35.8% to 43.3%, while there was a slight decrease in the figures for whites and only small increases in those for coloureds (mixed race) and Indians.[3]

Urbanization is associated with a health or epidemiological transition, with both detrimental and beneficial effects on health.[2,4-6] In many developing countries, the epidemiological transition is characterized by a decrease in infant mortality, fertility, and most infectious diseases and an increase in life expectancy and chronic diseases of lifestyle.[4-6]

Urbanization in developing countries, however, is not necessarily accompanied by industrialization and improved economic circumstances.[2] It can also lead to urban poverty and situations where behaviours which increase the risk of chronic diseases of lifestyle co-exist with raised exposure to infectious diseases, resulting in a 'double burden of disease'.[7]

Lack of baseline data on the impact of urbanization on health of Africans was the motive for the THUSA (Transition and Health during Urbanization in South Africa) study. *'Thusa'* is a Setswana word meaning 'help'. The aim of the study was to assess the effect of urbanization and the consequent demographic transition on health determinants and status of Africans in the North West Province. A conceptual framework was developed in which possible changes during urbanization guided decisions on which health determinants, indicators, risks and outcomes should be measured (Fig. 1). This led to a cross-sectional, multidisciplinary survey conducted from 1996 to 1998, in which health determinants and status as well as the underlying mechanistic relationships between these factors were measured in a sample of apparently healthy African men and women volunteers. In this paper, the design and methods of the THUSA study are described, and the impact of urbanization on health status is illustrated by comparing variables that reflect changes in socioeconomic background, health behaviours, risk factors for chronic diseases and health outcomes of rural and urban subjects.

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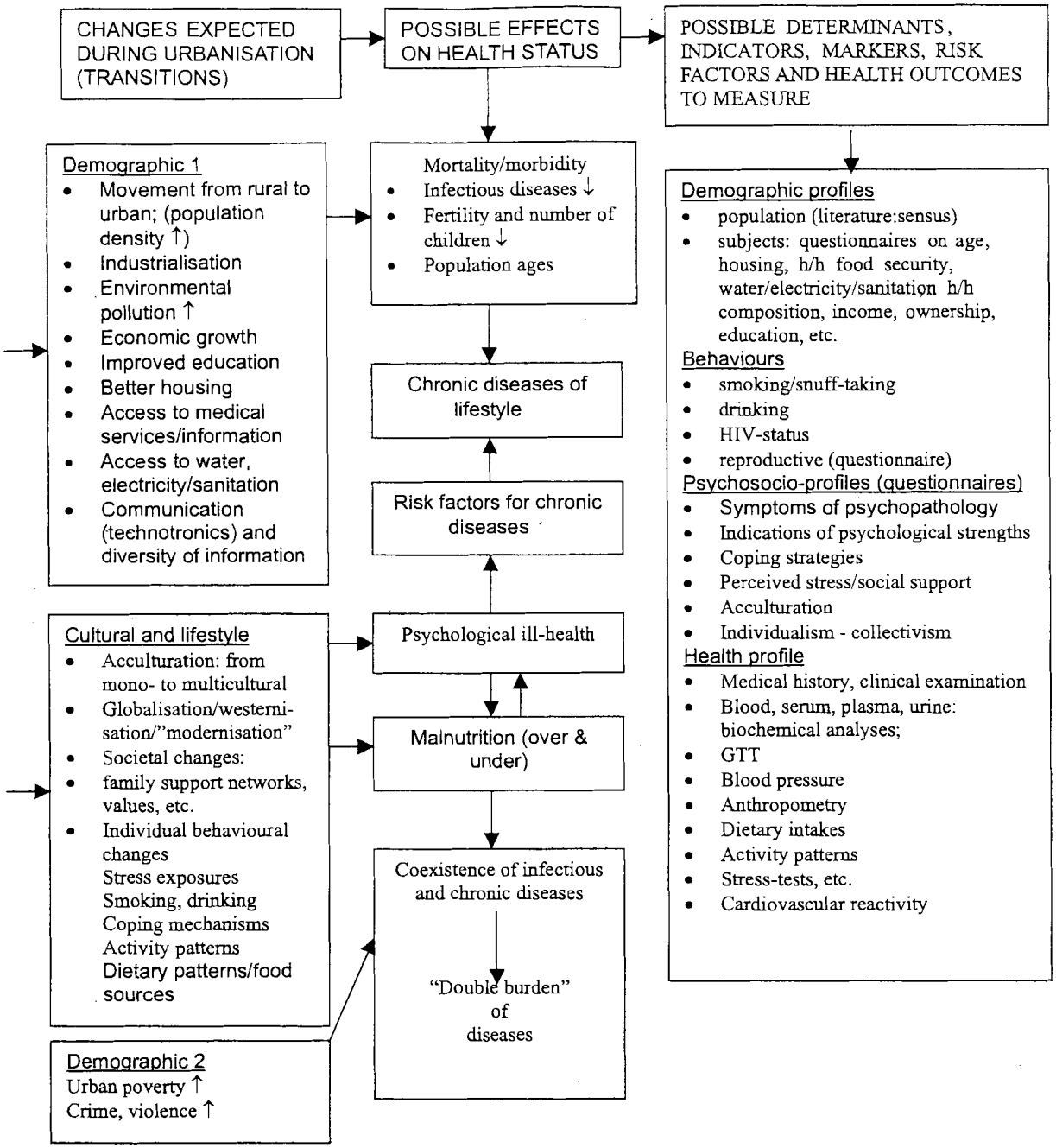

Fig. 1. Conceptual framework used to design the THUSA study (refs 1–7). GGT: glucose tolerance tests; ↓ decline; ↑ increase; h/h: household.

Methods

Study design and subject selection

The study involved a cross-sectional comparative survey in which a community-based sample of 1854 apparently healthy African volunteers were recruited from 37 randomly selected sites, representing all the health districts in the North West[8] and which gave access to subjects from all levels of urbanization, according to a model designed in consultation with the statistical consultation services of Potchefstroom University. Logistical considerations, such as taking a blood sample before 12:00 from volunteers and a period of 6 to 10 h needed to interview subjects, prevented the selection of a truly random sample. Pregnant and lactating women, subjects with known diseases or inebriated, those taking chronic medication and with oral temperatures above 37 °, were excluded. Initially (1996), only subjects between 15 and 65 years of age were included. But because so few 'healthy' individuals in the older age group were not hypertensive, individuals above 65 years who complied with the inclusion criteria were also recruited during 1998. Subjects were grouped into five levels of urbanization using criteria based mainly on where people lived but also on the type of income (jobs) they had. *Group 1* (G1) consisted of rural people living in traditional African villages with a tribal head. These villages were part of the former Bophuthatswana homeland. *Group 2* (G2) were farm workers, living and working on commercial farms. *Group 3* (G3) consisted of subjects living in informal housing areas also known as 'squatter camps', found adjacent to all major towns and cities. Most subjects living in these areas had moved there recently (mostly from rural areas and farms) and therefore represent people in the most rapid phase of transition. *Group 4* (G4) were volunteers from the established urban townships

(previously known as black locations), working as labourers in various industries and institutions. *Group 5* (G5) represented the 'upper-class urban' subjects consisting of professional people such as teachers, nurses, government employees, politicians, and people in business, living in affluent, westernized circumstances. Some of these subjects lived in the same areas as those in groups 1 and 4.

Ethical considerations

The study was approved by the Ethics Committee of Potchefstroom University. All subjects were fully informed about the objectives and procedures of the study in their home language and signed an informed consent form. Illiterate people signed with a cross. After completion of the study, additional approval from the same ethics committee was obtained to test *anonymously* for HIV status. Subjects identified with hypertension, diabetes mellitus, anaemia (or other abnormalities) were referred to local clinics, hospitals or their physicians. Volunteers who did not meet the inclusion criteria were screened for hypertension and diabetes mellitus. Subjects received lunch after completion of the glucose tolerance test and their travel expenses were paid.

Organizational procedures

The Department of Health of the North West Province was informed and approved the study and advised on the design and selection procedures. Permission to conduct the study at a selected site was obtained from the relevant authorities (tribal chief, community leaders, headmasters of schools, employers, mayors, etc.) A local person assisted in choosing the test venue, organized a meeting during which the particular community was informed about the study and helped with the recruitment of subjects through various community-based organizations. Information leaflets explaining the study and with instructions to fast for 10–12 h and to bring identity documents to assess correct age, were distributed in the week before testing. Recruitment started from 07:30 onwards and, after signing the consent form, each subject received a 'green card', which guided them through the 13 research 'stations' where the various measurements were done. The green card was signed at each station and information on the card regarding blood pressure, blood glucose, haemoglobin, etc. was used to advise each subject and to refer them for further testing and treatment where indicated.

Questionnaires

The questionnaires were designed or adapted for this study population and were validated with appropriate methods. Questionnaires were issued during individual interviews conducted by the researchers and specially trained African fieldworkers in the language of the subjects' choice.

The *demographic questionnaire* included questions on type of housing, access to electricity, water source, sanitation, personal and household income, health history (also of close family members), number and ages of people living in the house, ownership of property, education level, and smoking and drinking habits.

Dietary intakes were measured with a *quantitative food frequency questionnaire* developed after a pilot study in which all foods eaten by this population were assessed. This questionnaire was validated in a sub-sample of 100 subjects against a 7-day weight record and 24-h urine nitrogen excretion.[9] Books of photographs of three portion sizes of the most commonly eaten foods, food models, household utensils and food packages were used to assess quantities eaten. Nutrient intakes were analysed with a program based on the South African Food Composition Tables.[10] The ratio of total energy intake to basal metabolic rate was calculated to assess accuracy of dietary reporting. A ratio below 1.2 was regarded as representing an energy intake too low for the maintenance of body weight.[11] The method of Willet *et al.*[12] was used to adjust for under-reported energy intake.

Psychological questionnaires[13–24] were used by white and African clinical psychology master's students and trained Setswana fieldworkers to measure a variety of psycho-social variables including: general symptoms of psychopathology and negativity (such as anxiety, depression, social dysfunction, somatic symptoms), hostility, impulsiveness, resentment, verbal aggression, etc.; positive indications of psychological well-being/health (such as, sense of coherence and satisfaction with life); typical coping strategies (such as seeking social support, active coping, turning to religion, focusing on and venting of emotion, disengagement, anti-social action, aggressive action etc.); perceived social support and perceived stress; degree of acculturation (as reflected in preference for African things, traditional family practices and values, health beliefs and practices, religious beliefs and practices, superstitions, etc.); degree of individualism *versus* collectivism.

Household food security was measured during in-depth interviews with a sub-sample of women, using qualitative and quantitative methods.[25] Physical activity levels, and *knowledge* and *attitudes* towards *obesity* were measured by questionnaires designed for this population.[26] A further questionnaire was used to gather information on contraceptive use, age of menarche and menopause, child birth (parity) and breastfeeding histories in a sub-sample of women,[27] and in another group, other questions were asked to assess colo-rectal cancer risk.[28]

Anthropometric measurements

An anthropometrist and postgraduate students measured height (stature), weight, 7 skinfold thicknesses and body circumferences of subjects in their underwear with calibrated instruments (Precision Health Scale, A&D Company, Japan; Invicta Stadiometer, IP 1465, UK; Holtain® unstretchable metal tape; John Bull® callipers). The researchers' measurements were standardized by a level 3 anthropometrist (J.H.d.R.) and were taken in triplicate.

Clinical examinations

Two nursing sisters examined the subjects for signs of malnutrition. Oral temperatures were taken and blood pressure recorded in duplicate using a sphygmomanometer (Tycos®) with adjustable cuffs of different sizes. The first and fifth Korotkoff sounds were recorded in subjects seated for at least 10 min.

Glucose tolerance test (GTT)

After a fasting blood sample was taken, a two-hour GTT commenced during which subjects took a 75 g glucose load (Alpha® glucose powder, Allied Pharmaceuticals) dissolved in 250 ml water. Serum glucose and insulin levels were measured later in the laboratory but blood glucose was measured in the field with an enzymatic method to screen for diabetes mellitus (Ames Glucometer® G_x: Miles, and glucostrips from Glucostix®, Bayer Diagnostics Ames).

Blood, serum, plasma, urine and cell samples

Blood was drawn from the *vena cephalica* using a sterile butterfly infusion set (Johnson & Johnson, 21G, 19 mm) and syringes. For preparation of serum, 50 ml blood was allowed to clot in glass tubes, centrifuged at 3000 rpm for 15 minutes (Universal 16R™, Hettich, with cooling facilities), and transferred into 30 × 1 ml

Table 1. Gender and age of subjects per group.

Age group	Men					Women				
(years)	G1	G2	G3	G4	G5	G1	G2	G3	G4	G5
15–24.9										
Number	21	41	36	52	20	24	41	38	57	32
Mean	19.4	20.9	18.4	20.2	18.9	20.2	20.4	18.6	20.1	20.3
s.d.	25	2.2	2.8	2.4	2.7	2.6	2.7	2.6	2.7	2.9
95% CI	18.4–20.5	20.1–21.7	17.6–19.3	19.5–20.9	17.8–20.0	19.1–21.3	19.6–21.3	17.7–19.5	19.4–20.8	19.3–21.2
25–34.9										
Number	36	31	33	55	19	42	42	71	78	27
Mean	29.7	28.4	29.3	29.2	29.4	29.2	29.1	30.0	29.5	28.5
s.d.	3.1	3.0	2.7	2.9	3.2	2.8	2.8	2.8	2.8	2.6
95% CI	28.7–30.7	27.3–29.4	28.3–30.3	28.4–30.0	28.0–30.7	28.3–30.0	28.2–29.9	29.3–30.6	28.9–30.1	27.6–29.6
35–44.9										
Number	19	19	32	34	13	37	36	57	58	27
Mean	39.4	38.6	39.4	39.0	38.5	38.6	39.4	39.4	39.2	39.5
s.d.	2.7	2.7	2.6	2.7	3.1	2.6	3.2	3.0	2.9	3.0
95% CI	38.2–40.7	37.3–39.8	38.5–40.4	38.0–39.9	37.0–40.0	37.6–39.5	38.5–40.4	38.6–40.2	38.5–40.0	38.4–40.6
45–54.9										
Number	22	21	26	41	6	27	27	62	38	6
Mean	49.4	50.2	49.2	48.6	47.3	49.8	49.6	49.3	49.1	47.7
s.d.	3.1	2.7	2.8	2.7	3.4	3.2	2.9	3.2	2.9	1.9
95% CI	48.2–50.6	49.0–51.5	48.1–50.3	47.7–49.4	45.1–49.6	48.7–50.9	48.4–50.8	48.6–50.1	48.1–50.0	45.2–50.1
55–64.9										
Number	11	15	36	21	2	13	19	29	29	1
Mean	59.5	59.0	58.5	58.0	56.0	58.5	58.6	57.9	58.1	57.0
s.d.	2.7	2.6	2.7	2.6	1.4	2.3	3.1	2.6	2.4	–
95% CI	57.9–61.0	57.6–60.4	57.6–59.3	56.9–59.2	52.3–59.7	57.0–59.8	57.4–59.8	57.0–58.9	57.1–59.0	51.8–62.2
> 65										
Number	2	3	24	13	–	2	3	17	19	–
Mean	65.0	66.0	70.4	70.7	–	76.0	65.0	69.1	72.8	–
s.d.	0.0	0.0	5.0	5.6	–	4.2	0.0	3.9	7.0	–
95% CI	57.8–72.2	60.1–71.9	68.3–72.5	67.9–73.5	–	68.0–54.0	58.5–71.5	66.3–71.8	70.2–75.4	–

Group: level of urbanization, G1: deep rural; G2: farms; G3: informal housing areas; G4:urban; G5: urban professional.
s.d.: Standard deviation.
95% CI: 95% confidence interval.

Eppendorff tubes. Citrated blood was prepared by drawing 4.5 ml blood into a syringe containing 0.5 ml 1 mol/l citrate (pH 4.5–4.8). These samples were centrifuged for 10 min at 3000 rpm in plastic siliconized tubes and the plasma stored in 5 × 1 ml Eppendorff tubes. An additional 50 ml citrated plasma with 55 μl Trasylol was prepared from blood of 75 obese and control women to study fibrin network characteristics. EDTA blood was prepared by transferring 5 ml blood into EDTA in glass tubes. Haematocrit (centrifuge method) and haemoglobin levels (Boehringer Mannheim) were measured in the field on EDTA blood. All serum, plasma, and separated blood cell samples were immediately stored at –18° to –20° in the field for 2–4 days and afterwards at –84 ° in the laboratory. For DNA analyses, whole blood (four drops) was pipetted (4 × 200 μl) onto blotting paper, dried and sealed in separate envelopes. The butterfly system was kept in the vein for subjects who participated in the cardiovascular reactivity/stress tests. The system was kept viable with a solution of 2.5 units heparin (5000 m/ml) dissolved in 5 ml sterile saline. A random urine sample was collected and stored in 3 × 50 ml aliquots at –22 °.

Cardiovascular reactivity/stress tests

A sub-sample of volunteers with blood pressures <140/95 mm Hg were exposed to a lab stressor [a hand dynamometer exercise at 50% of maximum (Lafayette Instruments)], while continuous finger-arterial pressure was monitored, using a Finapres® (TNO-BMI, Netherlands). Blood samples were collected before and after the test for measurement of serum hormones: insulin (Immuno Biological Laboratories); renin (125-I RIA; DiaSorin CA-1529 & CA 1533); cortisol (125 I RIA; DiaSorin CA 1549); testosterone (125 I RIA DiaSorin CA 1558), and prolactin (Nichols Institute Diagnostics, CA-40-2165). The pressure data were analysed with the Fast Modelflo® program for cardiac output, stroke volume, heart rate, total peripheral vascular resistance and mean systolic and diastolic blood pressures.

Measurements of bone stiffness and turnover

A sub-sample of 100 postmenopausal women, 50 years and older, participated in measurements of Achilles bone stiffness with a portable quantitative ultra-sound bone densitometer (Lunar Achilles®, Ridge Diagnostics, Johannesburg). Markers of bone turnover were measured in serum and urine samples of these women.

Biochemical analyses

Serum proteins, minerals, electrolytes, glucose, lipids and enzymes were determined with the DAX system (discrete analyser, Technicon DAX 48) in the Department of Chemical Pathology, University of Pretoria. Serum vitamin A and E as well as iron, ferritin, iron-binding capacity and transferrin were determined in the MRC laboratory of the National Research Programme for Nutrition Intervention at Tygerberg, using immunological,

Table 2. Socioeconomic variables per group.

Variable	Group 1	Group 2	Group 3	Group 4	Group 5
Number (men)	196	113	134	236	84
Number (women)	300	148	175	293	106
% Households with ≤ 4 members**	46.5	70.5	44.9	52.0	62.5
% Households with 5–8 members	44.6	29.5	51.0	44.3	31.3
% Households with ≥ 9 members	8.9	0.0	4.1	3.6	6.3
#HI R0–100 (% subjects)	23.9	11.2	19.8	14.1	19.9
HI R101–500 (% subjects)	30.9	50.9	35.1	27.1	4.7
HI R501–1000 (% subjects)	29.0	31.5	27.0	22.7	4.5
HI R1001–2000 (% subjects)	11.5	5.7	14.2	23.7	15.1
HI R2001–3000 (% subjects)	2.0	0.9	2.4	5.8	20.7
HI R3000+ (% subjects)	2.9	0	1.7	5.9	35.3
No education (% subjects)	27.7	42.2	23.1	13.0	0
< Std. 6 (% subjects)	33.7	45.5	33.2	31.9	1.6
Std. 6–8 (± trade) (% subjects)	22.1	8.7	23.5	29.2	6.4
Std. 10 (± trade) (% subjects)	14.8	2.6	19.5	22.6	40.0
Std. 10 + tertiary education (% subjects)	1.9	1.1	0.7	3.9	52.1
Height (cm): men	167.1^{ab}	167.6^{c}	168.0^{d}	168.6^{a}	170.3^{bcd}
(95% CI)$	(166–168.2)	(166.7–169.3)	(166.7–169.3)	(167.6–169.5)	(168.4–172.2)
Height (cm): women	157.3^{e}	157.0^{f}	158.4^{g}	157.1^{gh}	159.1^{efh}
(95% CI)$	(156.6–158.0)	(156.0–158.0)	(157.4–159.3)	(156.4–157.8)	(157.9–160.4)

*Group: level of urbanization, G1: deep rural, G2: farms, G3: informal housing areas, G4: urban, G5: urban professional.
**Parents, children, grandparents and other relatives and friends living in house.
#HI: household income per month.
$CI: 95% confidence intervals.
^{abc}Means with the same symbol differ significantly ($P \leq 0.05$).

colorimetric, and HPLC methods. Plasma fibrinogen was measured with the method of Clauss using the ACL 200 (Milan) system and fibrin network characteristics as described by Veldman *et al.*[30] HIV status was determined with an enzyme-immunological method (Enzymum-Test®, anti-HIV 1 + 2 + subtype Φ from Boehringer Mannheim, cat. no. 1557319).

Statistical analyses

The mental health data were analysed with the Statistica program and the rest with the SPSS package.[30] Means, medians, standard deviations, standard errors and 95% confidence intervals were calculated. Data that were not normally distributed were logarithmically transformed and non-parametric tests used to test for significant differences between groups and effects of urbanization. Univariate analysis of variance (ANOVA), the post hoc test of least significant differences (LSD), multivariate regression analysis, stepwise regression models and Spearman rank-order correlations with adjustments for confounding factors were used to examine the influence of level of urbanization and the relationships between measured variables. Data collection for the THUSA study was done in 1996 and 1998. To test if the two sets of data could be combined, total reported energy intakes of women in the 1996 and 1998 data sets were compared. The mean intake of the 1996 group was 7975 kJ and of the 1998 group 7997 kJ, so the two sets of data were combined.

RESULTS

Selected variables that may reflect the impact of urbanization on socioeconomic status, health risk behaviours, risk factors for chronic diseases, and physical and mental health outcomes are reported here. Table 1 shows the number of men and women in the different groups and age groups and Table 2 those for whom complete data (1785 of the 1854 recruited subjects) were available. Of the total sample, 42.4% were rural people (groups 1 and 2), 40.3% came from the two urban groups (4 and 5), and 17.3% from informal housing areas (group 3).

Socioeconomic status (Table 2)

The indicators chosen were household composition, income, educational level and height. When the household income categories are combined to form only two (more or less than R1000 per month), 85% of the households in G1 had less than R1000 per month income compared to 25% in group 5. Almost 94% of the households in group 2 had an income of less than R1000 per month, but fewer of them were in the very low income category (less than R100 per month). Groups 1, 3 and 4 had the highest percentages of subjects without any formal education. Most of the subjects in group 5 had 12 or more years of education. Most of the farm workers had 8–12 years of schooling. Fewer of them had no schooling compared to subjects from groups 1, 3 and 4 and fewer had more than 12 years compared to groups 3, 4 and 5. Farm workers represented the highest percentage of households with 4 or fewer members and the lowest with 9 or more individuals. Groups 1 and 5 had the highest percentages of households with 9 or more members. Using height as a proxy for socioeconomic status is debatable, but it may reflect stunting and therefore chronic malnutrition and socioeconomic deprivation during childhood. Table 2 shows a significant increase in mean age-adjusted height[31] across groups for both men and women. The table indicates that the mean height of the men in group 5 was significantly greater than that of the men in groups 1 and 2, and in group 4 significantly higher than that of men in group 1. The women of G5 were significantly taller than those in groups 1, 2 and 4.

Health risk behaviours (Table 3)

Indicators selected to reflect behaviours that influence health were HIV status, smoking, drinking and some nutrient intakes.

In total, 13.0% of the men and 11.6% of the women tested HIV

Table 3. Variables reflecting health risk behaviours, including some nutrient intakes.

	Gender	Group 1[$]	Group 2	Group 3	Group 4	Group 5	All strata
HIV status:							
% of HIV-positive	Men	7.4	7.8	11.1	21.9	5.8	13.0
	Women	8.9	8.6	17.7	12.7	9.4	11.6
Smokers •							
% of group	Men	48.6	66.5	63.2	60.7	42.3	
% of total population		13.5	10.5	11.9	19.8	3.8	59.5
% of group	Women	19.8	27.3	20.7	11.5	1.0	
% of total population		5.8	4.1	3.6	3.4	0.1	17.0
Snuff takers* •							
% of group	Men	3.0	7.0	5.9	1.3	0.0	
% of population		0.8	1.0	1.0	0.4	0.0	3.2
% of group	Women	26.3	23.1	29.3	19.1	4.1	
% of population		7.7	3.5	5.0	5.6	0.4	22.2
Drinkers •							
% of group	Men	50.5	54.2	68.8	73.1	54.1	
% of population		13.5	8.6	12.9	23.9	4.8	63.7
% of group	Women	18.7	28.7	35.4	25.9	21.6	
% of population		5.5	4.3	6.1	7.6	2.2	25.7
Mean alcohol intake of drinkers • (g/day) (95% CI)	Men	30.4 (17.9–38.3)	20.5 (7.7–33.1)	29.6 (20.1–40.8)	35.2 (28.1–43.3)	24.3 (9.3–43.4)	30.2 (48.8)
	Women	12.0 (6.1–16.8)	15.7 (9.8–21.5)	10.9 (6.2–16.1)	11.4 (7.1–16.0)	2.9 (–5.0–11.5)	11.4 (19.1)
Energy distribution of diet#							
% from total fat	Men	22.9 (6.8)	22.5 (7.4)	24.2 (7.8)	26.0 (7.1)	30.6 (6.7)	24.9 (7.5)
	Women	23.6 (7.1)	22.5 (6.7)	25.7 (7.7)	27.7 (6.8)	31.8 (5.7)	25.8 (7.4)
% from total CHO	Men	67.4 (9.2)	67.5 (9.7)	65.6 (10.0)	64.0 (9.4)	57.3 (8.6)	64.9 (9.9)
	Women	67.0 (9.4)	68.4 (9.0)	64.1 (9.7)	61.5 (9.3)	55.6 (7.5)	63.9 (9.9)
% from total protein	Men	11.6 (2.2)	12.1 (2.1)	11.9 (1.9)	11.8 (2.1)	13.2 (1.8)	12.0 (2.1)
	Women	11.4 (2.0)	11.3 (2.1)	11.8 (2.0)	12.1 (2.3)	13.4 (2.3)	11.9 (2.2)
Vitamin A intake (RE/day)#	Men	609.5 (579.2)	595.5 (642.5)	730.8 (670.0)	765.1 (585.9)	899.3 (676.6)	704.8 (622.8)
	Women	569.4 (571.5)	533.6 (404.0)	765.8 (693.0)	892 (730.5)	1246.1 (1030.1)	761.4 (714.5)
Serum Vit. A (μg/dl)#	Men	47.4 (17.2)	48.7 (15.7)	50.0 (17.0)	47.2 (15.6)	51.2 (16.3)	
	Women	44.9 (15.7)	43.5 (13.2)	43.8 (14.5)	46.0 (16.1)	44.6 (13.1)	
Fibre intake (g/day)#	Men	19.2 (10.9)	15.6 (7.5)	17.3 (8.1)	18.8 (9.2)	19.7 (9.1)	18.3 (9.3)
	Women	15.8 (7.3)	15.4 (6.8)	16.1 (7.8)	17.1 (7.9)	17.7 (8.1)	16.4 (7.6)

[$]Group: level of urbanization, G1: deep rural; G2: farms; G3: informal housing areas; G4: urban; G5: urban professional.
•Adjusted for age.
*Snuff taking: nasally; CHO: carbohydrates; CI: confidence interval.
#Mean ± standard deviation (s.d.).

positive. The highest percentages were seen in the 15–24.9-year-old women of G3 (28.6%) and in the men of the same age in G4 (27.9%; data not shown). Men and women of groups 1, 2 and 5 had lower infection rates than those of groups 3 and 4.

The age-adjusted percentages of subjects per group who smoked cigarettes, pipe or home-rolled cigarettes made from brown paper and pipe tobacco were 59.5% of the men whereas only 17.0% of the women smoked. The percentages of smokers were highest in groups 3 and 4 (men) and groups 2 and 3 (women). Group 5 had the lowest percentages of smokers. Many more women (22.2%) than men (3.2%) took snuff on a regular basis. The highest percentages of snuff takers were women in group 3.

The mean daily reported alcohol intakes, calculated for all alcoholic beverages consumed, using the South African Food Composition Tables,[10] were substantially lower for women in all groups than that of the men. The mean intake of men in group 4 was significantly higher than those of groups 1 and 2. Male drinkers of groups 2 and 5 reported the lowest mean intake of between 20 and 24 g alcohol per day, whereas the mean daily intakes of male drinkers in groups 1, 3 and 4 were 29–35 g. The mean gamma glutamyl transferase (GGT) values of the different groups (Table 4) reflect the reported alcohol intakes, with men in groups 3 and 4 having the highest values. The mean GGT levels of women in the different groups did not differ significantly. However, women in group 4 had mean levels above 32 IU/l (the upper limit of the normal range), indicating that some women could have underreported intakes.

The differences in percentage energy from protein between groups were small but a significant increase was seen with urbanization. The increases in percentage energy from fat were larger. These increases were accompanied by significant decreases in total carbohydrate intakes from the two rural groups to groups 3, 4 and 5. Mean dietary fibre intakes increased significantly from group 2 to 5, however, mainly because of enhanced fruit and vegetable intake.[9,28] This improved quality of the diet is illustrated by the significant increases in vitamin A intake and serum vitamin A from the two rural to the urban groups. Therefore, although consumption changed towards a more westernized diet where subjects from G5 already took in

Table 4. Age-adjusted means (and 95% confidence intervals) of anthropometric and clinical variables and mean scores of some psychological variables per group.

Variable	Gender	Group 1	Group 2	Group 3	Group 4	Group 5
Body mass index (kg/m^2)	Men	20.7 (20.2–21.3)	20.6 (19.9–21.3)	20.3 (19.7–20.9)	21.3 (20.8–21.8)	23.1 (22.2–24.0)
	Women	25.6 (24.8–26.3)	26.3 (25.2–27.4)	26.7 (25.7–27.7)	28.0 (27.3–28.8)	28.1 (26.7–29.4)
TC (mmol/l)	Men	3.88^{a} (3.75–4.01)	4.10^{b} (3.82–4.17)	3.86^{c} (3.70–4.02)	3.98^{d} (3.86–4.10)	4.69^{abcd} (4.45–4.92)
	Women	3.99^{e} (3.88–4.10)	4.11^{f} (3.95–4.27)	4.10^{g} (3.95–4.25)	4.43^{efg} (4.31–4.54)	4.76^{efg} (4.57–4.96)
S-GGT (IU/l)[@]	Men	44.2 (16.9–60.5)	32.5 (5.6–62.8)	74.5 (50.9–103.4)	63.2 (43.3–83.0)	58.1 (28.3–105.2)
	Women	30.5 (24.3–36.7)	30.3 (21.7–38.9)	30.1 (22.1–38.1)	34.9 (28.8–41.1)	29.2 (18.8–39.8)
Systolic BP (mm Hg)	Men	125.3^{ab} (123.1–127.5)	124.6^{c} (120.1–129.0)	133.5^{acd} (129.7–137.3)	132.2^{b} (129.9–134.5)	125.0^{d} (119.6–130.3)
	Women	128.0^{efg} (125.6–130.4)	137.7^{eh} (132.6–142.9)	135.9^{fi} (131.6–140.2)	135.4^{gj} (133.0–137.8)	120.7^{hij} (114.6–126.8)
Diastolic BP (mm Hg)	Men	75.9^{ab} (74.4–77.4)	75.6^{cd} (72.5–78.6)	80.7^{ace} (78.1–83.3)	78.9^{aef} (77.3–80.5)	79.9^{bdf} (76.1–83.6)
	Women	77.5^{ghi} (76.0–79.0)	81.7^{gj} (78.4–84.9)	83.9^{hk} (81.2–86.7)	83.1^{il} (81.5–84.6)	75.1^{jkl} (71.2–79.0)
% Newly diagnosed DM[#]	Men	3.57	4.42	0.75	1.27	5.95
	Women	5.00	4.05	5.14	5.12	4.72
Psychopathology						
GHQ-T		9.3	10.6	8.6	9.5	4.7
NEO-PI-R: N		166.6	178.4	166.3	169.9	156.3
BD-T		43.4	46.4	44.0	45.0	42.9
Psychological well-being						
SOC		120.1	120.2	122.8	122.9	137.7
PNB		7.6	8.1	8.2	9.8	15.8
SWLS		21.1	21.3	22.6	23.3	22.4

Group: level of urbanization, G1: deep rural, G2: farms, G3: informal housing areas, G4: urban, G5: urban professional.
[a,b,c]Means with the same symbol differ significantly ($P \leq 0.05$; GLM multivariate test).
[@]S-GGT: serum gamma glutamyl transferase.
[#]Random blood/serum glucose ≥11 mmol/l.
GHQ-T = General Health Questionnaire Total Score; NEO-PI-R:N = Neurotism Domain Scale of the NEO Personality Inventory; BD-T = Buss Durkee Hostility Scale — Total Score; SOC = Sense of Coherence Scale; PNB = Positive-Negative-Affect Balance; SWLS = Satisfaction with Life Scale.
DM: diabetes mellitus.

more than 30% of their total energy as fat, the quality of the diet also improved with urbanization, resulting in improved dietary fibre and micronutrient intakes.

Risk of chronic diseases of lifestyle and health outcomes (Table 4)

The indicators selected to reflect risk of chronic diseases were body mass index and total serum cholesterol. The mean age-adjusted body mass indices (BMI) of men and women show that obesity was not a problem in men, with all sub-groups having a mean BMI of 25.2 kg/m^2 or less. In women however, almost half of the subjects in G1, 2 and 3 and more than 60% of those in groups 4 and 5 had a BMI exceeding 25 kg/m^2. Age influenced BMI significantly in both men and women (ANOVA, $F = 8.93$; $P < 0.000$). Women aged 35 to 65 years had the highest mean BMI. Men in group 5 and women in group 4 had the highest mean BMI for their respective genders, indicating that urbanization was associated with increased body mass, although rural women also displayed high prevalences of obesity.

Multivariate tests, controlled for age, showed that social group significantly influenced BMI in women ($F = 4.77$, $P < 0.001$), but not in men. Mean age-adjusted total serum cholesterol (TC) levels are shown in Table 4 for HIV-negative subjects only, since HIV-positive subjects had significantly lower levels (ANOVA, $F = 3.87$, $P < 0.05$). Age significantly influenced TC (ANOVA, $F = 14.79$, $P < 0.000$). In men, when controlled for age, no significant differences were seen from group 1 to 4, but those in group 5 had a significantly higher mean TC. In women, a gradual increase across groups was observed, with women in G4 and 5 having significantly higher values. However, mean levels of all groups were low. Using the South African age-specific limits for low, medium and high coronary heart disease risk levels,[32] more subjects in G3 and 5 fell into the high-risk category.

The two physical health criteria chosen were hypertension and diabetes mellitus (DM), which are both associated with increased risk of cardiovascular mortality and morbidity. Table 4 shows that men and women from G3 and men from G4 had the highest mean systolic and diastolic blood pressures. Groups 3 and 4 had more subjects with undiagnosed and therefore untreated hypertension than the other groups. Group 5 had the smallest percentage of subjects diagnosed with high blood pressures.

The percentages of subjects in each group who had either a fasting or a 2-hour blood glucose level >11.1 mmol/l are shown in Table 4 as 'newly diagnosed DM'. In men the highest percentage was seen in G5. The same percentage (4–5%) was found in women of all groups. The mean percentage of women (4.89%) was substantially higher than that of the men (2.75%).

Mental health outcomes

Table 4 also presents mean scores for participants from different groups on indices of psychopathology and psychological well-being. Data on psychometric aspects of these scales are reported elsewhere.[33,34] Reliability and validity proved to be acceptable. Mean scores on all indices of symptomatology differed significantly over groups (ANOVA: GHQ-T: $F = 3.48$. $P = 0.007$; NEO-N: $F = 7.97$, $P = 0.000$; BD-T: $F = 2.89$, $P = 0.02$). In all instances the highest scores were found for farm workers and the lowest among urban professionals. Farm workers scored the highest on all facets of the NEO-PI-R, i.e. anxiety, angry hostility, depression, self-consciousness, impulsiveness and vulnerability.

Mean scores on psychological wellbeing differed significantly among groups in the case of sense of coherence, ($F = 2.38$, $P = 0.4$) and satisfaction with life ($F = 4.34$, $P = 0.0001$), with a tendency in the same direction in the case of PNB ($F = 2.22$, $P = 0.06$). Urban professionals expressed the highest sense of coherence (i.e. the feeling that life is to a certain extent meaningful, understandable and manageable), and more common positive feelings and fewer negative feelings than participants from other groups. There seems to be an increase in the degree of psychological well-being with urbanization (cause or effect), with mean scores of G5 in line with those obtained for other multicultural groups in South Africa.[35] Scores as indices of psychopathology (symptomatology) in this community sample were extremely high in all groups, with those of urban professionals closer to 'norms' for other multicultural groups in South Africa,[36,37] and farm workers (G2) suffering the most.

There was no significant gender difference with regard to psychiatric symptomatology (GHQ-T) (men = 8.9, women = 9.6) as is the case elsewhere,[37] but women scored significantly higher on negative affect (NEO-PI-R:N) (men = 166.9; women = 171.2, $t = 2.68$, $P = 0.007$), and on hostility (BD-T) (men = 43.5, women = 45.3, $t = 2.91$, $P = 0.003$). Women also scored significantly lower on positive-negative affect balance (PNB) (men = 9.6, women = 8.0; $t = 2.0.2$, $P = 0.04$). Although the scores of women in terms of sense of coherence and satisfaction with life were also lower than those of men, these differences were not statistically significant.

DISCUSSION

The objective of this study was to examine the influence of urbanization on the health status of Africans to provide information that could be used in planning health policies, strategies and programmes. This discussion will therefore focus on the observed differences of the various chosen health indicators between the rural and urban groups. It will not address underlying mediating or moderating physiological, pathological or psychosocial mechanisms and inter-relationships.

Socioeconomic status

Socioeconomic circumstances, measured as income and education level, improved with urbanization. This was supported by increased stature with urbanization, possibly indicating less stunting and chronic malnutrition during childhood in these subjects. The number of people per household did not follow the same pattern. This may be ascribed to the 'African helping tradition',[38] which seems to operate also within the Setswana culture, leading to a coping strategy where children are sent away to households of relatives which are food secure. The farm workers in group 2 had households with the fewest members, possibly because their children were living with relatives in towns and cities while going to school. In the deep rural villages, schools are now more accessible than on farms. Yach *et al.*[2] consider that income, education and occupation may be inappropriate measures of social class, and that type of building materials used for the house or ownership of property and material possessions may be more sensitive indicators of vulnerable groups. The latter indicators were also measured in the THUSA study and were remarkably constant within groups. We therefore conclude that income and education were adequate indicators of socioeconomic status.

Health risk behaviours

The percentage of participants who tested HIV positive was lower than the 1998 estimated prevalence of 18.1% for the North West,[3] possibly because only apparently healthy subjects were recruited and those with symptoms of HIV infection or AIDS were excluded or did not volunteer to participate. Nevertheless, the percentage of just under 30% of young people in the more densely populated groups 3 and 4 who were HIV positive is alarmingly high. HIV infection could reflect, in most instances, unsafe sex because of a lack of knowledge, not understanding the available information on HIV/AIDS, or taking risks regardless of possible consequences. Our results emphasize the need for more effective awareness and intervention programmes. The much lower rates in the two rural groups may be because of relative isolation and in G5 could reflect sexual behaviour based on access to and understanding of available information. This possibility of more responsible health behaviours among subjects from G5 is also reflected in the lower rates of smoking and alcohol consumption.

In 1995, Yach[39] reported that 52% of South African men and 17% of women smoked compared to the 60% and 17% found in our subjects. It is a matter of concern that so many young people have started the habit despite awareness campaigns about the health consequences. More women took snuff than smoked cigarettes. The consequences of regular snuff taking are not known and should be examined in more depth. The mean daily alcohol intake of male drinkers of 30.2 g is substantially higher that the 13.6 g reported for white South African men who participated in the VIGHOR study[40] and the 14.4 g found in a Finnish study.[41] Alcohol intake has a U-shaped relationship with mortality[40,42] and moderate consumption is associated with increased HDL-cholesterol levels and decreased thrombotic tendencies. However, high intakes are associated with certain forms of cancer, hepatic cirrhosis, hypertension, accidents and violence.[40–42] In some of the THUSA subjects, high intakes in men were often accompanied by a pattern of weekend 'bingeing'. In addition to directly detrimental effects on health, indirect effects (through disruption of family life and social consequences) as well as the basic and underlying reasons for overconsumption should be examined in more depth to inform appropriate programming.

The urbanization and industrialization of traditional and rural people have generally been associated with a nutrition transition characterized by increased intakes of energy, fat and processed foods, resulting in enhanced rates of obesity and other risk factors for chronic diseases of lifestyle.[6,7] The dietary pattern of the THUSA participants is undoubtedly changing towards a more western diet during urbanization, although the diet of the urban groups can still be regarded as prudent[43] and is actually more adequate than among rural subjects regarding micronutrients. Farm workers had the lowest mean intakes of vitamin A with the majority not reaching two-thirds of the recommended amount. This was also true for most of the other micronutrients (data not shown), indicating that this group was nutritionally the most vulnerable. Nutrition interventions in South Africa

usually target children, pregnant and lactating women, regarded as the vulnerable groups. Our results indicate that adult men and women living on farms in the North West need urgent nutrition intervention.

Risk factors for chronic diseases

Rates of obesity in women increased with urbanization, but the high rates found in the rural groups suggest that other factors such as inactivity[26] and possibly foetal malnutrition and childhood stunting[44] also operate. Clearly, intervention or prevention programmes should target both rural and urban African women. Although total serum cholesterol also increased with urbanization, probably reflecting higher fat intakes, the low mean values may explain the present low incidence of coronary heart disease in this population.[45] Levels are increasing, however, and the majority of subjects fell in the moderate risk category, suggesting that the epidemic of coronary heart disease (CHD) seen in other developing populations may be expected in the future for this group. Although CHD risk factors in Africans are still low,[46] the high prevalence of hypertension may increase risk of heart disease when cholesterol levels rise with urbanization.

The percentage of subjects diagnosed with hypertension was greater than that reported by Steyn *et al.*[47] for an urban population in the Cape Peninsula, but comparable to the 29% and 30% that Mollentze *et al.*[46] found in rural and urban areas, respectively, in the Free State. The lower rates seen in subjects from group 5 probably indicate that they had better access to health-care facilities and that fewer people experience undiagnosed hypertension.

By contrast, the highest percentage of newly diagnosed diabetic men was found in G5, which may indicate less awareness to screen for diabetes than for hypertension in primary care settings or which may reflect an increased prevalence. The percentages of newly diagnosed diabetic women did not differ across groups and the rate of 4.9% was similar to the 4.8% reported by Mollentze *et al.*[46] for similar populations. The higher rates seen in women may be related to enhanced obesity.

Walker[48] recently pointed out that, although the health situation in South Africa is better than in other sub-Saharan African countries, the prevalence of obesity in women, and of hypertension and diabetes among our African population, already exceeds that in the white population — a situation also found among African Americans. He mentions that prevention and control of chronic diseases *are* possible, but only with planning, understanding and purpose.

Mental health outcomes

Participants in groups 1–4 all reflected relatively high levels of distress and symptomatology. This confirms what would be expected but only guessed in view of the lack of valid data on mental health profiles for black South Africans — against a background of a long history of abuse of human rights, repression, violence and poverty.[49] Farm workers are an exceptionally vulnerable group. Women suffer more than men, as is the case with American black women.[50] These findings indicate that intervention, empowerment and health promotion programmes should be specially targeted at women and farm workers. Psychological well-being (as measured by the selected instruments) seems to be improving with urbanization. The possible role of psychological strengths, as mediating variables (and not as outcome variables), should be further explored. The different patterns of results obtained for indices of psychopathology (symptomatology or mental ill-health) and psychological well-being (strengths) indicate that both symptomatology and strengths, risk factors and protective factors should be taken into account when a comprehensive picture of mental health and empowerment of people is sought.

Conclusions and recommendations

Holistically, the indicators investigated revealed that socioeconomic status improved with urbanization. The highest socioeconomic group, G5, seemed to have the best nutritional, physical and mental health status. They exhibited better health behaviours reflected in lower HIV-positive rates, less drinking and smoking, and lower blood pressures. But they also had the highest fat intake, the highest mean total serum cholesterol levels and the men exhibited the highest rate of undiagnosed diabetes mellitus. The farm workers in G2 seemed to have the worst nutritional status, and mental health profiles, whereas the subjects from groups 3 and 4 had the worst health behaviours. Thus, urbanization can be associated with an improvement in some health determinants but a deterioration in others, especially among people in transition. It is also associated with an emergence of some risk factors for chronic diseases of lifestyle. An important observation was that risk factors for chronic diseases, and some of these diseases such as obesity, hypertension and diabetes, were prevalent in the most rural areas as well as the towns. We conclude that because of these complexities, health strategies and intervention programmes designed to address specific problems in vulnerable or affected groups should be based on a thorough assessment of the situation.

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