

**THE ASSOCIATION BETWEEN IRON DEFICIENCY ANAEMIA AND ACADEMIC  
PERFORMANCE OF CHILDREN FOCUSING ON GRADE II PUPILS IN THE  
WINTERVELDT REGION, TSHWANE NORTH, SOUTH AFRICA.**

by

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DISSERTATION

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## TABLE OF CONTENTS

TITLE PAGE	PAGE NO
Project title	i
Table of contents	ii-iv
Declaration	v
Dedication	vi
Acknowledgements	vii
Lists of tables and figures	viii
Abbreviations	ix
Appendices	x
Abstract	xi-xii
<b>Chapter 1: Introduction</b>	
1.1 Introduction	1
1.2 Study problem	1
1.3 Purpose of the study	1
1.4 Justification of the study	1
1.5 Objectives	2
1.6 Research questions	2
1.7 Operational definitions	2
<b>Chapter 2: Literature review</b>	
2.1 Introduction	3
2.2 Biology and physiology of iron	4
2.2.1 Acquisition and distribution of iron	4
2.2.2 Iron absorption	3
2.2.3 Iron storage	4
2.2.4 Iron losses	5
2.2.5 Iron requirements	5
2.2.6 Role of iron in cell proliferation	5
2.3 Stages of iron deficiency	5
2.4 Causes of iron deficiency	5-6
2.5 Definition of anaemia and iron deficiency anaemia	6
2.6 Effects if iron deficiency on body systems	6-7
2.7 Prevalence of anaemia, ID and IDA in the world	7-9
2.8 Prevalence of anaemia, ID and IDA in Africa	9-10
2.9 Prevalence of iron deficiency anaemia in South Africa	10-13
2.10 Biological effects of ID and IDA on central nervous system	13-15

2.11 Association of ID and IDA with school performance and intelligence	15
2.11.1 Studies which showed negative association	15-17
2.11.2 Studies which found no association	17-18
2.12 ID & IDA and school performance/cognitive performance in SA	19
2.13 Conclusion	19-20
<b>Chapter 3: Methods</b>	
3.1 Introduction	21
3.2 Study design	21
3.3 Research sample	21
3.3.1 Sample frame and settings	21
3.3.2 Sample selection	21-22
3.3.3 Research instruments	23-24
3.3.4 Bias, reliability and validity of instruments	24
3.4 Data collection procedure	24
3.4.1 Phase 1- screening	25
3.4.2 Phase 2- Data on academic and intelligence performance	25-26
3.5 Data management and analysis	26
3.5.1 Data entry and checking	26
3.5.2 Statistical analysis	26-27
3.6 Ethical considerations	27
<b>Chapter 4: Results</b>	
4.1 Sample demographics	28-29
4.2 Distribution of sample variables among the three schools	30
4.3 Anthropometry	30-31
4.4 Haemoglobin levels	31
4.5 Ferritin levels	31-32
4.6 Prevalence of IDA	32
4.7 School reports	32-33
4.8 Raven's coloured progressive matrices	33-34
4.9 Association between cases (IDA & severe anaemia) and school performance	34
4.10 Association between IDA and cognitive performance	34-35
4.11 Comparison of RCPM and academic performance & other parameters	35-36
4.12 Conclusion	36-37
<b>Chapter 5: Discussion</b>	
5.1 Sample and results discussion	38
5.1.1 Study design	38

5.1.2 Sample demographics	38-40
5.1.3 Haemoglobin & ferritin levels	40-42
5.1.4 Prevalence of IDA	42-43
5.1.5 RCPM scores	43-45
5.1.6 The association between RCPM & IDA	45-46
5.1.7 The association of IDA & school performance	46
5.2 Limitations	46-47
<b>Chapter 6: Conclusion and recommendations</b>	
6.1 Conclusions	48-49
6.2 Recommendations	49
<b>References</b>	50-63
<b>Appendices</b>	64-77

## **DECLARATION**

I declare that the dissertation hereby submitted to the University of Limpopo, for the degree of Master of Medicine in Paediatrics and Child Health has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

Signed \_\_\_\_\_

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## **DEDICATION**

This study is dedicated to the following people:

- The two most important people in my life, my daughter Nontobeko and my mother Essinah Hlatshwayo for being so understanding during my hectic training period. Nonto made my life so easy with all the computer knowledge.
- My niece Zama and my nephew Sandile who helped out with all the paper work and tidying up after my mess in the house.

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<b>LIST OF TABLES AND FIGURES</b>	<b>PAGE NO.</b>
Table 2.1 Definition of anaemia and IDA in different age groups	6
Table 2.2 Global anaemia prevalence and number of individuals affected (WHO, 2005)	8
Table 2.3 African prevalence of anaemia, iron deficiency and iron deficiency anaemia	9
Table 2.4 National estimated anaemia prevalence in children 6-71 months (1994)	10
Table 2.5 Prevalence of iron deficiency in 6-71 months old children in South Africa in 1994	11
Table 2.6 Age-related tests for cognitive development (Batra and Sood, 2005)	18
Table 4.1 Total number of participants	28
Table 4.2 Summary of anthropometry	30
Table 4.3 Interpretation of anthropometry	31
Table 4.4 Summary of blood test results of cases and controls	31
Table 4.5 Comparison of academic scores between cases and controls	33
Table 4.6 Summary of RCPM scores	33
Table 4.7 Comparison between the two groups of the RCPM scores	34
Table 4.8 RCPM scores between gender	36
Figure 2.1 Estimates of the number of people in the world with anaemia, IDA and ID (2001)	8
Figure 3.1 A schematic presentation of the sampling procedure	22
Figure 4.1 Results of the sampling procedure	29
Figure 4.2 Prevalence of anaemia and iron deficiency anaemia	32
Figure 4.3 The means of the participants who were tested on the RCPM	35



## **ABBREVIATIONS**

- CRP:** C-reactive protein  
**CDC:** Centers for Disease Control and Prevention  
**DOE:** Department of Education  
**DNA:** deoxyribonucleic acid  
**EEG:** electroencephalogram  
**Hb:** haemoglobin  
**IDA:** iron deficiency anaemia  
**ID:** iron deficiency  
**IQ:** intelligence quotient  
**KZN:** KwaZulu Natal  
**MEDUNSA:** Medical University of Southern Africa  
**NHLS:** National Health Laboratory Services  
**POPD:** Paediatric Out-Patient Department  
**RCPM:** Raven's Coloured Progressive Matrices  
**UNICEF:** United Nations Children's Fund

## **APPENDICES**

	<b>PAGE NR</b>
Appendix I: Consent form	64
Appendix II: Patient information leaflet	65-67
Appendix III: Letter to parent of normal pupil	68
Appendix IV: Letter to the parent of control pupil	69
Appendix V: Letter to the parent of case pupil	70
Appendix VI: Data collection sheet	71
Appendix VII: Raven's Coloured Progressive Matrices	72-73
Appendix VIII: Medunsa Research and Ethics Committee clearance certificate	74
Appendix IX: Gauteng Department of Education letter of approval	75-76
Appendix X: Local Department of Education letter of permission	77

## ABSTRACT

**BACKGROUND AND OBJECTIVES:** Iron deficiency anaemia (IDA) is the most common nutritional disorder in the developing world. A large number of children under the age of 5 years do not reach their developmental potential, IDA and iron deficiency being well documented risk factors. IDA has been shown to be an important cause for decreased attention span, reduced alertness and learning difficulties in both young children and adolescents. South Africa has a growing burden of anaemia and iron deficiency and the most affected areas are the poor communities. There is vast evidence on the negative effects of iron deficiency to a child's developing brain from studies done internationally but limited data on the subject in South Africa, despite the huge burden of iron deficiency. We investigated the association between IDA and school performance and intelligence and also determined the local prevalence of IDA in the Winterveldt region, North of Tshwane, South Africa.

**METHODS:** Three primary schools from Winterveldt were sampled. All subjects with parental consent were screened for anaemia using Hemocue 201+ Hb meter (n=194). Blood for iron studies and CRP was collected on all anaemic pupils (n=75) to define IDA (Hb<11.5g/dl, ferritin<12ug/L and CRP<10). Cases and controls were recruited after results using matching anthropometry at a 1:2 ratio (one case to two controls). A total of 90 pupils (30 cases & 60 controls) were compared using 2009 school reports. Analysis was done per subject using the national scoring system, where one means incompetent and four means excellent achievement. The Raven's Coloured Progressive Matrices (RCPM) was used as our psychometric test and scores were recorded as percentiles and interpreted by the educational psychologist who conducted the test.

**RESULTS:** Point prevalence of iron deficiency anaemia for the Winterveldt region was found to be 9.8%. The prevalence of under-weight was 19% and that of stunting 23% with no significant differences between cases and controls ( $p=0.368$  for under-weight and  $p=0.863$  for stunting). There was no statistically significant association between IDA and performance in mathematics ( $\chi^2=1.34$  and  $p=0.511$ ). However, cases scored poorly in life skills ( $p=0.00017$ ) and in literacy the test for level of significance approaches significance ( $p=0.071$ ). There was also no statistically significant association between IDA and low scores on the RCPM test ( $\chi^2=3.31$  and  $p=0.65$ ).

**CONCLUSION:** The point prevalence was high compared to the national prevalence of IDA which is about 5%. This could be related to a number of factors including the socio-economic background of the pupils. Since dietary history and knowledge of fortified food was not investigated, we cannot draw conclusions on the cause of this high prevalence. The study also found that the general population was under-nourished, which is consistent with the poor socio-economic status of the study area. However, our participants were more under-weight and stunted when the data was compared with previous national surveys.

The study found a negative correlation between IDA and two areas of academic performance which is consistent with international data. In mathematics however, we believe that the low curriculum standard in all South African schools affected the outcome.

The results of the psychometric test were not consistent with international data where most studies showed a negative correlation between IDA and the Ravens Matrices. South African studies have demonstrated poor performance of black students on the Ravens Matrices when compared to other races and our results followed this trend as our scores were similar to most of the studies.

## **CHAPTER 1 - INTRODUCTION**

### **1.1 INTRODUCTION:**

Iron deficiency is the most common nutritional disorder in the developing world. A large number of children under the age of five years (> two million) do not reach their developmental potential, iron deficiency (ID) and iron deficiency anaemia (IDA) being well documented risk factors (Wu, Lesperance & Bernstein, 2002). IDA is one of the most widespread health problems especially among children: approximately 40% of children are anaemic across various African and Asian settings (Hall, Bobrow, Brooker, et al., 2001). IDA leads to weakness, poor physical growth and a compromised immune system. IDA also impairs cognitive performance and delays psychomotor development (Centers for Disease Control & Prevention, 1998). Through its impact on school participation and learning, anaemia could also be central to understanding the intergenerational transmission of poverty.

### **1.2 STUDY PROBLEM:**

Iron deficiency anaemia is a preventable cause of cognitive impairment and other negative effects on academic potential of children. The developmental deficits related to IDA can to some extent be corrected with iron treatment; however, there is evidence that some deficits are not reversible with iron treatment. Irreversible developmental delays in children and the fact that iron is needed continuously throughout the entire period of brain growth are strong arguments for active and effective combating and prevention of iron deficiency. The highest risk of iron deficiency anaemia occurs during periods of rapid growth and nutritional demand, thus infants, early childhood, adolescence and pregnant women are the most affected (Jacobson, 2008).

The latest South African studies on the prevalence of iron deficiency and iron deficiency anaemia showed that many children are iron deficient with a national prevalence of 5.1% of IDA. Rural children were found to have the highest prevalence of ID. Faber & Wenhold (2007) found 43.2% of rural children aged 6-24 months to be iron deficient. Another study done in disadvantaged Western Cape communities found 32% of coloured infants and 46% black infants to have IDA (Jacobson, 2008).

### **1.3 THE PURPOSE OF THE STUDY:**

The purpose of the study was to explore the effects of IDA and moderate to severe anaemia on the academic performance and cognition in primary school pupils in a resource poor community. This was done by assessing school performance and intelligence of pupils diagnosed with IDA and moderate to severe anaemia in comparison with pupils with normal iron status.

### **1.4 JUSTIFICATION OF THE STUDY:**

From the above mentioned statistics of IDA prevalence in South Africa, it is clear that there is a huge burden of poor growth and development of children resulting from iron deficiency and IDA. Although the association of IDA and moderate to severe anaemia and poor academic performance and reduced intelligence is well studied in overseas countries, in South Africa literature is lacking on the subject despite the high prevalence of IDA and anaemia. Berry & Hendricks (2009)

reported a deteriorating iron status of South African children compared to previous studies on prevalence.

As mentioned before, the problem of IDA and anaemia seems to be higher in poor communities. This worrying trend may be the major cause of intergenerational transmission of poverty. The study is thus intended to find out if the association of IDA and anaemia, and poor school performance and reduced intelligence holds true for South African children. Since IDA is easily preventable with iron supplements, results of the study might be a break-through to future studies to gain more evidence on supplements and improved school performance and thereafter productivity of the general population.

### **1.5 OBJECTIVES OF THE STUDY:**

- To determine the local prevalence of IDA and moderate to severe anaemia among grade 2 learners in the Winterveldt region, North of Tshwane, South Africa.
- To evaluate the association between IDA and moderate to severe anaemia, and academic performance and cognition in grade 2 learners in the region of interest.

### **1.6 RESEARCH QUESTIONS:**

- Is IDA and moderate to severe anaemia prevalent among primary school-going children in the government schools within the peri-urban area of South Africa?
- Is IDA and moderate to severe anaemia associated with poor school performance among primary school children?
- Is IDA and moderate to severe anaemia associated with poor cognitive and reasoning abilities?

### **1.7 OPERATIONAL DEFINITIONS:**

- Iron deficiency anaemia refers to haemoglobin of less than 11.5 g/dl and ferritin of less than 12 µg/l (WHO/UNICEF/UNU, 2001).
- Academic performance: For this study, this refers to how primary school learners perform in the three areas on which they are tested. School reports were used to assess academic performance.
- Cognitive and reasoning abilities were measured by a psychometric tool, the Ravens Coloured Progressive Matrices (Raven & Court, 1990).

## CHAPTER 2 - LITERATURE REVIEW

### 2.1 INTRODUCTION:

Micronutrient deficiencies are a group of common health conditions which affect more than two billion people in the world and are common in low income countries. They often co-exist with protein energy malnutrition (PEM) and children with moderate to severe PEM have deficiencies of key vitamins and minerals like vitamin A, iodine, iron and zinc. The micronutrient deficiencies are detrimental as they increase the risk of infectious diseases, leading to death especially in children under the age of five years (WHO/WFP/UNICEF, 2006). The WHO has documented the relationship between under-nutrition and the risk of infectious diseases in several studies. The risk of death increases with moderate to severe malnutrition (Black, Morris & Bryce, 2003).

Children who are iron deficient tend to be shorter than non-iron deficient children. The anorexia observed in iron deficiency is postulated to be the cause of stunting (Harris, 2007). Although iron is classified as a type 1 micronutrient in relation to the effect on growth, i.e. rarely affects growth unless the deficiency is severe (Branca & Ferrari, 2002), several studies suggest that iron deficiency causes stunting but has no effect on weight. Soliman and colleagues studied growth velocities of stunted iron deficient children younger than 4 years of age before and after iron therapy and growth velocities of these children significantly increased following three months of iron supplements (Soliman, Al Dabbagh, Habboub, et al., 2009).

Angeles and colleagues also reported improved growth in iron deficient preschool children following iron supplementation in Indonesia. Children's anthropometric parameters were measured before and after a two months supplementation period. There was a significant change in height in the treatment group compared to the controls but weight gain was observed in both groups (Angeles, Schultink, Matulesi, et al., 1993). Booth and Aukett (1997) documented these growth effects of iron supplementation in their review paper where data on the causes and consequences of iron deficiency anaemia were summarised. A Jamaican study showed that food supplementation is age-specific and that children respond well to supplements before the age of one year (Walker, Powell, Grantham-McGregor, et al., 1991).

In South Africa, Faber (2007), found stunting to be more prevalent in anaemic infants aged 6-12 months when compared to non-anaemic infants of the same age group (23% vs. 9%;  $p=0.0001$ ). Prevalence of underweight was also higher in the anaemic group. However, this study did not investigate whether the anaemia was due to iron deficiency or not. In South Africa, a Kimberley (Northern Cape) study showed significant improvement in the Z-scores for weight-for-age ( $p<0.05$ ) and height-for-age ( $p=0.001$ ) in preschool up to grade 5 children with low iron status following a micronutrient supplement containing iron and zinc (Troesch, van Stuijvenburg, Smuts, et al., 2011).

In this chapter the importance of iron in the body and the effects of its deficiency to several body systems will be highlighted. Some studies related to iron deficiency (ID) and iron deficiency anaemia (IDA) and school performance and intelligence will be reviewed.

## **2.2 THE BIOLOGY AND PHYSIOLOGY OF IRON:**

Iron is an essential micronutrient which is necessary for maintaining the normal structure and function of virtually all cells of the body. It is a component of many proteins and also of haemoglobin, the latter being important for transport of oxygen to tissues through-out the body. Oxygen is poorly soluble in plasma, the iron atoms in the heme group of haemoglobin can bind reversibly to oxygen molecules thus providing transport to 98.5% of the total oxygen to body tissues (Miller & Baehmer, 1990).

### **2.2.1 Acquisition and distribution of iron:**

Total body balance depends on dietary uptake and gastrointestinal (GIT) loss of iron. No organ performs the physiological role of iron excretion and approximately 1 mg of iron is lost each day through sloughing of cells from mucosal surfaces and skin. Consequently, absorption is the sole means of regulating body iron stores rather than control of excretion (Miller & Baehmer, 1990).

### **2.2.2 Iron absorption:**

The absorption of iron occurs in two steps, the first involves movement of iron from the lumen into the intestinal epithelial cells and the second entails absorption of iron from these cells into the blood. Iron is absorbed predominantly in the duodenum and upper jejunum. Dietary iron exists in two forms, ferrous iron,  $Fe^{2+}$ , which is absorbed easily and ferric iron,  $Fe^{3+}$ , which must be reduced to  $Fe^{2+}$  before absorption. At physiological pH, ferrous iron is rapidly converted to the insoluble ferric form. A number of dietary factors influence iron absorption. Ascorbate, citrate and amino acids increase iron uptake by acting as weak chelators to solubilise the metal in the duodenum. Iron deficiency also increases uptake of iron by the GIT. Conversely, iron absorption is inhibited by plant phytates and tannins, and sources of pica e.g. soil, clay and laundry starch. Other competitors of iron absorption are heavy metals like lead, cobalt and strontium (Sherwood, 2007).

Iron enters the mucosal cell by receptor mediated endocytosis of a mucin-iron complex called gastroferrin formed when gastric acid combined with iron is neutralised in the duodenum. Some of this iron enters the bloodstream and is carried by a plasma protein, transferrin to all parts of the body. The excess iron in the mucosal cell is stored as mucosal ferritin. The mucosal cell has a life span of 2-3 days, thus it constitutes a temporary holding zone for iron if there is iron overload (Powell, Jugdaohsingh & Thompson, 1999).

### **2.2.3 Iron storage:**

There are several iron pools in the body, the largest functional pool being haemoglobin of the circulating blood cells. Most of the iron is stored as ferritin in hepatocytes in the liver, spleen and bone marrow. Macrophages of the reticuloendothelial system also contain iron from break down of engulfed red blood cells. Ferritin is soluble, thus the iron in it is easily available when required. Hemosiderin is another tissue storage form of iron and is more stable as it is insoluble (Miller & Baehmer, 1990).



#### **2.2.4 Iron losses:**

Iron loss is small and relatively fixed in contrast to the wide variations of iron intake and fluctuations in absorption. One milligram is lost per day from GIT by exfoliated mucosal cells and through bile, desquamated skin cells and from urinary tract cells. Iron losses are greater in infants and post-pubertal females. Cow's milk feeding in early infancy is associated with occult intestinal blood loss which contributes to iron loss as the mucosal cells temporarily store ferritin when iron is not immediately needed by the body (Nathan & Orkin, 1998).

#### **2.2.5 Iron requirements:**

The American Academy of Paediatrics Committee on nutrition recommends the following: 1 mg/kg/d to a maximum of 15 mg in full term infants, starting after 4 months of life, 2 mg/kg/d to 15 mg maximum in LBW (low birth weight) babies, starting after 2 months and 4 mg/kg/d for very low birth weight babies (American Academy of Pediatrics, 1999). The WHO recommendations for iron supplementation to prevent iron deficiency in infants are the same for all infants younger than 24 months: 2 mg/kg/d, however, treatment is started earlier in low birth weight infants (2 months of age vs. 6 months in normal weight babies). Supplements are given up to the age of 23 months. The following recommendations are only for areas where prevalence of anaemia is above 40%: 2 mg/kg/d in children aged 24 to 59 months for a period of 3 months; 30 mg/kg/d for school-aged children for a treatment duration of 3 months (UNICEF/WHO, 1999).

#### **2.2.6 Role of iron in cell proliferation:**

Iron is indispensable for DNA synthesis and a host of metabolic effects. Iron starvation arrests proliferation because iron is required by ribonucleotide reductase and other enzymes. This role of iron is demonstrated in T-lymphocytes. Transferrin receptors, absent from resting T cells, are a marker of T cell activation. Initiation of cell division by a mitogen increases both transferrin receptor surface expression and iron uptake (Nathan & Orkin, 1998).

### **2.3 STAGES OF IRON DEFICIENCY:**

Development of iron deficiency proceeds through a series of steps. Iron deficiency without anaemia is when haemoglobin (Hb) synthesis is impaired but haemoglobin levels have not fallen sufficiently to meet the definition of anaemia.

The first stage entails depletion of iron stores and is characterised by reduced ferritin levels. This reflects a decrease in iron concentration in the liver, spleen and bone marrow. This is followed by iron deficient erythropoiesis (IDE) whereby erythroid iron supply is diminished but Hb remains in the normal range. There is reduction of mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) and low serum iron with low transferrin saturation. The third stage is iron deficiency anaemia (IDA) where the low iron supply restricts Hb production leading to the development of detectable anaemia. Features include low Hb, reduced red blood cell size and reduced transferrin saturation (< 16%) (Nathan & Orkin, 1998).

### **2.4 CAUSES OF IRON DEFICIENCY:**

Development of IDA in infancy and young children is related to several factors. Babies are born with low iron stores and this is further compromised by antenatal and perinatal factors. A normal full-term infant has sufficient iron stores for up to six months if small amounts are ingested daily.

Increased iron needs during rapid body growth e.g. in infancy and in very low birth weight preterm babies also results in IDA.

Inadequate iron absorption may be due to a diet low in bioavailable iron as in cow's milk ingestion before six months of age. Impaired absorption may also be due to intestinal malabsorption or inhibition of absorption by substances which chelate iron to form insoluble salts.

Blood loss is another factor which causes iron deficiency. In children this is caused by cow's milk enteropathy, worm infestation e.g. hookworm, inflammatory bowel disease, reflux esophagitis and food sensitivity. Other sources of blood loss are the pulmonary and urinary routes (Lanzkowsky, 1995).

## **2.5 DEFINITION OF ANAEMIA AND IRON DEFICIENCY ANAEMIA:**

The following table summarises the age related definitions of both conditions (adapted from WHO, 2005).

**Table 2.1:** Definition of anaemia and IDA in different age groups (WHO, 2005):

<b>Age (years) or gender group</b>	<b>Haemoglobin level (g/dl)</b>	<b>Ferritin level (µg/l)</b>
Children (0.50-4.99)	11.0	6-24
Children (5.00-11.99)	11.5	12-200
Children (12.00-14.99)	12.0	12-200
Non-pregnant women (≥15.00)	12.0	12-150
Pregnant women	11.0	12-200
Men (≥15.00)	13.0	12-300

For primary school going children, iron deficiency anaemia is a haemoglobin level of less than 11.5 g/dl and ferritin of less than 12 µg/l. Anaemia is further graded into mild (9.0-11.4 g/dl), moderate (6.0-8.9 g/dl) and severe (<6.0 g/dl) (WHO, 2000).

## **2.6 EFFECTS OF IRON DEFICIENCY ON BODY SYSTEMS:**

Iron deficiency anaemia is characterised by a defect in haemoglobin synthesis, resulting in red blood cells that are abnormally small (microcytosis) and contain a reduced amount of haemoglobin (hypochromic). The capacity of blood to deliver oxygen to body cells and tissues is thus reduced (Centers for Disease Control & Prevention, 1998).

Other cells of the body also require iron. Besides its importance in oxygen transport and delivery to tissues, iron is involved in energy metabolism, gene regulation, muscle oxygen use and storage, enzyme reactions, neurotransmitter synthesis and protein synthesis (Beard, 2001). Potential consequences of iron deficiency which occur in relation to severity include: decreased immune function, impaired temperature regulation, lowered endurance, increased rates of infection, impaired cognitive functioning and memory, decreased school performance and compromised growth and development (Wharton, 1999). Several studies have demonstrated the effects of iron deficiency anaemia on humoral, cell-mediated and non-specific immunity (Ekiz, Agaoglu, Karakas, et al., 2005).

Iron deficiency produces significant GIT abnormalities such as anorexia and malabsorption syndrome which contribute to growth failure. Some patients develop angular stomatitis and glossitis with painful swelling of the tongue. A rare complication of ID is the Plummer-Vinson syndrome with the formation of a postcricoid oesophageal web resulting in dysphagia. Pica is another complication of unknown pathophysiology whereby patients consume non-nutritious substances like clay, ice and laundry starch. Both the soil and starch bind to iron in the GIT exacerbating the deficiency (Nathan & Orkin, 1998).

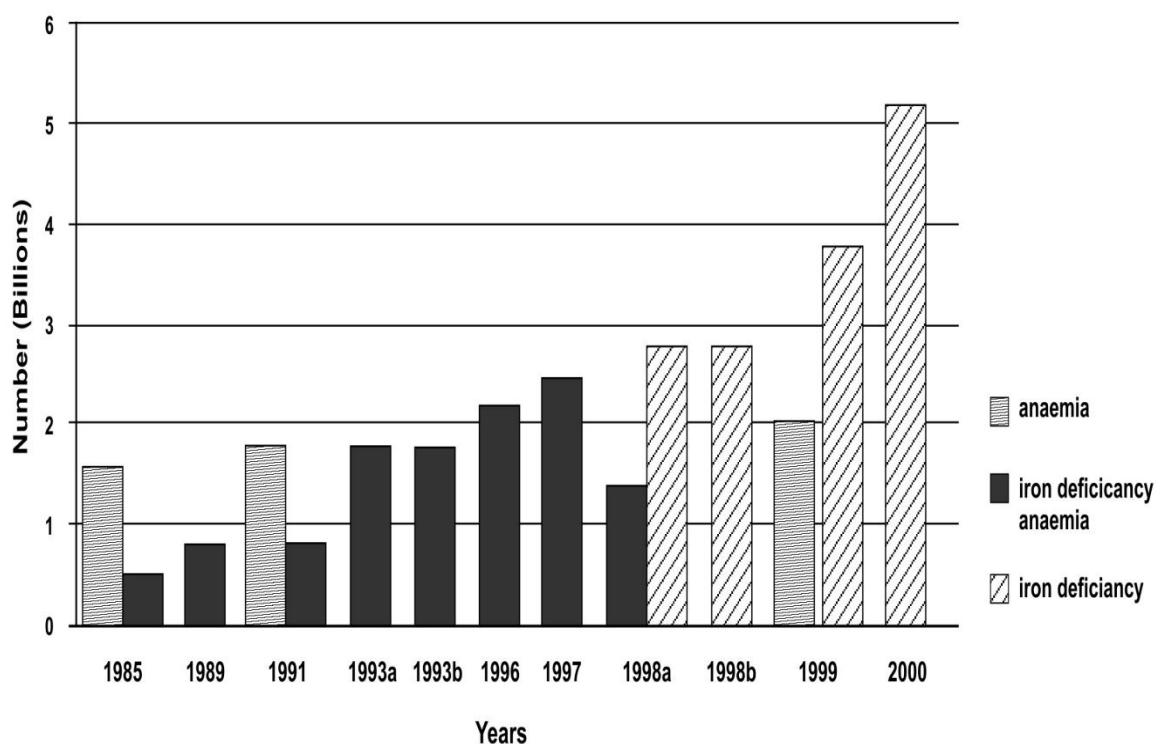
IDA also has a negative effect on physical growth. Growth hormone secretion is related to serum transferrin levels suggesting a positive correlation between iron-transferrin levels and an increase in glucose levels and weight (Walker, Wachs, Gardner, et al., 2007). Bobonis and colleagues evaluated the impact of a health intervention delivering iron supplements and de-worming drugs to two to six year old children through an existing school network in the slums of Delhi in India during the year 2000. The sample of pre-school children was randomly divided into groups: a comparison group without treatment and the treatment group. At baseline, Z-scores showed that 21% were stunted, 30% underweight and 24% were wasted with the treatment group having lower Z-scores. Weight significantly increased in the treatment group and more gains observed were in the low socio-economic status area. The pre-school participation rates also improved by 5.8% and a reduction of one fifth in school absenteeism was observed in the first five months of the programme. This study adds to the body of evidence that iron deficiency affects growth and general well-being (Bobonis, Miguel & Sharma, 2004).

Another important consequence of iron deficiency is the apparent increased risk of heavy metal poisoning in children. Absorption of heavy metals is increased in iron deficiency states as the body responds by increasing the absorption capacity of iron thereby secondarily affecting absorptive capacity of the other divalent metals as well, especially lead and cadmium (Beard, 2001).

## **2.7 PREVALENCE OF ANAEMIA, ID AND IDA IN THE WORLD:**

The world-wide trend of IDA has risen dramatically from 1985 to 2000 (see figure 2.1 below) and at a rate exceeding the global population growth (Stoltzfus, 2001). The magnitude of the problem of nutritional anaemia was first estimated in 1985. Anaemia attributed to iron deficiency was estimated to be 50%. In 1996, the Global Burden of Disease project adjusted the numbers upward based on the fact that the world population was increasing. In 1997-1998, three documents gave a higher prevalence of iron deficiency anaemia (2.1 billion). The UNICEF/UNU/WHO/MI (1999) Technical Workshop estimated that 3.5 billion people suffer from iron deficiency and IDA.

Since 1985, the definition of anaemia has changed from nutritional anaemia (of which iron deficiency is one important part) to iron deficiency anaemia as the major health problem. In 1993, a WHO/UNICEF/UNU consultation stated that anaemia is an indicator of iron deficiency rather than iron deficiency being considered a contributing cause of anaemia. However, even though iron deficiency is a major factor contributing to the anaemia problem, in parts of Africa, there are other factors that contribute to the problem, like other nutrient deficiencies such as folate and vitamin B<sub>12</sub>, malaria, human immunodeficiency virus (HIV), other infectious diseases and inherited anaemias (MI/UNICEF, 2003).



**Figure 2.1:** Estimates of number of people in world with anaemia, IDA and ID (Stoltzfus, 2001).

Table 2.2 below by WHO (2005) gives the global anaemia prevalence and population groups affected.

**Table 2.2:** Global anaemia prevalence and number of individuals affected (WHO, 2005):

Population group	% prevalence of anaemia	95% CI of prevalence of anaemia	Number of population affected(millions)	95% CI of population affected
Pre-school children	47.4	45.7-49.1	293	283-303
Scholl-age children	25.4	19.9-30.9	305	238-371
Pregnant women	41.8	39.9-43.8	56	54-59
Non-pregnant women	30.2	28.7-31.6	468	446-491
Men	12.7	8.6-16.9	260	175-345
Elderly	23.9	18.3-29.4	164	126-202
<b>Total population</b>	<b>24.8</b>	<b>22.9-26.7</b>	<b>1620</b>	<b>1500-1740</b>

The most recent statistics by WHO (2005) puts the globally anaemia prevalence at 1.62 billion people, which corresponds to one-quarter of the population. This shows that the total number of people with anaemia is decreasing, however, the trend of iron deficiency and iron deficiency

anaemia is increasing. The highest prevalence of anaemia is in pre-school children and lowest in men. WHO regional estimates generated for pre-school age children, pregnant and non-pregnant women indicate that the highest proportion of individuals affected are in Africa (see table 2.2 above).

## **2.8 PREVALENCE OF ANAEMIA AND IRON DEFICIENCY IN AFRICA:**

African statistics collected between 1998-2008 on the prevalence of anaemia, iron deficiency and iron deficiency anaemia in school children are summarised in table 2.3 below.

**Table 2.3:** African prevalence of anaemia, iron deficiency and iron deficiency anaemia (adapted from Banda, Khonje, Bobrow & Galloway, 2006):

<b>Study year</b>	<b>Country</b>	<b>N</b>	<b>Subjects (children)</b>	<b>Anaemia prev (%)</b>	<b>ID prev (%)</b>	<b>IDA prev (%)</b>
1998	Kenya (Embu district)	519	6-14 years	48.9	nr	nr
1999	Kenya (Marsmit district)	275	5-10 years	8	18.5	31.2
2000	Chad	1024	9-10 years	25.1	nr	nr
2000	Côte d'Ivoire	1014	4-16 years	nr	38.2	19.2
2000	Mali (Kolondieba district)	1113	Grade 4	55.8	nr	nr
2001	Zambia (Lusaka)	406	7-15 years	12	18.6	nr
2001	Egypt (Deshna & Armant)	1844	6-11 years	12	nr	nr
2002	Gambia (West Kiang)	472	7-9 years	10	nr	nr
2002	South Africa (KZN)	172	5-10 years	32	56	18
2004	Côte d'Ivoire (Dabou & Toumoudi)	281	Grade 1-5	nr	59.2	36.2
2004	Kenya (Malindi)	516	3-8 years	56	15	11
2005	Côte d'Ivoire (north, west, central & south)	1016	Mean age 9±2 years	39.4	19.7	11
2005	Ethiopia (national)	6118	7-12 years	6.2	nr	nr
2007	Rwanda (national)	7202	6-16	3.5	nr	nr

Key: nr means not recorded

The prevalence varies by region and country; few of the statistics were from national surveys. Some of the studies were done in urban areas, like Lusaka in Zambia, thus the lower prevalence. Considering the 2005 study in Côte d'Ivoire, the results are similar to the findings of the analysis by Best et al. (2010) given below, making the west African country number one on the list of countries with the burden of anaemia, ID and IDA.

In a recent review of several studies done in Africa, statistics of several countries were summarised. The African region was found to have the highest prevalence of anaemia when compared to Latin America, South-East Asia and Western Pacific. Rwanda and Ethiopia were found to have the lowest prevalences of anaemia (4% - Dushimimana, et al 2007 and 6% - Hall, et al 2008 respectively). Regional prevalence of anaemia for Côte d'Ivoire, Kenya and Mali was 40% or higher. Iron deficiency in Africa was found to be the highest (29%) when compared with the other areas mentioned above. The country with the highest prevalence of both iron deficiency and iron deficiency anaemia was Côte d'Ivoire where 59% of rural school children were iron deficient and 36% were having IDA (Best, Neufingerl, van Geel, et al., 2010).

## **2.9 PREVALENCE OF IRON DEFICIENCY IN SOUTH AFRICA:**

Several studies have been done in South Africa on the prevalence of IDA. In 1994-95 SAVACG (South African Vitamin C Consultative Group) did a survey on anaemia and iron status in children between six and seventy-one months old. The prevalence was found to be 5% nationally, using the criteria of Hb <11 g/dl and ferritin <12 µg/l. Before the SAVACG study, other smaller studies found higher prevalences of 10-15% of IDA in infants and young children. Statistics thus far vary by province with Limpopo having the highest percentage of IDA (Labadarios & van Middelkoop, 1995).

The prevalence of iron deficiency in South Africa is summarized in the following tables, adapted from Labadarios and van Middelkoop (1995).

**Table 2.4:** National estimated anaemia prevalence for children 6-71months in 1994 (Labadarios & van Middelkoop, 1995):

	<b>Definition</b>	<b>Prevalence (%)</b>	<b>Area/location/group</b>	<b>Sample size</b>
<b>Anaemia</b>	Hb <11 g/dl	21.4	National (6-71 months)	4494
<b>Iron deficiency</b>	Ferritin <12 µg/l	9.8	National (6-71 months)	4456
<b>IDA</b>	Hb <11 g/dl; ferritin <12µg/dl	5	National (6-71 months)	4206

The above table shows that a large number (961) of children had anaemia while 210 had iron deficiency anaemia. Iron deficiency was found in 437 children.

The following table (2.5) compares prevalence in the nine provinces to the national prevalence of anaemia, iron deficiency and iron deficiency anaemia. The prevalence of anaemia in the rural and urban areas did not show a wide variation, but when provinces were compared to the national prevalence, there were wide variations. The Limpopo province showed a high prevalence of

anaemia and iron deficiency anaemia. Children from the Western Cape had more iron deficiency compared to the other provinces and the province was second to Limpopo in having high prevalence of anaemia and iron deficiency anaemia. Mpumalanga came third in the leading prevalence of anaemia, iron deficiency and IDA. The survey did not investigate possible causes of these variations (Labadarios & van Middelkoop, 1995; MI/UNICEF, 2003).

**Table 2.5:** Prevalence of iron deficiency in 6-71 month old children in South Africa in 1994 (Labadarios & van Middelkoop, 1995):

Province	Sample size	% anaemic	% iron depleted	% IDA
South Africa	4206-4494	21.4	9.8	5.0
Rural	2107-2264	21.1	8.3	4.6
Urban	2032-2169	20.7	12.1	5.4
Eastern Cape	457-498	20.6	5.0	2.4
Free State	601-646	17.1	6.8	3.9
Gauteng	332-390	16.3	9.2	3.8
KwaZulu Natal	474-516	10.4	13.4	3.5
Limpopo	552-578	34.2	11.0	9.1
Mpumalanga	461-500	27.7	11.5	7.0
Northern Cape	475-513	21.5	10.9	6.5
North West	462-553	24.5	8.1	5.0
Western Cape	462-553	24.5	8.1	5.0

A study in the Ndunakazi community, in the KwaZulu Natal Province, done by Oelofse and colleagues concluded that there was a high prevalence of anaemia in the community and marginal vitamin A and iodine deficiencies. Questionnaires were used for socio-demographic, dietary and medical information including the number of children who died before the age of five. The level of education of the mothers was low and 54.5% had four or more children, however, most of the children died before 12 months of age (61.4%), with diarrhoeal diseases causing 67% of the deaths.

The study population consisted of six month to 11 years old and their mothers (127 mothers, 105 six month to 5.99 years old children and 131 6-11 years old children). Anthropometric data and blood samples for serum ferritin and folate were collected. Among pre-schoolers, anaemia was present in 23.8% and iron deficiency in 19.8%. In primary school children (6-11 years), 22% were anaemic and 7.1% had severe iron deficiency. Their results were attributed to poor dietary intake of iron rich foods. The study was followed by another intervention study aimed at addressing these nutritional deficiencies (Oelofse, Faber, Benadé, et al., 1999).

The National Food Consumption Survey (NFCS, 1999), conducted by Labadarios and colleagues in children one to nine years old (n=2894) found that one third of children were anaemic on the basis of haemoglobin concentration. The provinces worst affected by poor iron status were Free State, Mpumalanga, Limpopo and Western Cape. The prevalence of a poor iron status in the

children in the country appeared to have increased when compared with previous national data. These data formed the basis on which decisions on food fortification were made and legislated for in October 2003. Since that date, it is mandatory for manufacturers to add zinc, iron, vitamin A, thiamine, riboflavin and vitamin B<sub>6</sub> to maize and wheat bread flour (Labadarios, Steyn, Maunder, et al., 2000).

Another national survey was done between February and May 2005, as a fortification baseline (NFCS-FB-1), to check for prevalence of use of the fortified food products and knowledge, attitudes and practices regarding the use of such products and access to such products. They found that one out of seven children had poor iron status and that the prevalence has increased when comparison was done with previous national data. Provinces which were worse affected were Free State, Mpumalanga and the Western Cape (Labadarios, Swart, Maunder, et al., 2008).

Mamabolo, in 2001 and 2003, did a study in the Limpopo province to check if micronutrient deficiencies and stunting can be explained by diet. Assessment of children's diet was done at one year and three years of age by food frequency questionnaires. Blood samples were also analysed for haemoglobin, ferritin, vitamin B<sub>12</sub>, folate and red cell indices. A large proportion of the children were found to have iron deficiency (33%) and folate deficiency (20%). The high prevalence of iron deficiency at both one and three years was linked to low dietary intake of iron as the diet consumed was energy rich with low micronutrients, particularly iron and folate (Mamabolo, 2006).

Berry and Hendricks reported that the iron status of children in South Africa was deteriorating after conducting a study in 2005. They studied children between one to nine years of age from different socioeconomic backgrounds. Findings showed higher rates of iron deficiency in rural areas (13%), followed by informal settlement at 6%. Three provinces had higher prevalence rates than the national prevalence of 6%, with Free State having 18.9% iron deficient children. The national prevalence rate of iron deficiency anaemia (IDA) was 8%, but the 1-3 years age group was more than double the rate for children aged 1-9 years at 17%. Infants are prone to iron deficiency because their iron requirements, due to rapid growth and other factors outweigh their iron intake. As children younger than four years have higher rates of iron deficiency than older children, it is crucial to target interventions at this age group (Berry & Hendricks, 2005).

In October 2007, at the Global Health in a Globalized World Symposium in Virginia, Heckman presented a study done in Thohoyandou, Limpopo province in South Africa. He studied point prevalence and aetiology of anaemia among children under the age of five years at Thohoyandou Health Centre (Heckman, 2007). Anaemia was observed in 75% of the children; the mean haemoglobin was 9.65 g/dl. Girls were significantly more likely to be anaemic than boys (20/20 v. 19/31 respectively;  $p=0.001$ ) and anaemic children were significantly less likely to be underweight compared with their peers (32/38 v. 5/12 respectively;  $p=0.007$ ).

In 2008, a follow up study was done to investigate the prevalence of anaemia among mother-child pairs. The pairs were recruited from two clinic sites: Thohoyandou health centre and Pfanani clinic, both in suburban Thohoyandou. Children from 6-60 months were enrolled. The results showed that 76% of the children were anaemic with no significant differences in prevalence between the two clinics. There were no gender differences as in the 2007 study. Intestinal



helminths ( $p=1.000$ ), *Helicobacter pylori* ( $p=0.729$ ), food insecurity ( $p=0.515$ ), concomitant illness and other causes of anaemia did not significantly contribute to the rate observed in 2007. Malaria also did not play a role as the study was conducted during June and July when transmission rates are lowest. Only one child was found to have hookworm on stool analysis. (Heckman, Samie, Bessong, et al., 2010).

A survey of a randomised controlled trial was conducted by Faber (2007) in a rural area in KwaZulu Natal to determine anthropometric measurements, socio-demographic data and dietary intake of anaemic and non-anaemic infants aged 6-12 months. Her results showed a lower average weight gain per month in anaemic children. Three risk factors, low birth weight, young mother and consumption of tea were identified as risk factors associated with anaemia.

## **2.10 BIOLOGICAL EFFECTS OF ID AND IDA ON THE CENTRAL NERVOUS SYSTEM:**

Iron deficiency (ID) can cause morphologic, physiologic and biochemical changes in many organs before a drop in the haematocrit occurs. Therefore effects of ID are independent of symptoms of anaemia. Iron is required for several neurological metabolic processes including neurotransmitter synthesis, myelin formation and brain growth (Walker, Wachs, Gardner, et al., 2007). The highest iron concentrations in the adult brain are found in the basal ganglia, substantia nigra and deep cerebellar nuclei which are known to be involved in motor control and coordination. Iron deficient individuals show selective decrease in dopamine neurotransmission which is also involved in motor control. Dopamine is also involved in the prefrontal-striatal system which is involved in spatial/working memory and selective attention. Additionally, dopamine plays a role in intentional processing of environmental information. This evidence suggests that ID can potentially affect multiple cognitive functions including motor control, memory and attention. Such neurological changes would likely be expressed behaviourally in certain motor tasks, scholastic achievement and/or problem-solving skills (Lozoff, Jimenez, Hagen, et al., 2000).

An Event-Related Potential (ERP) study of attention and recognition memory in infants with iron deficiency anaemia provided further evidence on the effects of iron deficiency to the developing brain. Event-related potentials (ERPs) provide a non-invasive means for measuring transient changes in the brain's electrical activity in response to stimuli, allowing the evaluation of attention and memory in very young infants. In their study, Burden and colleagues collected artefact-free ERP data at nine and 12 months from 15 infants with IDA and 19 who were iron replete. They tested the infant's ability to discriminate a highly familiar stimulus, the mother's face from a stranger's face. Consistent with the age-appropriate pattern of development at nine months, the iron replete group showed a greater attentional response (negative component) to the mother and a greater updating of memory for the stranger (positive slow wave). The IDA group did not show similar responses until 12 months, suggesting a delay in cognitive development, which may reflect alterations in the efficiency of the central nervous system functions that seem to be related to early iron deficiency (Burden, Westerlund, Armony-Sivan, et al., 2007).

Iron is among the well-studied metals (with zinc and aluminium) with a role in neurological diseases like multiple sclerosis, Huntington's disease, Alzheimer's disease, Parkinson's disease and depression. Several studies were presented in the third International Metals and Brain

Symposium in Cape Town in 2005. Speakers presented evidence which show the long lasting effects of iron deficiency early in life on the central nervous system. Emphasis was placed on myelin deficits which lead to cognitive and motor impairment and disturbance of the neurotransmitter system with permanent altered brain function (Sensi & van Rensburg, 2005).

Iron deficiency is also linked to attention deficit hyperactivity disorder (ADHD). A clinical study was conducted in Paris, France between 2002 and 2003 on 110 children who were referred for school-related problems. The children were aged between four and 15 years. Fifty-three met the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) criteria for ADHD. Children with additional behavioural disorders, mental retardation, mood and anxiety disorders, physical diseases and malnutrition were excluded. Children who met the criteria for mild reading disability were used as age- and sex-matched controls. Serum ferritin levels were found to be twice as low in children with ADHD as in controls. There was no evidence of malnutrition or intestinal malabsorption in these children. As dopaminergic neurotransmission is affected by low brain iron levels, the hypothesis was that low ferritin levels might alter brain dopaminergic activity and contribute to ADHD symptoms. Another major finding in this study was that serum ferritin levels were inversely correlated with the severity of ADHD (Konofal, Lecendreux, Arnulf, et al., 2004). To support this hypothesis, a study done by Sever, Ashkenazi, Tyano et al. (1997), where ADHD children were treated with iron supplements, showed reduction in symptoms of ADHD and cognitive deficiency.

Anaemia alone without ID can cause cognitive dysfunction. This has been demonstrated in patients with renal dysfunction who displayed altered mental status, impaired cognitive function, decreased intellectual capacity and slowing of EEG waves. These changes correlated with decreases in hematocrit levels and were directly related to decreased brain oxygen. The treatment of anaemia with epoetin (synthetic erythropoietin) has improved cognitive function in patients with chronic renal failure (Stivelman, 2000). Correction of anaemia, partially or fully improves performance on cognitive tests and electrophysiological markers of cognitive function (Brunelli & Berns, 2009). Slickers and colleagues studied associations between chronic kidney disease and cognitive function. Children between age 7 and 19 years with chronic kidney disease were enrolled. A small percentage of subjects who had low haemoglobin levels ( $Hb < 11 \mu g/dl$ ) scored poorly in tests for memory and attention when compared to those who were not anaemic (Slickers, Duquette, Hooper, et al., 2007).

Anaemia was also identified as a factor in the neuro-cognitive outcome of children with chronic renal failure when studies related to neuro-cognitive and psycho-social impact of chronic renal failure in children were reviewed by Gerson and colleagues (Gerson, Butler, Moxey-Mims et al., 2006). Renal transplant seemed to improve these effects of anaemia on the brain as demonstrated by Mendly and Zelko. They administered intelligence tests to children pre-transplant and one year following renal transplant. Results showed improved memory, reaction time and attention (Mendly & Zelko, 1999).

## **2.11 ASSOCIATION OF ID AND IDA WITH SCHOOL PERFORMANCE AND INTELLIGENCE:**

### **2.11.1 Studies which showed negative association:**

Several studies suggest that ID at a young age can cause permanent detrimental effects. In a 10 year follow-up study in Costa Rica, infants who were initially iron deficient and anaemic were given consistent iron supplements over 10 years. The results of several motor and cognitive tasks were measured before and after treatment and compared to a control group. No improvement was seen in the treated group; moreover, these children showed more disciplinary problems and were more likely to repeat a grade (Lozoff, Jimenez, Hagen, et al., 2000). Contrarily, iron supplements given over 8 weeks have been shown to increase cognitive performance in iron deficient non-anaemic high school girls (Bruner, Joffe, Duggan, et al., 1996).

Further studies during adolescence were conducted to assess cognitive functioning after iron deficiency taking socioeconomic status into consideration. The results showed that the cognitive scores of participants who had chronic severe iron deficiency in infancy did not catch up over time compared to those who were iron replete before and/or after treatment in infancy. In addition, those from middle socioeconomic status families who had chronic iron deficiency in infancy, continued to have poor cognitive scores up to age 19 years. Those in lower socioeconomic status families seemed doubly burdened as the gap widened from 10 IQ points in infancy to 25 IQ points at the age of 19 years, thus indicating the value of preventing iron deficiency during infancy (Lozoff, Jimenez & Smith, 2006).

Idjradinata and Pollitt (1993) studied the effects of iron supplements on reversal of developmental delays. The study was a randomised, double-blind trial to monitor the effects of iron supplements on performance in Bayley scales of mental and motor development among 12-18 month old infants in Indonesia. IDA infants were assigned randomly to receive dietary iron sulphate or placebo for 4 months. Similar treatment randomization was given to non-anaemic ID and non-ID infants. Before intervention, mean mental scores of IDA infants were significantly lower than those of non-IDA and iron replete groups. After intervention, developmental delays were reversed among IDA infants who had received iron but remained the same in the placebo-treated group.

In Indonesia, in a double-blinded cross-over study, iron deficiency anaemic school children scored less in their motor and mental skills (88.5 and 88.8 respectively) compared to non-anaemic children (105.3 and 105.4 respectively). After receiving 3 mg/kg elemental iron daily for four months, the scores of the iron deficient group increased to 112.0 and 108.1 respectively. In a study of a group of Costa Rican children aged five years, those who had IDA in infancy were considered to be at risk for long-lasting developmental disadvantage as compared with their peers with better iron status. Lower mental scores persisted in infants with IDA despite extended oral iron therapy and excellent haematological response (Lozoff, Jimenez & Wolf, 1991).

Pollitt (1997) reviewed four studies on the educational progress of school-age children with iron deficiency anaemia in low income countries. The first study was done in Indonesia in children aged eight to thirteen years. Anaemic children were compared to non-anaemic subjects before and after intervention with ferrous sulphate to the IDA group and placebo to the non-anaemic group.

The Raven Progressive Matrices test was used to assess non-verbal intelligence. An educational assessment test which included mathematics, social science and language was administered pre- and post-intervention. At baseline, performance on the educational assessment test was better for the non-anaemic group. There was no significant difference on the IQ test between the two groups (97.7 vs. 98.9) at baseline. Following intervention for three months, iron-anaemic children showed improved IQ scores but performance on the educational assessment test did not improve.

The second study by Pollitt (1997) was done in Guatemala whereby the association between iron deficiency without anaemia and cognitive performance was assessed. The psycho-educational set of tests included the Raven Progressive Matrices for IQ and tests for literacy, numeracy and general knowledge. The children were also tested for reaction time, memory task and paired-association task. Differences were observed in only two of the tests: reaction time and the Raven Progressive Matrices. Iron depleted children responded slower to the memory test than the control group and low serum ferritin was associated with low IQ. The other two studies are discussed in the next section of those studies where no association was found.

Sunghong and colleagues studied school children in Thailand for the effects of haemoglobin and serum ferritin concentrations on cognitive function. The sample size was 427 school children from two schools in socio-economically deprived communities of southern Thailand. Cognitive function was measured by an IQ test and school performance by Thai language and mathematics scores. Linear regression models were used to investigate the effects of anaemia and iron deficiency on cognition and school performance. Results showed that children with IDA consistently had poor cognitive scores and below average scores for mathematics and Thai language. Non anaemic iron deficient pupils had high IQ and above average language and mathematics scores (Sunghong, Mosuwan, Chongsuvivatwong, et al., 2002).

In the United States of America, the National Health and Nutrition Survey III investigated the relationship between iron status and academic performance on more than 5000 children aged 6-16 years. Standardised mathematics scores were examined and children with iron deficiency with or without anaemia had lower scores than did children with normal iron status. Thus iron deficiency even without anaemia may place children at risk for cognitive delay (Halterman, Kaczorowski, Aligne, et al., 2000). In a meta-analysis of studies of the relationship between haemoglobin and IQ, Stoltzfus and co-workers estimated the IQ to be 1.73 points lower for each 1 g/dl decrease in haemoglobin. Haemoglobin data were supplied by WHO (Stoltzfus, Mullany & Black, 2004).

Studies on the effect of IDA on children's cognition and behaviour were selectively reviewed by Grantham-McGregor and Ani (2001), to look for evidence of a causal relationship. Most correlational studies found associations between IDA and poor cognitive and motor development and behavioural problems. Longitudinal studies consistently indicate that children anaemic in infancy continue to have poor cognition, school achievement and more behavioural problems into middle childhood. However, the possible confounding effects of poor socioeconomic backgrounds prevent inferences from being made. In anaemic children younger than two years, short term trials of iron treatment failed to show benefit to development, thus it was concluded that early treatment with iron is warranted especially in young children (Black, 2009).

More evidence of the negative correlation of IDA with cognitive function and school performance was presented by Aboussaleh and colleagues. A sample of 296 children aged 6-16 years was enrolled in a Moroccan primary school. Socio-economic data were considered and intellectual ability was assessed by the Raven's Progressive Matrices. School performance was assessed using mathematics scores and average annual school score. Iron deficiency was found in 20.4% of pupils and IDA in 7.7%. There was a negative correlation between low serum ferritin and mathematics scores and average annual scores. Socio-economic factors also appeared to be significantly related to academic performance as other factors which were considered, such as maternal level of education, negatively correlated to the rank of the child (Aboussaleh, Ahami, El Hioui, et al., 2009).

Walker, Wachs, Gardner, et al. (2007) studied risk factors for adverse outcomes in children in developing countries and generated enough evidence to support the role of psychosocial, parenting and contextual factors on child development, especially children's cognitive and socio-emotional competence. Thus the outcome of iron deficient children is affected by several factors like low socio-economic status, poverty, lack of maternal warmth and other home stimulation, poor maternal education and IQ, maternal depression, absent fathers, low birth weight, parasitic infections, increased blood lead levels and over-all poor nutrition.

#### **2.11.2 Studies which found no association:**

The remaining two studies by Pollitt (1997) were done in Egypt and Thailand. The Egyptian study tested effects of iron anaemia on cognitive style of primary school children and findings showed no significant difference between the iron deficient anaemic and the control group on Continuous Performance Test and the Peabody Picture Vocabulary Test. The Thailand study assessed the effects of iron treatment on psycho-educational performance, following sixteen weeks of iron therapy. The IQ scores and educational achievement in mathematics and Thai language did not improve following therapy.

Antunes and colleagues conducted an eight year prospective study of IDA in Portuguese infants from Sao Marcos hospital during 1994-2000. Their definition of IDA was Hb <11.0 g/dl and ferritin of <12 µg/l. The Griffiths scales of mental development and school performance reports were analysed at eight years of age. Their results showed no significant difference in school performance at eight years of age between cases and controls. The only scale on the Griffiths test with a significant difference between IDA and non-IDA children was the eye-hand scale where IDA was associated with a decrease in eye-hand scale (Antunes, Gonçalves, Santos, et al., 2005).

A more recent study reported contradictory results to most of the studies. Dissanayake and colleagues studied the relationship between iron status and cognitive function among adolescents aged 13-15 years in Sri Lanka. Each iron deficient student was matched with an iron replete student of the same school, class and sex. Marks for mathematics, science, local language and social sciences were considered to assess educational performance during the third term. Intelligence was measured by Raven's Standard Progressive Matrices. Their results showed no significant relationship between intelligence and iron status. Marks obtained by students with IDA, ID without anaemia and students with moderate to severe IDA were compared with marks of matched iron replete students. No significant differences in educational performance were

observed between the groups. Their conclusion was that iron status does not play a major role in educational performance and intelligence of school going adolescents and that other factors affect educational performance and intelligence (Dissanayake, Kumarisiri, Nugegoda, et al., 2009).

The following table below (2.6) shows how the different cognitive scales used at different age groups are affected by iron deficiency anaemia.

**Table 2.6:** Age-related tests for cognitive development (Batra & Sood, 2005):

Age	Instrument	Description of test	Outcome
6-30 months	Bayley Scales of infant development	Measures mental and motor development. Tests development in three domains: cognitive, motor and behavioural	Anaemic children were found to have significantly reduced scores
36-84 months	Peabody picture vocabulary test (PPVT)	Assesses verbal intelligence Involves use of black and white pictures which are numbered Child is given a word and must identify picture which corresponds to word Scores are given in percentiles	Scores were reduced in anaemic children
School age	Arithmetic and other school assessment tests developed from school curriculum	Battery including tests of literacy, reading comprehension, numeracy and general knowledge	Scores in all parameters were reduced in anaemic children
	Peabody picture vocabulary test	Description given above Can be used from 2 years until adulthood	Scores were reduced in anaemic children
	Raven Progressive Matrices	Tests age-related non-verbal intelligence and uses picture puzzles	Raven scores were also reduced in anaemic children

For school-aged children, the most appropriate tests for intelligence are those which assess non-verbal IQ and picture vocabulary. For educational assessment, achievement in subjects administered per educational policy such as mathematics, reading and general knowledge are used.

## **2.12 ID AND IDA AND SCHOOL PERFORMANCE/COGNITIVE PERFORMANCE IN SOUTH AFRICA**

In South Africa there is limited data on the association of anaemia, iron deficiency and iron deficiency anaemia and school performance and cognitive function. The following discussion

summarises the only two studies which investigated effects of micro-nutrient deficiencies on growth, health, school performance and cognitive function of school children.

In their study on the effect of iron, iodine and  $\beta$ -carotene fortified biscuits on micronutrient status of primary school children, van Stuijvenberg and co-workers concluded that consumption of the fortified biscuit resulted in significant improvement in the micronutrient status and also appeared to have a favourable effect on morbidity and cognitive function of the school children. The study population (n=126 intervention & n=126 control) consisted of children aged 6-11 years in grade 1-5 of the Ndunakazi Primary School in rural KwaZulu-Natal. This community is characterised by low socio-economic status. Biscuits were supplied on a daily basis (school days only) with a cold drink to supply vitamin C. Micronutrient status was assessed at baseline and six and 12 months after the study began. All children were de-wormed with 400mg of albendazole at four month intervals for the duration of the study (215 school days), to exclude parasitic infestation as a confounding factor (van Stuijvenberg, Kvalsvig, Faber, et al., 1999).

Cognitive tests were designed to measure a range of mental processes and fine motor skills (adapted from guidelines by Connolly & Grantham-McGregor, 1993). These included verbal learning, visual memory, arousal, attention, retrieval, eye-hand perception and coordination. Results after 12 months intervention showed a decrease in the percentage of children with low serum ferritin from 23.8% to 13.9% in the study group. Prevalence of anaemia decreased from 29.6% to 15.6% in the intervention group. The cognitive tests showed a significant difference ( $p < 0.05$ ) between pupils who received treatment and those that did not in the short term memory and attention assessment only (van Stuijvenberg, Kvalsvig, Faber, et al., 1999).

In 2000 a study was done to estimate the burden of disease due to IDA nationally by Nojilana and colleagues. They found a prevalence of IDA of 5.1% in children under the age of five years which was comparable to the SAVACG study done in 1994. They estimated intelligence quotient (IQ) points by using the shift in the mean haemoglobin as described by Stoltzfus et al (2004) and then estimated the proportion of children with mild mental disability (MMD). Their results showed a very small percentage rate (0.14%) of MMD due to iron deficiency anaemia. This was used to calculate disability-adjusted life years (DALYs) due to MMD and 17% was attributed to IDA. It was concluded that IDA is a less serious public health problem in South Africa compared to other developing countries and that it is a preventable burden with food fortification. (Nojilana, Norman, Dhansay et al., 2007).

### **2.13 CONCLUSION:**

The above statistics show a high world-wide prevalence of anaemia and iron deficiency anaemia. Although the anaemia prevalence seems to be decreasing, the iron deficiency statistics are increasing. Since anaemia is caused by several infections like malaria, HIV, worm infestations etc., the downward trend could be related to the control of such diseases especially in Africa. In South Africa, the prevalence of both anaemia and iron deficiency is increasing. Studies have attributed this increase to both disease burden such as HIV and to nutritional insufficiency. The reviewed studies also highlighted a provincial variation which puts the poor provinces at high risk for both anaemia and iron deficiency. The emergence of squatter camps in the peri-urban areas seemed to have perpetuated the problem as the informal settlements were found to have the highest

prevalence of iron deficiency and IDA when compared to both rural farming areas and urban areas.

Iron deficiency and iron deficiency anaemia are associated with several detrimental effects to child development and general wellbeing of the entire population as highlighted above. The above studies provide a huge body of evidence of the vulnerability of developing countries to the problem of iron deficiency which is often overlooked, yet causing reduced developmental outcomes, impaired intelligence, reduced growth in children and reduced work potentials in adults. Despite these facts, the association of iron deficiency and iron deficiency anaemia on academic and cognitive performance is not well studied in South Africa as shown by the above studies. Most of these studies investigated the prevalence of anaemia, iron deficiency and IDA and their association with poor growth. International studies, however, indicate a need for more research on the subject which motivated the current study.

The following chapters describe the first study that investigated the association between anaemia and iron deficiency anaemia on academic performance and cognitive function of school children in South Africa.



## **CHAPTER 3 - METHODS**

### **3.1 INTRODUCTION:**

This chapter provides a description of the research design and the methods utilized in the collection of the data. The research sample is delineated in terms of the sample frame, the sampling process and the sample demographics. The research instrument is described with an account of reliability and validity. The procedure for data collection is described followed by an account of the statistical analysis procedures used to analyse the data and ethical considerations of the study.

### **3.2 STUDY DESIGN:**

The study was conducted using a quantitative approach. The design used in this study was a case-control observational design.

### **3.3 RESEARCH SAMPLE:**

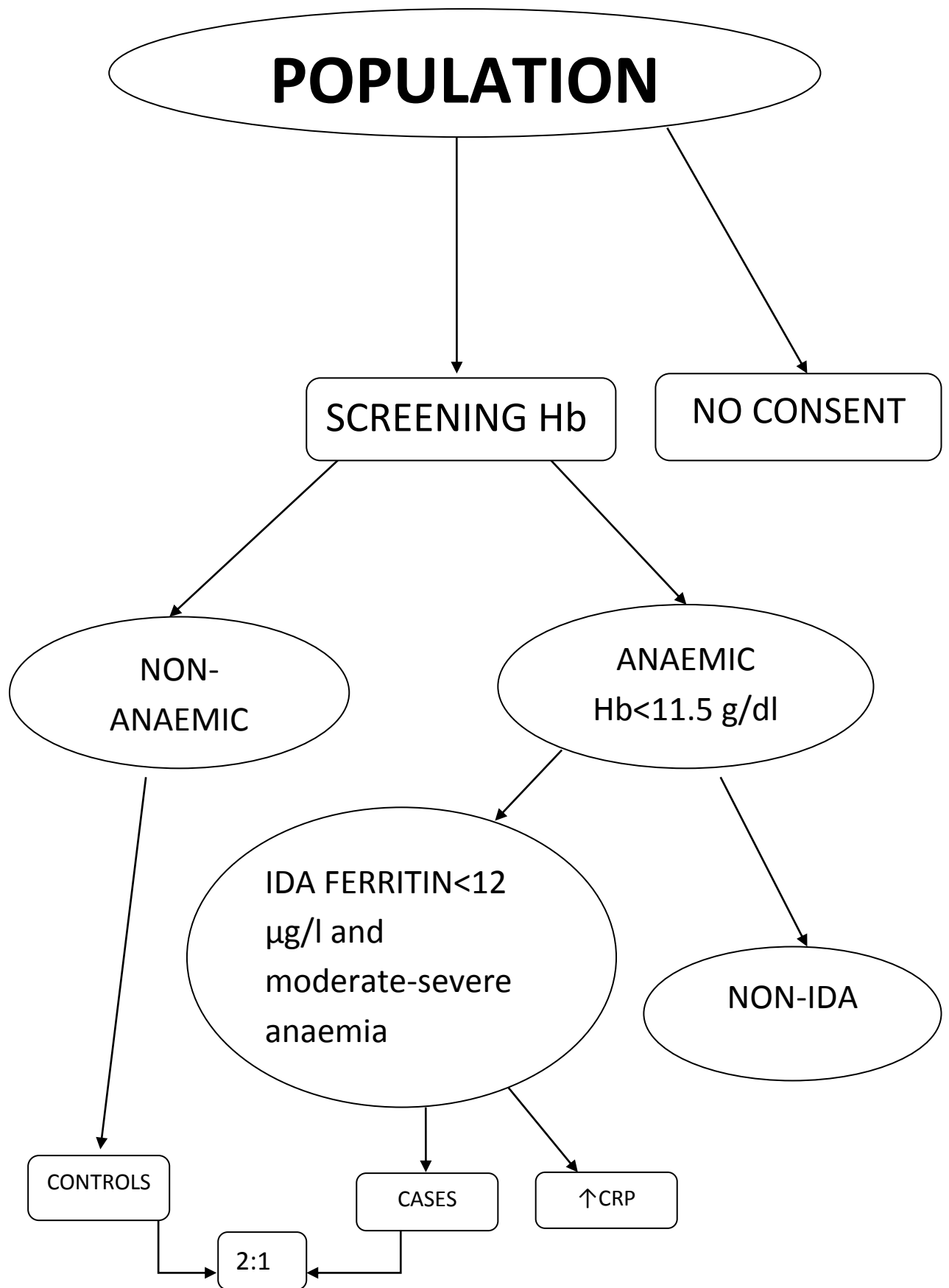
#### **3.3.1 Sample frame and setting:**

The sample was derived from a target population of primary school-going children doing grade 2 in three public sector primary schools in Winterveldt (Tidimalong, Philemon Montsho and Refilwe primary school), north of Tshwane in the Gauteng province of South Africa. Winterveldt is a historically disadvantaged peri-urban area which is typically characterised by poverty, low standards of living and low socio-economic conditions.

#### **3.3.2 Sample selection:**

A purposeful sampling procedure was used to select three schools from the targeted area. The schools are located about 25 km from the University of Limpopo (Medunsa Campus) and close to the tarred road. After all the ethical considerations were observed (Appendix 1-parental consent), the screening procedure was completed with the grade 2 learners (Jan 2010 to Feb 2010). Screening was done using a finger prick Hb meter. Two groups resulted from this screening procedure: group A with no anaemia (Hb >11.5 g/dl) and group B with anaemia. Further testing was done on the anaemic group to check for iron status, using ferritin and C-reactive protein (CRP). After blood results were available, cases and controls were recruited at a 1:2 ratio (one case: two controls) by matching anthropometry. Cases were the pupils with ferritin lower than 12 µg/l and those with moderate to severe non-IDA anaemia. Controls were taken from group A (non-anaemic group). A control match was a subject whose weight and height were as close as possible to that of the case regardless of gender. Age was also considered during the matching process as haemoglobin increases by age, although by definition 6-11years olds must have Hb <11.5 g/dl to qualify as anaemic (WHO, 2005).

Figure 3.1 below shows a schematic presentation of the sample screening process.



**Figure 3.1:** A schematic presentation of the sampling procedure.

### 3.3.3 Research instruments:

The following instruments were used for data collection for this study:

#### Stadiometer and electronic scale:

The stadiometer used was the SECA model 214, manufactured by Medizinische Waagen und Messsysteme, Hamburg, Germany. It is a portable stadiometer which is easy to assemble and requires a flat surface to accurately measure height. Weight was measured using the Safeway electronic scale model EB727 by Clicks, Cape Town, South Africa. The scale is digital and records weight to the nearest decimetre.

#### HemoCue 201+ Haemoglobin meter:

The Hb 201+ Photometer model used is manufactured by HemoCue AB, Angelholm Sweden and was acquired via HemoCue SA, Bryanston who also supplied the cuvettes, safety lancets and cleaners for the meter. This instrument was used for screening of all pupils with parental consent by the researcher. The test entails collecting a drop of blood by finger prick onto a test strip with immediate haemoglobin value displayed. The HemoCue Hb 201+ meter provides quick, simple and accurate quantitative haemoglobin results with the same performance as a large haematology analyser (WHO/UNICEF/UNU, 2001; Ferreira, da Silva-Nunes, Bertolino, et al., 2007; Ali, Fathy, Fathy, et al., 2011; Heckman, 2007).

#### School reports:

Official grade 1 school reports were collected from each school after cases and controls were identified and recruited. All reports were of the standard format that is prescribed for all public primary schools in South Africa. A national coding system is used for all the foundation phases and pupils are tested on 3 areas: literacy (languages), numeracy (mathematics) and life skills (life orientation). The rating scores range from 1 to 4 where 1 means that competence was not achieved, 2 for partial achievement, 3 for satisfactory achievement and 4 means excellent achievement. Assessment is done for each of the four terms of the school year. The maximum total for each term (Term 1, 2, 3 and 4) is 12 points.

#### Psychometric instrument:

The psychometric instrument used for this study was the Raven's Coloured Progressive Matrices (RCPM) - Appendix VII. This test is a culture-fair test and designed to test non-verbal intelligence. It can be used in children between the ages of 5.5 and 11.5 years (Raven & Court, 2004). It purports to assess the educative component of intelligence. It is regarded as a suitable and effective assessment tool in multicultural context and is a very popular test in developing countries. It has been used extensively in South Africa (Knoetze, Bass & Steele, 2005).

The RCPM is an easily administered, multiple-choice pencil and paper test. It comprises three sets of twelve matrix designs arranged to assess mental development -

“up to a stage when the person is sufficiently able to reason by analogy to adopt this way of thinking as a consistent method of inference” (Knoetze, Bass & Steele, 2005).

Each design is printed with a brightly coloured background making the test more appealing to children. The respondent is shown a series of patterns with parts missing. The missing parts have a simple shape and are below the matrix, among other similarly shaped pieces. The items are arranged in increasing level of difficulty. The respondent can either point to the missing pattern or record its corresponding number on a record form.

Interpretation of the RCPM percentiles is as follows:

- i. 5 means very low intellectual function
- ii. 10 is below average intellectual capacity
- iii. 25-50 means intellectually average
- iv. 75 above average intellectual capacity

The test instructions were translated into seTswana since it is the most common language used by the community of Winterveldt. Translation was done and verified by language experts in line with Vass's recommendations (Vass, 1992).

#### 3.3.4 Bias, reliability and validity of the instruments:

The reliability of the RCPM is reported to be high (Knoetze, Bass & Steele, 2005). It has been widely used in South Africa mainly by educational psychologists and there have been attempt to develop norms with South African populations of children.

Regarding the selection of participants, bias was minimized by using anthropometry and age range for both case and control groups. Sampling bias was unavoidable as we used only pupils with parental consent.

The HemoCue Hb201+ meter offers important benefits like simplicity, speed, the requirement of only a small volume of blood together with laboratory precision and accuracy. It has an internal electronic self-test. Each time the analyser is turned on, it will automatically verify the performance of the optronic unit and this is done every second hour if the analyser is on. Other benefits include no calibration between cuvette batches and it can automatically compensate for turbidity due to lipids and leukocytosis (Hemocue.com, 2004).

The researcher was aware of a possible confounding factor that could have an effect on the laboratory studies, which was the fact that ferritin is an acute phase reactant which can be elevated in any form of acute inflammation. This could have resulted in a false negative IDA. This confounding factor was minimized by including C-reactive protein which is a marker of acute infection/inflammation.

### **3.4 DATA COLLECTION PROCEDURE:**

The Gauteng Department of Education was contacted and a written letter of permission was provided to conduct the study in the three primary schools of the Winterveldt region. The Education Department of the Sub district, Tshwane West, was also consulted (Appendix IX and X). The three primary schools were thereafter contacted by the researcher. A parental gathering was called by the principal in each school for all parents of grade two learners. The researcher

verbally explained the details of the research and issued the participant information leaflet which was in both English and Setswana languages to all parents (Appendix II). Parents were also given a chance to ask questions, after which the consent form was signed by those who were willing to enrol the children. Next, all the necessary arrangements were made to commence with data collection. All data collection was done after school hours.

#### 3.4.1 Phase 1: Screening:

Screening was done by the researcher with the assistance of two professional nurses who specifically assisted with anthropometry measurements, as well as two BSc students who assisted with paper work such as allocation of study numbers and filling of laboratory forms for blood specimens. The nurses were selected randomly by availability from the paediatric ward of the teaching hospital. The BSc students were also selected on the basis of availability to assist the researcher.

Screening was done using the Hemocue 201+ haemoglobin meter under aseptic conditions. Weight to the nearest decigram and height to the nearest millimetre were measured. These measurements were done twice to ensure data quality. Learners were weighed without shoes and heavy clothing like jerseys and jackets. Study numbers were allocated from 1-194. Pupils' names were included in this initial screening but recorded at the back of the data sheet for easy identification during case and control sampling. Only the researcher had access to the data sheet to ensure confidentiality (Appendix VI).

Only participants who were found to be anaemic were enrolled for iron status testing. Blood for ferritin levels and CRP was collected to define IDA (4ml of blood per subject). C-reactive protein was done to rule out acute infection / inflammation which could have resulted in falsely elevated ferritin. All blood samples were immediately put in a cooler box and transported to the teaching hospital's National Health Laboratory Services (NHLS) as soon as possible for further testing. Blood results were recorded on the data sheet (Appendix VI). Once blood results were available, the researcher allocated participants into either case group or control group. In addition to the pupils who had ferritin  $< 12 \mu\text{g/l}$  and CRP  $< 10 \text{mg/l}$  pupils with severe anaemia but with normal ferritin levels were also included in the experimental group to ensure proper follow up and these were labelled non-IDA anaemia. Thus a case refers to those participants with IDA and also to those subjects with severe non-IDA anaemia.

#### 3.4.2 Phase 2: Data on academic and intellectual performances

Phase 2 of data collection was done by the researcher with the assistance of a registered psychologist from the Department of Psychology of the University of Limpopo (Medunsa Campus). Data on participant's academic performances were collected from school reports which were provided by the participating schools. Copies of school reports were given to the researcher by the class teachers of the respective schools. The researcher then used the copies to collate all the information relevant for the study (Appendix VI).

Data on participants' cognitive functioning were collected by the researcher together with the registered psychologist. The three schools were tested separately; however, one class was used for

each school to test all participants in that school. The RCPM was used as a tool and testing was done after school in the presence of class teachers who helped with the translation of instructions. Each participant was seated at a separate table and enough space was provided in between the tables to prevent participants from copying from each other. The record forms and the test items were handed to each participant. The instruction phase was handled by the psychologist following standardised test procedures. At the end of the testing, the record forms were collected and taken for scoring and interpretation by the psychologist.

### **3.5 DATA MANAGEMENT AND ANALYSIS:**

#### **3.5.1 Data entry and checking:**

The Epi Info software (version 3.4.3, November, 2007) was used to analyse the results of the study. Information from the data collection sheet (Appendix VI) i.e. the study number, anthropometry, screening Hb, blood tests and marks from school reports were entered twice to ensure data quality. The results of the psychometric test were entered after analysis was done by the educational psychologist. Anthropometric data were entered as the average of the two measurements. School marks were entered as an average of the term mark per subject using the national coding of score 1-4 (explained under research instruments). A new cell was created to indicate whether the subject was a control or case, to allow for comparisons between the two groups.

The researcher entered the all the data initially and one of the assistants (BSc student) entered the same data into a different computer file for the second time. The Data Compare Module of the Epi Info was used to check for differences between the two sets of data and corrections were done.

#### **3.5.2 Statistical analysis:**

The Epi Info software was also used to verify the nutritional status of our participants by using the Nutrition Program to compare the data with the percentiles from the Centers for Disease and Control reference data from the National Center of Health Statistics (NCHS, 2008). The definition for stunting is less than 2 SD below the median or less than the 5<sup>th</sup> percentile and the same definition applies for underweight. The 50<sup>th</sup> percentile is taken as the population median. Only data from the final study population of 90 pupils were entered and analysed (Mcdowell, Fryar, Ogden, et al., 2008). Weight-for-age (W/A) and height-for-age (H/A) were computed.

The Chi Square Test was used to test for associations between the variables and to compare the two groups. Comparisons were done between controls and cases in the following sets of data, viz: academic scores, RCPM scores, IDA and cognitive function, anthropometry and RCPM scores and lastly gender and RCPM scores. The 95% confidence interval (CI) was used to test for significance.

Other calculations included the means of weight, height, Hb, ferritin, CRP, the RCPM score and school marks. The range and standard deviation were also calculated. Totals of gender and group categories were done, as well as frequencies of other parameters like IDA and anaemia.

### **3.6 ETHICAL CONSIDERATIONS:**

Permission to conduct the study was granted by the Gauteng Department of Education (Appendix IX) as well as local education office, Tshwane West District Director (Appendix X) and the management of the schools involved. Ethical clearance was granted by the Medunsa Research and Ethical Committee (Appendix VIII).

The study was voluntary. There was a parental gathering where verbal and written information and explanation of the study was given (Appendix II). Parents who were willing to enrol their children signed a translated consent form (Appendix I). Participants were allowed to withdraw from the study at any time with no influence on future intervention or schooling. Feedback letters were written to the parents following screening, after selection of controls to inform them that pupils were to be used for comparison and after blood results for those pupils who required follow up in the hospital by the researcher (Appendices III, IV and V).

Pupils who had IDA and severe anaemia were referred to the University hospital - Dr George Mkhari where they were seen by the researcher on Wednesdays only. Further tests including full blood count (FBC) and human immunodeficiency virus (HIV) Elisa were done. Patients with proven iron deficiency anaemia were started on iron supplements as per the guidelines for weight (10-18 kg: 200 mg FeSO<sub>4</sub>; 18-25 kg: 300 mg FeSO<sub>4</sub> and 25-30 kg: 400 mg FeSO<sub>4</sub>) and vitamin C (to improve absorption of iron), referred to the local clinic for monthly treatment and given a six months follow up date. However, some patients could not come to the hospital due to financial constraints.

Results of the study were made available to parents and caregivers to ensure intervention with iron supplements as necessary. The publication will be strictly confidential and the data will be stored for a minimum of five years.

The following chapter presents the results of study.

## CHAPTER 4 - RESULTS

### 4.1 SAMPLE DEMOGRAPHICS:

There were a total of 383 grade 2 pupils in the three schools. The first school had four grade 2 classes with 123 pupils, 73 were males and 50 females, the second school had three grade 2 classes and a total of 151 pupils of which 83 were males and 79 females and the third school had 3 grade 2 classes with 112 pupils, 61 were male and 51 female. The sampling procedure results are illustrated by figure 4.1 below.

Following permission from parents, 194 learners were enrolled at screening for anaemia using Hemocue Hb meter needle prick test. There were 119 pupils with normal Hb by definition (WHO, 2005): Hb >11.5 g/dl for 6-12 year olds regardless of gender). Seventy-five were found to be anaemic and qualified for iron studies. Of the 75, 19 had IDA (ferritin <12 µg/l and CRP <10 mg/l). Fifty six had normal ferritin levels, however 11 had severe anaemia (Hb <10 g/dl) and were thus also included in the cases.

For recruiting controls, a 1:2 ratio (one case to two controls) was used, resulting to a final study sample of 90 participants comprising of 30 cases (experimental group) and 60 controls as shown in table 4.1 below.

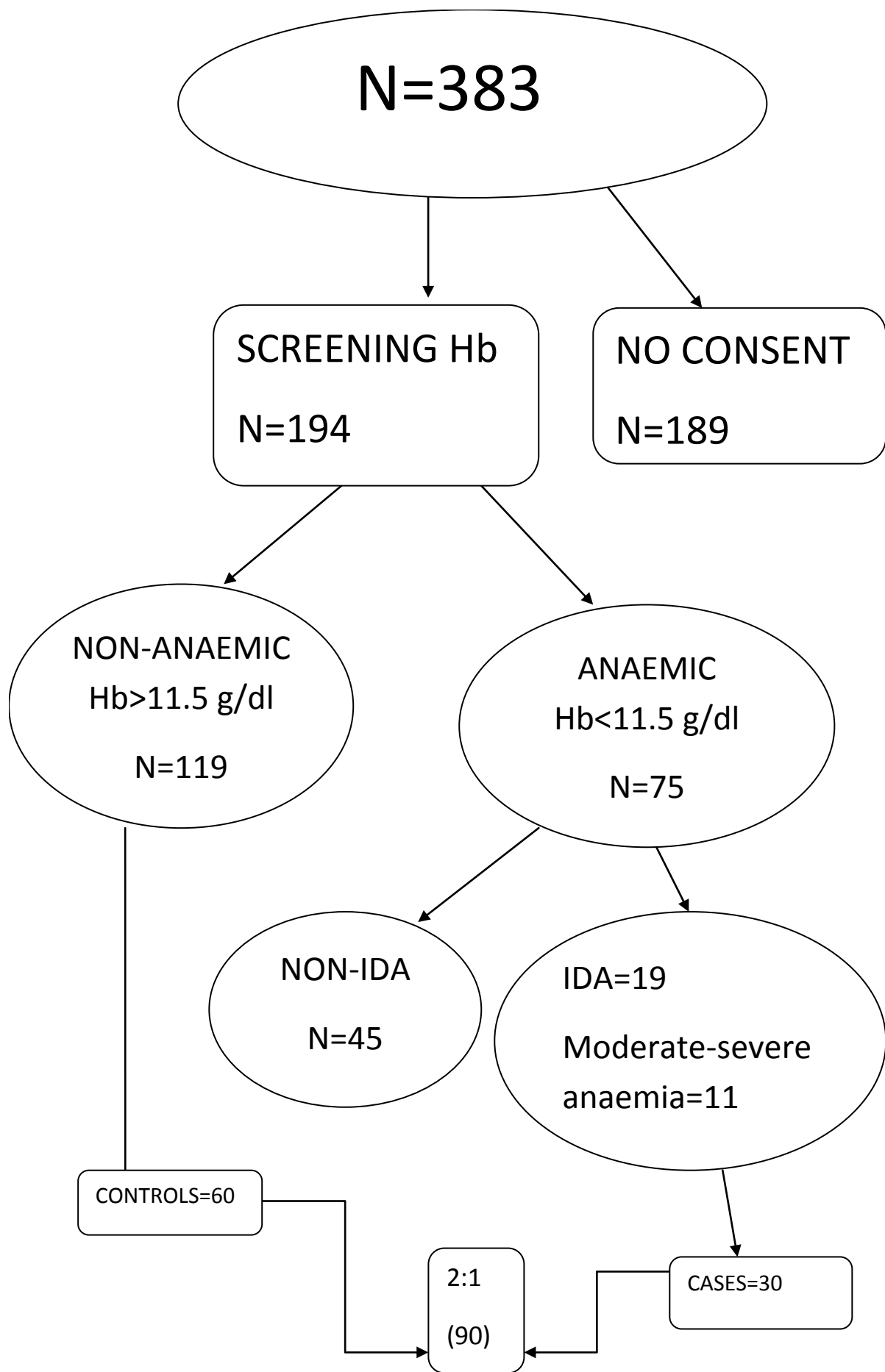
**Table 4.1:** Total number of participants:

	<b>Participants</b>	<b>Females</b>	<b>Males</b>	<b>Total</b>
<b>Control group</b>	60	33	27	60
<b>Experimental group IDA</b>	19	12	7	30
<b>Anaemia</b>	11	6	5	
<b>Total participants</b>	90	51	39	90

The controls were pupils who were not anaemic, matched closely with the case using age, height and weight. Gender was disregarded as there is no gender difference in haemoglobin for children less than 12 years of age.

Exclusion of pupils from total of 383 is explained as follows: (figure 4.1 below)





**Figure 4.1** Results of the sampling procedure.

#### **4.2 DISTRIBUTION OF SAMPLE VARIABLES AMONG THE 3 SCHOOLS:**

The final study population in the first school, Tidimalong Primary School was 33 pupils, of which 16 were girls and 17 were boys. Six pupils had non-IDA anaemia (three females and three males) and five had IDA (all males), making a total of **11 cases**.

The second school, Philemon Montsho Primary School had 30 participants out of the 151 total number of grade two's. Twenty were females and 10 were males. Of the **10 cases**, only three (two females and one male) had non-IDA anaemia and seven had IDA (six females and one male).

The last school, Refilwe Primary School, had 27 pupils making up the final study population out of the total of 112 grade two pupils. Fifteen were females and 12 were males. **Cases were made up of nine pupils** and only two had non-IDA anaemia (1 male and 1 female) and the rest had IDA (5 females and 2 males).

The total sample (90) consisted of 51 females and 39 males. Females comprised 17 cases and 13 cases were male, making a total of **30 cases**.

#### **4.3 ANTHROPOMETRY:**

Table 4.2 below summarises anthropometry of the final participants. The means for both weight and height did not differ statistically significantly between males and females ( $p>0.05$ ). There were also no statistically significant differences between the anthropometry of the cases and controls ( $p>0.05$ ).

**TABLE 4.2:** Summary of anthropometry (n=90):

	<b>Female N=51</b>	<b>Male N=39</b>	<b>Total (n=90)</b>	<b>Cases (n=30)</b>	<b>Controls (n=60)</b>
<b>Weight (kg)</b>					
Mean	20.47	20.97	20.69	20.74	20.78
Median	20.20	20.50	20.35	20.50	20.40
Standard deviation	2.43	2.76	2.57	2.66	2.52
<b>Height (cm)</b>					
Mean	116.86	116.83	116.85	117.28	117.32
Median	116.00	116.50	116.35	117.00	117.20
Standard deviation	4.76	4.89	4.79	4.67	4.84

The anthropometric status of the pupils was compared with the CDC's National Center for Health Statistics data and the results are summarised in the following table (Table 4.3).

**TABLE 4.3:** Interpretation of the anthropometric status of the pupils (n=90):

Anthropometric parameter	% < -2SD/ %/ 5 <sup>th</sup> percentile	% < 50 <sup>th</sup> percentile
W/A	23 %	85.1%
H/A	19.3%	81.8%

There were no significant differences between cases and controls with regard to both stunting and under-weight ( $p=0.863$  for height and  $p=0.368$  for weight).

The age range for the cases and controls was 6-8years. Age was rounded up to the nearest year, yielding three categories, six years (38 pupils), seven years (49 pupils) and eight years (three pupils).

#### **4.4 HAEMOGLOBIN LEVELS:**

The overall range of haemoglobin at screening was 8.3-14.3 g/dl with a mean of 11.7 g/dl for the 194 pupils enrolled. Females had a range of 8.6-12.5 g/dl with mean haemoglobin of 11.8 g/dl. Haemoglobin levels ranged from 8.3-14.3 g/dl in males with a mean of 11.7 g/dl. The mean haemoglobin did not differ between males and females ( $p >0.05$ ).

Table 4.4 below shows that 19 pupils were iron deficient and 11 had severe anaemia but were iron replete. The mean haemoglobin of the final study population (n=90) was 11.8 g/dl.

**TABLE 4.4:** Summary of the blood test results of cases and controls:

Hb level g/dl	Cases	Controls	Total	Ferritin levels $\mu\text{g/l}$	Cases	CRP values mg/l	Cases
<10	11	0	11	<12.0	19	<1.0	22
10-11.4	19	0	19	12.1-30.0	6	1.0-10.0	8
$\geq 11.5$	0	60	60	>30.0	5	>10.0	0
Mean	10.19	12.58	11.8	Mean	15.30	Mean	1.8
SD	0.858			SD	12.555	SD	1.69
Total			90	Total	30	Total	30

#### **4.5 FERRITIN LEVELS:**

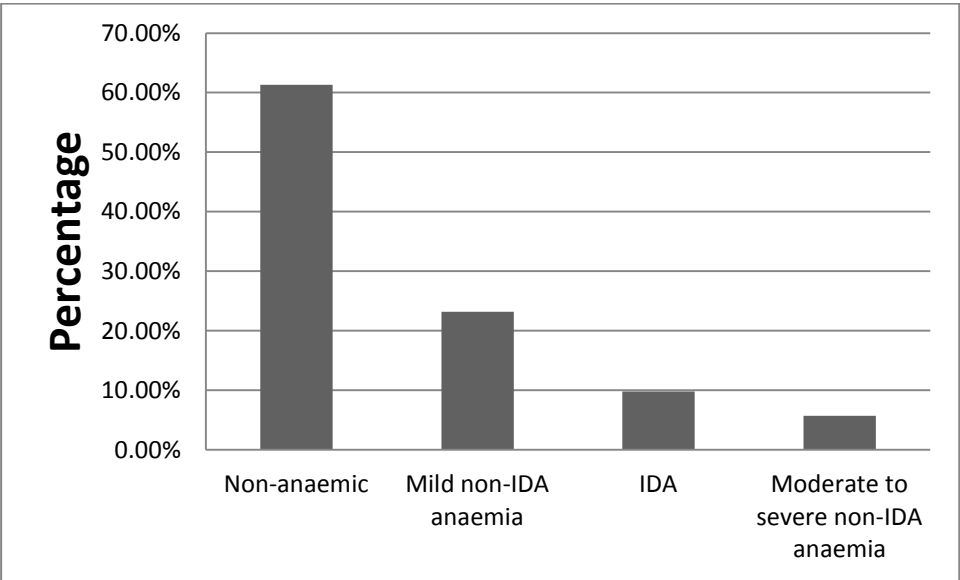
The overall range of ferritin in all pupils who were tested was 3.4-43.0  $\mu\text{g/l}$  and the mean was 15.90 (SD=11.99). Females had a mean of 16.7  $\mu\text{g/l}$  with levels ranging from 3.4-43.0  $\mu\text{g/l}$ , while males had a mean of 14.8  $\mu\text{g/l}$  and a range of 4.1-37.0  $\mu\text{g/l}$ . Normal ferritin is defined as ferritin > 12  $\mu\text{g/l}$ . Low ferritin was common in females, with 12 female pupils having ferritin < 12  $\mu\text{g/l}$  and seven males with low ferritin, making a total of 19 IDA cases. No pupil was found to have

elevated CRP and high ferritin levels (false negative for IDA). The 11 cases with severe anaemia had normal ferritin levels.

**4.6 PREVALENCE OF IDA:**

The total number of pupils who were found to have iron deficiency anaemia after iron studies was 19. IDA was more prevalent in girls, with 11 out of 19 (58% of) IDA cases. Boys formed 42% of the IDA cases. Eleven pupils had moderate to severe anaemia but normal ferritin levels (non-IDA anaemia). Non-IDA anaemia was slightly higher in males (6 or 55%) compared to 5 females (45%).

The prevalence of iron deficiency anaemia (IDA) was found to be 9.8% among the 194 pupils who were screened for IDA. Anaemia was found to be 38.7% of the screened population with 23.2% having mild non-IDA anaemia. Pupils who had moderate to severe anaemia made up 5.7% of the screened sample while 61.3% had no anaemia. The figure (4.2) below depicts the above statistics.



**Figure 4.2:** Prevalence of anaemia and iron deficiency anaemia

**4.7 SCHOOL REPORTS:**

Academic records for 2009 were collected from all the three schools. The first school had 33 enrolments and only 31 reports were available. Two students were transfers from other schools during the fourth term with lost portfolios. The two other schools were able to provide all reports for the participants. Due to an unequal number of school terms, analysis was done per subject using the national coding system for school performance. The total is out of 4 per subject for each term, where 1 means competence not achieved and 4 for excellent achievement. Assessment is done in three areas: Mathematics, Life Skills and Literacy. The results are summarised in table 4.5 below.

**TABLE 4.5:** Comparison of academic scores between cases and controls:

Subject	Cases	Controls	<i>p</i> value	X <sup>2</sup>
<b>Mathematics:</b>				
N	29	59		
Mean	2.9	2.9	0.511	1.34
Range	1.0-4.0	1.0-4.0		
SD	6.54	6.57		
<b>Life skills:</b>				
N	29	59		
Mean	2.9	3.2	0.00017	22.36
Range	2.0-4.0	2.0-4.0		
SD	5.35	5.54		
<b>Literacy:</b>				
N	29	59		
Mean	2.6	2.8	0.071	5.59
Range	1.0-4.0	1.0-4.0		
SD	7.29	6.39		

Mathematics scores ranged from 1.0-4.0 for both the cases and the controls, with a mean of 2.9 (SD=6.54 for cases; SD=6.57 for controls). In literacy the means were slightly different, with 2.6 (SD=7.29) for cases and 2.8 (SD=6.39) for controls. Life skills was the only area with a wide difference on the scores. Cases had a mean of 2.9 (SD=5.35) and controls had a mean of 3.2 (SD=5.54). The level of significance of these differences is discussed in section 4.9 below.

#### **4.8 RAVEN'S COLOURED PROGRESSIVE MATRICES:**

A total of 84 pupils sat for the test. Six pupils (one case and five controls; four females and two males) were absent. Of the 84, 47 were females and 37 males. The percentile scores ranged from 5-75. There were no gender or age related differences on the percentile scores ( $p>0.05$ ). The whole group scored poorly on the test.

The following tables summarises the scores obtained in the psychometric test i.e. the RCPM:

**TABLE 4.6:** Summary of RCPM scores:

Percentile	Cases	Controls	Total
5	16	24	40
10	5	13	18
25	7	12	19
50	1	3	4
75	0	3	3
	29	55	84

The number of cases who scored above the 25<sup>th</sup> percentile was 27.6% compared to 32.7% of controls who scored above the 25<sup>th</sup> percentile. Three controls managed to score 75, with no case reaching that percentile. The 50<sup>th</sup> percentile was reached by four pupils (three controls and 1 case). However these differences were not statistically significant (see below for Confidence Interval).

**TABLE 4.7:** Comparison between the two groups of RCPM scores:

<b>Percentile:</b>	<b>Cases</b>	<b>Controls</b>	<b><i>p</i>-value</b>	<b><math>\chi^2</math></b>
Mean	12	17		
Median	5	10		
Range	5-50	5-75	0.612	2.680
SD	11.06	18.34		

Controls scored better than cases with the highest score of 75<sup>th</sup> percentile. The mean percentile was also higher for the control group. However, statistical analysis revealed no significant differences between the two groups ( $p=0.612$ ).

#### **4.9 ASSOCIATION BETWEEN CASES (IDA AND SEVERE ANAEMIA) AND SCHOOL**

##### **PERFORMANCE:**

The hypothesis was that participants from the control group would perform better in all the three areas than the case group.

For mathematics there was no statistically significant difference in the two groups,  $\chi^2 = 1.34$  and  $p = 0.511$  at 2 degrees of freedom.

There was also no significant gender related difference in the mathematics scores, with  $\chi^2 = 0.51$  and  $p = 0.776$  at 2 degrees of freedom.

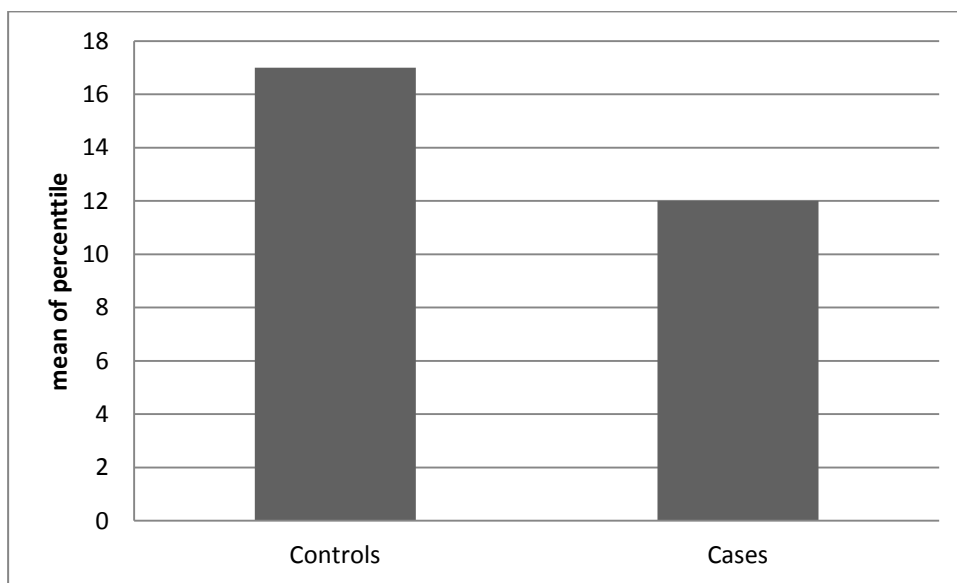
For life skills, a statistically significant difference between cases and controls was found. The control group had better scores compared to the case group. The Chi Square was 22.36 and  $p = 0.00017$  at 4 degrees of freedom. Although the test was invalid for life skills vs. gender because the cells had too few numbers, the Chi Square Test yielded 20.28 and  $p = 0.000439$ , suggesting a significant difference between female and male scores (females scored better).

In literacy or languages, the Chi Square Test was found to be  $\chi^2 = 5.59$  and  $p = 0.071$ . The  $p$  value approaches significant levels. No gender differences were found on the scores,  $\chi^2 = 0.33$  and  $p = 0.845$  at 2 degrees of freedom.

#### **4.10 ASSOCIATION BETWEEN IDA AND COGNITIVE PERFORMANCE:**

The mean percentile scores of the Raven's Coloured Progressive Matrices (RCPM) of the case group was 12, while that of the control group was 17. Statistical analysis was conducted between the 2 groups to check for significant difference using the Chi Square Test. The hypothesis was that participants from the control group will perform better on the RCPM compared to the case group. The Chi Square Test was  $\chi^2=3.31$  and  $p =0.65$ , indicating no statistically significant association between either IDA or non-IDA anaemia and cognitive function.

Figure 4.3 below illustrates the means of the cases and controls. The mean of the controls indicate that they scored better than the cases, although the difference is not statistically significant ( $p>0.05$ ).



**Figure 4.3:** The means of the participants who were tested on the RCPM (n=84).

#### **4.11 COMPARISON OF RCPM WITH ACADEMIC PERFORMANCE AND OTHER PARAMETERS:**

When Mathematics scores were compared with all the percentiles of the RCPM, there was no statistically significant difference. For the 5<sup>th</sup> percentile versus Mathematics the  $\chi^2 =5.73$  and  $p =0.767$  at 9 degrees of freedom. Mathematics versus 10<sup>th</sup> percentile had a  $\chi^2 =6.37$  and  $p =0.702$  and 25<sup>th</sup> percentile the  $\chi^2 =8.40$  with a  $p =0.277$ . Statistical testing for the 50<sup>th</sup> and 75<sup>th</sup> percentiles were not valid as no case scored that high.

When life skills and literacy were compared with RCPM using the Chi square Test no statistically significant differences were found. Literacy vs. 5<sup>th</sup> percentile yielded  $\chi^2 =11.51$  and  $p =0.243$ . At the 10<sup>th</sup> percentile,  $\chi^2=9.69$  and  $p =0.37$  and at 25<sup>th</sup> percentile,  $\chi^2=11.26$  was found and  $p =0.127$ . For life skills versus RCPM, analysis was also done at 5<sup>th</sup>, 10<sup>th</sup> and 25<sup>th</sup> percentiles as no cases scored 50<sup>th</sup> and 75<sup>th</sup> percentiles. At 5<sup>th</sup> percentile,  $\chi^2=4.59$  and  $p =0.800$ ,  $\chi^2=3.87$  and  $p =0.793$  at 10<sup>th</sup> percentile and  $\chi^2=3.60$  and  $p =0.608$  at 25<sup>th</sup> percentile.

The RCPM were also compared to the anthropometric results and gender to look for statistically significant differences.

- i. Weight versus the RCPM: Weight was divided into two groups, those weighing above 20 kg and those weighing less than 20 kg. The scores were then compared, taking 25<sup>th</sup> percentile as average performance. Controls who weighed more 20 kg and scored above 25<sup>th</sup> percentile were 19 vs. seven cases in the same category. Thus heavier controls scored better than cases, however, when the Chi Square Test was applied, there was no statistically significant difference between the two groups,  $\chi^2=87.00$  was found and  $p = 0.304$ . Control pupils who weighed less than 20 kg and scored below average (below 25<sup>th</sup> percentile) were 37 compared to 21 cases in the same category.
- ii. Height versus RCPM: Height was also categorised into two groups, above 115cm and below 115cm. Controls who had height above 115cm were 35 and 14 scored above average compared to only three cases in the same category. Thus taller controls did better on the psychometric tests compared to their counterparts. The Chi square test, however, did not show statistically significant difference ( $p = 0.668$ ) between the 2 groups, although most of the cases (25) were below 115cm and scored below average.
- iii. Gender versus the RCPM: Analysis of this association revealed that females did better on the test when considering the average percentile. Table 4.8 below summarises the scores of females and males in the RCPM:

**Table 4.8:** RCPM scores between gender (n=84):

Score (percentile)	Female N=47	Male N=37	Total
5	23	17	40
10	9	9	18
25	10	9	19
50	2	2	4
75	3	0	3
<b>Mean percentile</b>	<b>16.60</b>	<b>13.51</b>	<b>15.23</b>

Females who scored between the 25<sup>th</sup> and 75<sup>th</sup> percentiles were 15 compared to 11 males for the same category. Below the 25<sup>th</sup> percentile, there were 32 females and 26 males. In total there were more females (47) than males (37). There was no statistically significant difference between the two groups ( $p = 0.591$ ).

#### **4.12 CONCLUSION:**

The results show that the pupils were generally under-weight and stunted with no significant differences between cases and controls on both anthropometric parameters. The prevalence of IDA was found to be high at 9.8%. With regard to association of IDA and both school performance and cognitive function, the study did not show any significant associations between IDA/severe



anaemia and cognitive function. There was a significant association between IDA and one of the areas of the academic assessment. Cases scored poorly on life skills ( $p < 0.05$ ). In literacy, the test for level of significance between cases and controls approaches significance ( $p = 0.071$ ). For mathematics the differences between cases and controls were not statistically significant. The hypothesis was that controls will perform better in both academic performance and cognitive function as compared to the cases. The following chapter gives a detailed discussion of the findings.

## **CHAPTER 5 - DISCUSSION**

### **5.1 SAMPLE AND RESULTS DISCUSSION:**

#### **5.1.1 Study design:**

The study was conducted using a quantitative approach. The research approach has proved to be both cost effective and time efficient. Another advantage of a quantitative study is that the results can be statistically demonstrated by means of comparison (Neuman, 1997). The design used in this study was a case-control observational design.

#### **5.1.2 Sample demographics:**

The sample was derived from a target population of primary school-going children doing grade 2 in three public sector primary schools in Winterveldt, North of Tshwane in the Gauteng province of South Africa. Winterveldt is a historically disadvantaged peri-urban area which is typically characterised by poverty, low standards of living and low socio-economic conditions. This area was selected firstly, because there is evidence of that IDA and anaemia tends to be prevalent among the disadvantaged communities in rural and peri-urban areas of South Africa (Faber, Jogessar & Benadé, 2001; Jacobson, 2008). Secondly, the area was selected for convenience and accessibility to the researcher as the area is about 25km from the hospital-university complex.

Children doing grade 2 in public primary schools were enrolled in the study. This age group was selected because it is regarded as being amongst the groups that are vulnerable to iron deficiency and anaemia in South Africa (Mansvelt, 2009) and thus would benefit from intervention at a later stage of the study should the study indicate a deficiency in them. Research also indicates that the risk of anaemia appears early in childhood for both boys and girls, after which it subsides for boys but remains in girls due to menstrual loss (FAO/WHO, 1992). Targeting the pre-pubertal children was therefore appropriate for this study since it aimed at using data from both boys and girls regardless of gender. Lastly, grade 2 pupils were selected because they had previous school records from grade 1 available from which this study aimed to record their overall academic performances.

Three hundred and eighty three pupils were available for the study, however only 194 had parental consent. The large group (n=189) without parental consent could have been caused by failure of the parents to recognise the importance of the study. This large number of pupils without parental consent could have affected our results as well. All the parents who attended the gathering signed the consent form after verbal explanation of the purpose of the study by the researcher. The children's age range was 6-8 years and was consistent with other studies on the effects of iron deficiency on academic performance and cognition which focus on school-age children. Pollitt (1997), in his three experimental studies in low-income countries, used almost similar age groups: 8.2-13 years in Indonesia, 9-12 years in Thailand and 8-11 years in Egypt. Another study done in Thailand recruited primary school children who were iron deficient. The aim was to see if iron supplements improved cognitive function. However, subjects were from grades 1-6 (Sungton, Mo-suwan, Chongsuvivatwong, et al., 2004). Following screening, 61% of participants were found to have normal haemoglobin, 38% were anaemic, and of whom 9.8% had iron deficiency anaemia.

Participants with non-iron deficiency anaemia were included amongst the cases as several studies had found that such patients suffer similar effects on school performance and neuro-cognitive performance as do patients with IDA. Slickers, Duquette, Hooper et al. (2007) found that children with anaemia due to chronic kidney disease performed poorly on neuro-cognitive tests. Intelligence tests administered before renal transplants and one year following renal transplants showed improved memory, reaction time and attention in children from the dialysis unit of Children's Memorial Hospital in Illinois, USA. However the influence of improved school attendance on the performance of the tests was not investigated and the improved scores could have been caused by treatment of the chronic uraemia (Mendly & Zelko, 1999).

The sample distribution among the three schools was 33:30:27, respectively. The schools are within walking distance from each other, thus they are all from low socio-economic area where one or both parents are unemployed. Most of the residents are immigrants from the neighbouring countries. Most of the studies reviewed were done in low income countries. In Costa Rica, participants from middle socioeconomic status were compared with those from lower socioeconomic status during cognitive assessment and the subjects from low socioeconomic status demonstrated more cognitive impairment (Lozoff, Jimenez & Smith, 2006). A study in Delhi, India was also done in a community living in slums, where health intervention with iron supplements and de-worming drugs was given to iron deficient school children. At baseline a large number (69%) of children were found to be anaemic, with significant improvement after five months of intervention (Bobonis, Miguel & Sharma, 2004).

The anthropometry and age were recorded for matching purposes during case-control selection. We compared our data with the CDC's National Center for Health Statistics data because most of the studies reviewed used the NCHS data for comparison (Mcdowell, Fryar, Ogden, et al., 2008). The prevalence of stunting was 23% (i.e. <5<sup>th</sup> percentile/-2SD below the median) and 85.1% of the pupils were below the 50<sup>th</sup> percentile. There were no significant differences between cases and controls ( $p=0.863$ ) with regard to the stunting. Labadarios, Steyn, Maunder, et al. (2000) found a national prevalence of stunting of 13 % in children aged 7-9 years and 6% for the Gauteng Province, thus our prevalence is very high. Berry, Hall & Hendricks (2010) compared data from 1999 and 2005 for children aged 1-9 years for the Gauteng Province and found that the prevalence of stunting decreased from 20.4% in 1999 to 18.8% in 2005 and these differences were statistically significant ( $p<0.05$ ). Severe stunting (-3SD/< 3<sup>rd</sup> percentile) was also shown to be decreasing. Oelofse, Faber, Benadé, et al (1999) found stunting prevalence of 20.4% in 6-11 years old children but a study done earlier in the same community found a lesser prevalence of 14.8% suggesting that the problem of stunting was worsening in the Ndukazi community (van Stuijvenburg, Kvalsvig, Faber, et al., 1999).

Under-weight prevalence was found to be 19.3%. The majority of pupils were below the 50<sup>th</sup> percentile (81.8%) and there was no significant differences in the weight of cases and controls ( $p=0.368$ ). This reflects a very high prevalence when compared to other studies done in the same age group; Labadarios et al. (2000) - 7.7%; Oelofse et al. (1999) - 3.3% and 2.2% for Gauteng Province by Labadarios, Steyn, Maunder, et al. (2000). Although our data shows a high prevalence of both stunting and underweight, we observed a very wide variation from the mean of both the weight and height values, thus the prevalence may not be a true reflection of the population. The

data of the remaining group of pupils who were not used in the final study sample was not entered for analysis and that could have also influenced the outcome. The small sample size could have also influenced the results as most of the pupils did not have parental consent (n=189) and thus not included in the study.

In a meta-analysis of randomised controlled intervention trials by Ramakrishnan, Aburto, McCabe, et al. (2004), it was found that IDA does not contribute to growth faltering. Interventions aimed at only iron or vitamin A did not improve growth while those with multi-nutrient supplementation improved both linear and ponderal growth. The limitation of the analysis was that most programmes focused on vitamin A and iodine, thus there were limited data on iron. As mentioned in the literature review, several studies implicate iron deficiency in growth retardation (Harris, 2007; Soliman, et al., 2009; Angeles, et al., 1993; Troesch, et al., 2011). Our results did not show significant differences in the weight and height of cases and controls and a possible explanation is that our controls could be iron deficient but not yet anaemic (Stage II iron deficiency) as blood ferritin levels were only done on anaemic pupils. The above confounding factors could have also contributed to the outcome.

Assessment of nutritional status in school age children from developing countries showed that malnutrition was prevalent. Underweight and thinness were prominent in South-East Asia and Africa. These studies calculated Z-scores (height-for-age and weight-for-age) for accurate definition of under nutrition (Best, Neufingerl, van Geel, et al., 2010). Most of the studies on effects of IDA on cognition did not consider anthropometry but used age alone. Age is valuable in choosing the correct psychometric test for the participants. For school age, tests include psycho-educational test comprising literacy, numeracy, general knowledge and reading comprehension and also the Raven's Progressive Matrices, either coloured (6-11 years) or Raven's Standard Progressive Matrices (older than 11years) (Batra & Sood, 2005).

### **5.1.3 Haemoglobin and ferritin levels:**

Altitudes above 3000 feet (900 m) raise the haemoglobin definition for anaemia because as the altitude increases, the partial pressure of oxygen decreases resulting in increased red cell production as a compensatory mechanism by the body in response to the lowered oxygen saturation. Hypoxia stimulates erythropoietin production resulting in production of more red blood cells. Thus adjustments are done for the diagnosis of anaemia (Alton, 2005). Dirren and colleagues proposed that altitude correction for haemoglobin is applicable to all age groups after studying two groups of populations living at sea level and at an altitude of 3400 m. Exponential regression curves were drawn from their data, resulting to calculation of correction factors which can be applied when interpreting haemoglobin levels at different altitudes (Dirren, Logman, Baclay, et al., 1994).

Ferritin levels however, fall with increases in altitude as the stored iron is used to make more red blood cell haemoglobin. Several studies have been done to prove this normal physiological phenomenon. Cook and co-workers investigated the influence of high altitude living on the total body iron. The studied populations lived at altitudes between 156 to 3750 m. The mean ferritin levels for subjects living below or above 3000 m were 30.2 µg/l and 24.4 µg/l respectively. Thus people living at altitudes above 3000 m have a higher prevalence of IDA imposed by the

physiological expansion of the red cell mass (Cook, Boy, Flowers, et al., 2005). Rice and colleagues studied the mechanism resulting to the increase in ferritin levels on descent from altitude. The subjects were living at an altitude of 4380 m and were tested for haemoglobin, red cell mass, erythropoietin, ferritin and hematocrit before leaving the high altitude to sea level. The blood tests were repeated from day 11 after arrival at sea level and blood was collected daily for the next nine days. Red blood cell neocytolysis was confirmed as the mechanism that brings down the red cell mass to normal at lower altitude thus releasing iron for storage, dropping the haemoglobin and red cell mass and increasing ferritin levels (Rice, Ruiz, Driscoll, et al., 2001).

Haemoglobin levels ranged from 8.3-14.3 g/dl and the mean haemoglobin did not differ between males and females. This is consistent with literature which states that anaemia appears early in both boys and girls but normalises in boys as they approach puberty. In girls, anaemia persists due to menstrual losses (FAO/WHO, 1992). The mean haemoglobin was 11.8 g/dl and when compared to the Durban study by Coutsoudis and colleagues where the mean haemoglobin was 11.7 g/dl among 3-6 years old from Besters, north of Durban, our subjects have a low haemoglobin mean when taking altitude into consideration. Durban is at sea level when compared to Pretoria where altitude ranges between 1250 to 1750 m, thus Pretoria residents are expected to have higher haemoglobin levels (Coutsoudis, Jinabhai, Coovadia, et al., 1994). The Limpopo study by Heckman et al (2010) found mean haemoglobin of 9.6 g/dl but his subjects were younger than 60 months of age. A comparable study in terms of age of the subjects was done in the Western Cape where the mean haemoglobin of 6-11 years old was found to be 11.8 g/dl but Cape Town is also at sea level, thus our subjects have lower haemoglobin levels when altitude is taken into consideration (van Stuijvenberg, Smuts, Lombard et al., 2008).

International studies were also reviewed to compare our findings in the same age group. An Egyptian study found much lower mean haemoglobin in a group of 6-12 years old primary school children. The mean haemoglobin for children found to be iron deficient was 9.6 g/dl and 10.2 g/dl in those with no iron deficiency. Egypt lies between 133 to 2629 m above sea level, however, the exact location of the study region was not mentioned (Ali, Fathy, Fathy, et al., 2011). A Brazilian study however, found higher mean haemoglobin in 5-11 years old school children compared to our study. This study investigated prevalence and risk factors of anaemia and iron deficiency and their mean haemoglobin was 12.6 g/dl. Brazil is generally a low lying country with altitude of between 30 to 900m above sea level and the study area is 100 to 208 m above sea level, thus low haemoglobin levels are expected due to the low altitude (Ferreira, da Silva-Nunes, Bertolino, et al., 2007).

Low ferritin levels were common in girls compared to boys. The mean ferritin was 15.9 µg/l which is consistent with the effect of altitude on ferritin levels when compared to other South African studies done in low lying areas. The Ndakazi study in KZN found a mean ferritin of 29.2 µg/l among school going 6-11 years olds (van Stuijvenberg, Kvalsvig, Faber et al., 1999). For the similar age group as ours, mean ferritin was found to be 20.4 µg/l in the Western Cape among school children (van Stuijvenberg, Smuts, Lombard, et al., 2008). Both Cape Town and Durban are at sea level, and thus are expected to have low haemoglobin and high ferritin levels. In Japan, the prevalence of anaemia and iron deficiency were investigated in school-aged children with ages between eight and 17 years. The mean ferritin levels of boys and girls were 33.7 µg/l and 33.5 µg/l

respectively. Japan lies at a low altitude (4 to 377 m above sea level), thus higher ferritin levels are expected (Hashizume, Chiba, Shinohara, et al., 2005). The higher ferritin values for the Japan study (ferritin >30 µg/l) could also be attributed to the older age of their subjects compared to ours who were between six and eight years and had a mean of 15.9 µg/l.

#### **5.1.4 Prevalence of IDA:**

Point prevalence for IDA was found to be 9.8% which is significantly higher than that found in previous South African studies. National prevalence of IDA was found to be 5.0% although variations between provinces were found in the South African vitamin A consultative group study, a study which enrolled children under the age of five years (Labadarios, van Middelkoop, 1995). Poor socioeconomic status can affect the prevalence of IDA which is consistent with the study settings where most of the subjects came from. Prevalence of IDA in the Ndukazi study in KZN was much higher at 27.8% among 6-11 years old primary school children and this may be due to the overall poor socio-economic status of the region (van Stuijvenberg, Faber, Kruger, et al., 1999).

Anaemia was also found to be highly prevalent in our study: 38.7% compared to the national prevalence of 21.4%, which could be related to the poor generalised nutritional status of the pupils or other confounding factors which need further investigation. In 2007, in a Western Cape study in 6-11 year old school children, anaemia was found to be 50% prevalent which is much higher compared to our finding. However, the definition for anaemia used was Hb <12 g/dl. Iron deficiency was found to be highly prevalent (47%) using a ferritin level of <20µg/l to define ID (van Stuijvenburg, Smuts, Lombard, et al., 2008). When using that level of ferritin (<12 µg/l), our study found a high prevalence of iron deficiency of 73%.

Berry and Hendricks (2005) reported that the iron status of South African children was deteriorating after studying children between one to nine years of age from different socioeconomic backgrounds. IDA prevalence was found to be 8% nationally for 1-9 years but even higher for 1-3 years at 17% compared to the 5% reported in 1994 for 6-71 months old children. A Limpopo study done in 2003 found the prevalence of iron deficiency to be 33% but their subjects were three years old which is consistent with the literature that younger children have a double burden of iron deficiency (Mamabolo, 2006).

A higher prevalence of both anaemia and iron deficiency can be associated with certain disease states like hookworm infestation, malaria and human immunodeficiency syndrome (HIV) infection. Results of a Red Cross War Memorial hospital study in Cape Town showed very high prevalences of anaemia, iron deficiency and IDA, namely 73%, 52% and 18% respectively, in HIV-1 infected, antiretroviral naive children (Eley, Sive, Shuttleworth, et al., 2002). The latest South African study done in Kimberley, in the Northern Cape found the prevalence of iron deficiency to be 30.6% (Troesch, van Stuijvenburg, Smuts, et al., 2011). Although it was an intervention study aimed to test whether iron/zinc supplements improve somatic growth, it does reflect the provincial variation in the prevalence of iron deficiency in South Africa.

South Africa has legislation on iron deficiency anaemia with regulations related to iron supplementation for pregnant women and children and also to food fortification (National Food

Fortification Programme, 2008). All pregnant women should be given prophylactic iron supplements (ferrous sulphate, 200 mg daily) but if they have anaemia the capsule should be given three times per day. In children there is prophylactic and therapeutic doses based on age and weight of the child. Once daily dosing is used for prophylaxis (1.5 mg/kg of elemental iron), while three times per day dosing is used for treatment (5 mg/kg) of anaemia. Fortification of certain foodstuffs involves adding a mixture of vitamin A, thiamine, riboflavin, niacin, folic acid, vitamin B<sub>6</sub>, iron and zinc. Regulations relating to the food fortification of foodstuffs were drafted on the 18<sup>th</sup> of October, 2002 but only made compulsory on the 7<sup>th</sup> of October 2003. The following foods were targeted by the fortification programme: wheat flour, bread and maize meal (Department of Health, 2002).

To ensure success of the programme, the Department of Health and the Department of Trade and Industry created an incentive scheme to subsidise for costs incurred, with the smaller millers getting 100% re-imburement. Compliance to the guidelines was also monitored by deploying Environmental Health Practitioners who were trained on the food fortification guidelines, to the communities. Several campaigns were also started for consumer awareness pertaining to prevalence and consequences of micronutrient deficiencies, including the media campaign of 2006 and the radio/TV campaign of 2007. By the end of 2008, 90% of wheat flour and 70-85% of maize meal consumed in South Africa was fortified. These products were also labelled using a specific logo: 'fortified for better health' to increase consumer awareness (Randall, 2001).

However, consumer awareness was still lacking. Between 2004 and 2008, the Global Alliance for Improved Nutrition (GAIN) partnered with UNICEF to support the national programme to make fortified staple food available to the entire South African population. The programme was officially closed in March 2008 following the above statistics which indicated success (GAIN, 2011). There is still no comprehensive monitoring system in place for the micronutrient deficiencies in South Africa, thus coverage is still unknown. An earlier study on knowledge of vitamins and minerals by a Unilever group (2002) revealed poor knowledge of vitamins and minerals and the consequences of their deficiencies. Only 7% of the respondents knew what fortified/enriched foods were and there was lack of knowledge was for minerals as compared to vitamins (JB Consultancy for Unilever, 2002).

We can speculate that since sorghum-meal is the staple food of the study area, fortified maize meal consumption is not adequate. Most of the poor families cannot afford bread and there is reason to believe that this contributes to the problem of low consumption of the fortified foods. Without any data of the diet history or knowledge by the residents of fortified foods, we cannot draw conclusions on why the programme is not successful for this area.

#### **5.1.5 The RCPM scores:**

The Raven's Coloured/Standard/Advanced Progressive Matrices is an instrument used to assess non-verbal intelligence and logical reasoning. The tests are designed for particular age groups, the RCPM for children aged 5 to 11.5 years, the standard test for 12 years until high school and the advanced test for college students. Less gifted adults are assessed using the RCPM. The test assesses the ability to identify missing pieces from a pattern of pictures almost like fitting pieces of a puzzle. It consists of 36 items in three sets of 12, in increasing order of difficulty within each set

(appendix IV). The colourful and appealing design of the RCPM makes it attractive to children and helps to sustain their motivation. The other two types viz. Raven's Standard Progressive Matrices (RSPM) and the Raven's Advanced Progressive Matrices (RAPM) are in black and white.

Chronological age affects performance on the Raven, with a sharp increase in scores through-out childhood and adolescence, followed by a gradual decline after early adulthood until old age (McArdle, Ferrer-Caja, Hamagami, et al., 2002; Salthouse, 1996; Carlson & Jensen, 1981). The Flynn effect states that intelligence is improving across centuries and that children are getting cleverer in terms of performance on all intelligence tests compared to decades ago, with an increase of 3 IQ points per decade. This was discovered by Richard Lynn (1977) and documented by James R. Flynn in 1987. Thus some of the scores are interpreted by taking the Flynn effect into consideration (Flynn, 1999). Brouwers and colleagues studied the variation in the RCPM scores across time and place and observed that older cohorts performed low in all the three versions of the Raven, although the RAPM showed the strongest effect. Another factor which had an effect on the scores was the educational age, which is thought to account to the cross-cultural differences in the performance on the Raven. Countries with a growing economy, who invest more on education were found to have no Flynn effect and had higher average scores on the Raven (Brouwers, van de Vijver & Hermet, 2009).

Our scores for the RCPM were consistent with other South African studies done in rural areas. Scores ranged from 5<sup>th</sup> to 75<sup>th</sup> percentile. Females scored better than males, 4% of the girls scored on the 75<sup>th</sup> percentile vs. 0% males. Females who scored between the 25<sup>th</sup> and 75<sup>th</sup> percentile made up 18% vs. 13% of males. A study done in Pietermaritzburg in KwaZulu Natal (KZN) in 2005 found a mean percentile of 16.7 among primary school children from grade 2 to grade 7 on the RCPM. Grade two pupils had a mean percentile of 15.2 which was similar to our study. Males scored higher than females with mean scores of 17.3 and 16.1 respectively, in contrast to our findings. Another finding was that scores improved with age; however, our study did not compare scores with age (Kihn, 2005).

In 2004, a study was conducted in rural KZN, in the Vulamehlo district, to assess mental abilities of rural primary school children. The RCPM was among the battery of tests used to assess intelligence in 11 rural primary schools. Only grade three pupils were enrolled in this study and the results were comparative to our findings. Although our study population was grade two pupils, the age group was almost similar (8-11 years) to ours which was 6-10 years. The total mean score was 13.9, which was less than our mean, with girls scoring more than boys (means of 14.6 and 13.4 respectively). Their results also showed that the Zulu children performed 3-5 years below children used in the international studies. Zindi (1994) in Jinabhai et al. 2004 reported a similar trend in black Zimbabwean children when compared with British counterparts, where the scores were significantly lower (almost 2SD) than those of the British children. The results of this KZN study were consistent with our findings as their female pupils also scored higher than the males. (Jinabhai, Taylor, Rangongo, et al., 2004).

In a study done in isiXhosa speaking primary schools, children's performance was comparable to the KZN study. The mean score for the whole sample was 20.2 with a range of 6-35. Grade two pupils had a mean score of 14.3. In this study males outperformed their female counterparts with a



mean score of 21.3 compared to 19.1 in females. Depression of scores was also observed in this study when compared with international norms. The trend showed improvement of scores with increasing age (Knoetze, Bass & Steele, 2005). The increase in scores with age is an expected phenomenon according to the Raven's manual, with performance increasing by 2.0 IQ points per decade (Raven, Court & Raven, 1990). Thus, our results agree with previous studies done in similar settings, however our subjects managed to reach higher maximum scores (50<sup>th</sup> and 75<sup>th</sup> percentiles).

The outcome of the cognitive function is consistent with other South African studies; however, Owen (1992) found that the Raven's Progressive Matrices is not culturally biased but that black and white South African pupils tend to follow their own ethnic group pattern. Black students performed 3SD below white students in the RSPM. Therefore, the overall poor performance of our participants in the RCPM may be attributed to this trend as all the above studies were done in black communities.

Data on the RCPM use in Africa is limited. A Kenyan standardisation study of the RCPM was done in 1370 pupils in grades one to five to check for Kenyan norms, reliability and validity of the RCPM. The mean scores were calculated per age group in contrast to our study where total means for cases and controls were generated. Their mean for boys was 16.86 and 14.96 for girls, consistent with other South African studies where boys outperformed the girls. The Kenyan children performed well below UK and USA counterparts when the mean scores were compared. In our study girls did better on the RCPM than boys. We did not anticipate this and thus cannot explain this finding. The mean percentile scores increased with age, 12.08, 13.56, 15.64, and 17.65 for six, seven, eight and nine year olds respectively. This finding is in keeping with original data from the Raven's manual that led to three different types of tests for the different age groups, the RCPM, RSPM and RAPM (Constenbader & Ngari, 2001).

#### **5.1.6 The association between the RCPM and IDA:**

The results for the RCPM showed that cases generally scored less compared to the controls. The 50<sup>th</sup> percentile and 75<sup>th</sup> percentile had the widest differences, three controls scored 50<sup>th</sup> percentile vs. one case and no case reached the 75<sup>th</sup> percentile. However, these differences were not statistically significant ( $p=0.65$ ). Overall performance on the RCPM was poor. This could be attributed to failure to understand the instructions of the test due to language of instruction. The class teachers from all the three schools highlighted the rich diversity of vernacular of the study area as already mentioned. Most pupils start learning seTswana from the first grade as it is the local language and we used seTswana to explain the instructions. However, inferences cannot be made at this point as this could be due to many confounding factors. These results warrant further research on the confounding factors.

Data were very scarce on IDA and cognitive performance in both South Africa and Africa. The RCPM has been widely used in South Africa in different clinical settings, especially to test mental abilities in the different cultural groups in the country, as highlighted in the section 5.1.5 above. In Sri Lanka, the Raven's Standard Progressive Matrices was used to compare 13 to 15 years old iron deficient and iron sufficient students and no significant difference was found between the two groups (Dissayanake, Kumarasiri, Negegoga et al., 2009).

However, a positive correlation of IDA with cognitive function and school performance was found in Morocco, in children aged 6-16 years using the RCPM as a psychometric test. Low ferritin level was associated with low IQ, poor mathematics scores and poor average annual scores (Aboussaleh, Ahami, El Hioui, et al., 2009). Earlier studies also found an association between IDA and poor cognitive function. In Indonesia, children (8-13 years) were assessed using the RCPM at baseline and after treatment of both controls and cases. At baseline, the non-anaemic children scored better but after intervention the IDA group showed the improvement in scores. A positive correlation between serum ferritin and poor scores in the RCPM was also found in another study conducted in Guatemala (Pollitt, 1997).

Several other studies have demonstrated that iron deficient children younger than 2 years have failed to catch up with non-anaemic children even after supplementation. This was demonstrated in a Costa Rican study where children aged 5 years who had IDA in infancy were compared with their peers with good iron status. Lower mental scores persisted despite extended oral iron therapy in the IDA group (Lozoff, Jimenez & Wolf, 1991).

#### **5.1.7 The association between IDA and school performance**

The hypothesis was that participants from the control group would perform better in all three areas i.e. mathematics, literacy and life skills. For mathematics, there was no statistically significant association between the two groups. This could be explained by the general low standards set by the current curriculum. The Department of Education undertook a national survey during 2011 to assess students' performance using comparison with other countries (DoE, 2011). The results of the survey showed poor performance in mathematics and science by most of the pupils. Several studies have found a positive correlation between IDA and poor mathematics scores (Sungthong, Mo-suwan, Chongsuvivatwong, et al., 2002; Stoltzfus, Mullany & Black, 2004). The control group scored better in life skills compared to the case group ( $p=0.00017$ ) and this is in agreement with most of the studies where children with IDA performed poorly in general knowledge (Aboussaleh, Ahami, El Hioui, et al., 2009; Pollitt, 1997). The test for literacy and IDA did not reveal any statistically significant differences but approaches significance. The small sample size could have influenced this result.

In South Africa, an intervention study done in KZN, showed that iron, iodine and  $\beta$ -carotene supplementation improved cognitive function of school children but school performance was not investigated (van Stuijvenberg, Kalsvig, Faber, et al., 1999). Literature is scarce on the association of iron deficiency anaemia and academic performance in South Africa and Africa.

Although most of the studies found a positive correlation between iron status and both intelligence and academic performance, there are several studies which did not find an association between IDA and intelligence. In Portugal, infants who were followed up for 8 years after diagnosis of IDA were compared with controls using school performance and the Griffiths test. The results showed no significant difference between cases and controls (Antunes, Gonçalves, Santos, et al., 2005). The study in Sri Lanka where marks for mathematics, science, local language and social sciences were compared among IDA students vs. iron replete counterparts also yielded no significant relationship between educational performance and IDA (Dissanayake, Kumarasiri, Negegoga, et al., 2009).

## **5.2 LIMITATIONS:**

Firstly, the study sample (n=194) was small compared to previous studies and in some of the results, the Chi Square Test was rejected or reported as invalid because of low cell numbers.

In the current study, academic performance was assessed by using overall scores from the previous year (2009), based on national scoring system as explained under data collection. We were faced with a problem of incomplete school reports, with several pupils (23) having fewer than four terms recorded on the report form. Five pupils had only 1 term marks; sixteen had two terms and two with three term marks. Two pupils had no school reports (transfers from other schools with lost portfolios). The final score was recorded as an average of the number of terms each child attended. Thus, as scoring in the first term might be different from that of the last term; the final calculation could have influenced the results.

The different languages spoken in South Africa (11 in total) also impacts on adjustment of pupils transferred from other provinces. Several pupils had moved from one province to the other, with each province having one/two dominant language being spoken. The sampling site also has a rich diversity of tribes but the native language is seTswana. The area is home to many immigrants and local migrants from other rural areas of different provinces and is characterised by squatter camp dwellers. Most pupils speak a different language at home while the medium of instruction at school is seTswana. Therefore, there is reason to believe that the grades obtained by the pupils in our study were influenced by the language of instruction at school as most of the pupils are still adjusting to the local language.

Another drawback is that the topic is not well studied in South Africa and there were no data to compare and draw conclusions from. Prevalence of IDA and anaemia are well documented in the South African literature but not their relationship to intelligence and academic performance. We did not investigate the causes of the IDA as dietary history was not taken and other illnesses not checked. Thus, conclusions drawn might be biased.

Although we found no effect of IDA on growth of these children, we have reason to believe that this was due to many confounding factors, especially the fact that iron studies were only done on anaemic pupils. We might not have identified participants with early and moderate iron deficiency without detectable anaemia.

The following chapter presents the conclusions and recommendations drawn from this study.

## CHAPTER 6 - CONCLUSION AND RECOMMENDATIONS

### 6.1 CONCLUSIONS:

Iron deficiency anaemia is a preventable cause of cognitive impairment and other negative effects on the academic potential of children. Iron is needed continuously for brain growth in children and there is also evidence that IDA impairs growth. The developmental deficits related to IDA can to some extent be corrected with iron treatment; however, there is evidence that some deficits are not reversible with iron treatment. The purpose of the study was to explore the effects of IDA on school performance and cognitive function. We found a positive correlation between IDA and performance in life skills and languages. This finding is consistent with literature as most of the previous studies found that IDA negatively affects academic performance. Therefore, we were able to prove that IDA is associated with poor school performance.

The association between IDA and mathematics was not statistically significant. We expected a positive correlation between IDA and performance in mathematics as shown in most of the international studies. We attribute this finding to the low curriculum standard which is currently being reviewed by the Department of Education. South African pupils are generally struggling with mathematics as indicated by the national survey. Thus, despite this result, the study proved that IDA affects school performance.

There was no significant association between IDA and cognitive function as measured by the RCPM. This result could also be related to several influences as mentioned in the discussion chapter. Thus we cannot draw reasonable conclusions on the effect of IDA on cognition. The results of the cognitive performance are consistent with other South African studies which also found similar mean percentiles. International studies however, showed that IDA affects intelligence and that participants with IDA scored poorly in all the three sets of the Ravens test.

The second objective was to investigate the prevalence of IDA in the Winterveldt area. The point prevalence was high (9.8%) compared to the national prevalence of IDA of 5%. This could be related to a number of factors which were not investigated. Even when compared to other studies done in the Gauteng province, the prevalence is still very high. South Africa has an IDA policy on iron supplementation in children and food fortification legislation (2003) but there is no comprehensive monitoring on the coverage of both policies. We can speculate that since iron screening is not done routinely in infants, the exact magnitude of the problem is not known. Thus, infants are not routinely given supplements and early treatment is not given. Regarding the food fortification guidelines, success in fortifying the staple foods was reported in 2008, but awareness is still lacking especially in the poor communities. Since dietary history and knowledge of fortified foods was not investigated, we cannot draw conclusions on whether these fortified foods are consumed in the study population. The poor socio-economic status of our study population makes us believe that the high prevalence is due to nutritional insufficiency.

An incidental finding of the study was the high prevalence of both under-weight and stunting in the area. This could be related to the IDA as studies have shown that IDA has a negative effect on growth. This finding could also indicate that the general study population is undernourished, as

severe malnutrition affects growth. Malnutrition is consistent with the poor socio-economic status of our study population. Most of the residents are unemployed and cannot afford nutritious food. The school principals also indicated that social problems are rife in the community with the elderly being the primary care-givers. There was also a complaint of lack of social services where such pupils can be referred to.

## **6.2 RECOMMENDATIONS:**

The following recommendations can assist in alleviating the problem of high prevalence of IDA and anaemia. Early screening should be done on all infants to identify those infants who require treatment early before damage is done by the condition. Infants should be the target group because they are at the age of accelerated brain growth and some studies show that once the damage is done, the effects cannot be reversed. Providing iron supplements during the first three years of life should be implemented, targeting the poor/vulnerable communities. Although this is feasible up to the age of 18 months which coincides with the 18 months vaccines, it can be achieved by increased awareness of the micronutrient deficiencies. Brief educational sessions at the clinics when parents bring their infants for vaccinations can enhance awareness. The schools in the poor communities should be supplied with the addresses of the nearest social service offices for referral of pupils with identified social problems.

In summary, the study is adding valuable information on the effects of IDA on child growth and development. We proved that IDA has a negative effect on school performance. The most worrying of the detrimental effects is cognitive deficits which lead to general poor productivity in the adult population. This leads to a continuous cycle of poverty as most of the children will never attain skilled and vocational training. South Africa is currently struggling with insufficient technologically skilled personnel. Thus, if pupils do not finish school, entrance to the technical and vocational colleges is not achieved; thereby exacerbating the problem of unskilled school drop-outs. The end result in these poor communities is a large population of uneducated and poorly skilled people who depend on social security for survival. The high magnitude of the problem warrants early preventive measures to combat the effects of IDA on general well-being of the children of South Africa.

## **REFERENCES:**

Aboussaleh, Y., Ahami, A., El Hioui, M. & Bonthoux, F. (2009). Cognitive performance of anaemic school children, North-western Morocco. Micronutrient Forum Meeting [Online] [<http://www.micronutrientforum.org/meeting2009/PDFs/Poster%20Presentations/4Friday/MCHDO/F66-Aboussaleh.pdf>] (Accessed 15 September 2009).

Ali, A., Fathy, G.A., Fathy, H.A. & Abd El-Ghaffar, N. (2011). Epidemiology of iron deficiency anaemia: effect on physical growth in primary school children, the importance of hookworms. *International Journal of Academic Research*, 3, (1), 495-500.

Alton, I. (2005). Iron deficiency anaemia. Guidelines for Adolescent Nutrition Services [Online] [[http://www.epi.umn.edu/let/pubs/adol\\_book.shtm](http://www.epi.umn.edu/let/pubs/adol_book.shtm)] (Accessed 14 August 2009).

American Academy of Pediatrics. (1999). Policy statement: Iron fortification of infant formulas. *Pediatrics*, 104, (1), 119-123 [Online] [<http://aappolicy.aappublications.org/cgi/content/full/pediatrics;104/1/119>] (Accessed 12 May 2010).

Angeles, I.T., Schultink, W.J., Matulesi, P., Gross, R. & Sastroamidjojo, S. (1993). Decreased rate of stunting among anaemic Indonesian preschool children through iron supplementation. *American Journal of Clinical Nutrition*, 58, 339-342.

Antunes, H., Gonçalves, S., Santos, C., Pereira, C., Tojo-Siera, R. & Aguiar, A. (2005). An eight years prospective study of iron deficiency anaemia in infancy [Online] [[http://www.dairyconsultant.co.uk/pdf/Infant\\_Formula\\_Book\\_Koletzko\\_ISBN\\_1402035349.pdf](http://www.dairyconsultant.co.uk/pdf/Infant_Formula_Book_Koletzko_ISBN_1402035349.pdf)] (Accessed 20 August 2009).

Banda, T.W., Khonje, D.C., Bobrow, E.A. & Galloway, R. (2006). Malawi national school health and nutrition baseline survey 2006. The Ministry of Education and Vocational Training, Malawi. The World Bank [Online] [<http://www.docstoc.com/docs/75618808/Table-Overview-of-reported-prevalence-of-anaemia-iron>] (Accessed 12 February 2011).

Bass, N. (2000). The Raven's Coloured Progressive Matrices Test. A pilot study for establishment of normative data for Xhosa speaking primary school children in the Grahamstown region. Eprints [Online]

[<http://eprints.ru.ac.za/1384/01/bass-med-thesis.pdf>] (Accessed 13 June 2009).

Batra, J. & Sood, A. (2005). Iron deficiency anaemia: Effect on cognitive development in children: A review. *Indian Journal of Clinical Biochemistry*, 20, (2), 119-125.

Beard, J.L. (2001). Iron biology in immune function, metabolism and neuronal functioning. *Journal of Nutrition*, 131, 568S-79S.

Berry, L. & Hendricks, M. (2005). Nutrition-iron deficiency anaemia in children. Children's Institute, University of Cape Town [Online]

[<http://www.childrencount.ci.org.za>] (Accessed 14 December 2010).

Berry, L., Hall, K. & Hendricks, M. (2010). Nutrition-Stunting in children. Children's Institute, University of Cape Town [Online]

[<http://www.childrencount.ci.org.za>] (Accessed 11 June 2011).

Best, C., Neufingerl, N., van Geel, L., van den Briel, T. & Osendarp, S. (2010). The nutritional status of school-age children: why should we care? *Food and Nutrition Bulletin*, 31, (3), 400-417.

Black, M.M. (2009). Micronutrient deficiencies and Child development. *Nutrition Today*, 44, (2), 71-44.

Black, R.E., Morris, S.S., & Bryce, J. (2003). Where and why are 10 million children dying every year? *The Lancet*, 361, 2226-2234 [Online]

[[http://www.who.int/child\\_adolescent\\_health/documents/pdf/slancet\\_child\\_survival\\_10mill\\_dying.pdf](http://www.who.int/child_adolescent_health/documents/pdf/slancet_child_survival_10mill_dying.pdf)] (Accessed 4 June 2011).

Bobonis, G.J., Miguel, E. & Sharma, C.P. (2004). Iron deficiency anaemia and school participation. Poverty Action Lab Paper [Online]

[<http://www-givewell-org.mht>] (Accessed 22 February 2011).

Booth, I.W. & Aukett, M.A. (1997). Iron deficiency anaemia in infancy and early childhood. *Archives of Disease in Childhood*, 76, 549-554.

Branca, F. & Ferrari, M. (2002). Impact of micronutrient deficiencies on growth: The stunting syndrome. *Annals of Nutrition and Metabolism*, 46, (1), 8-17.

Brouwers, S.A., Van de Vijver, F.J.R. & van Hemert, D.A. (2009). Variation in Raven's Progressive Matrices scores across time and place. *Learning and Individual Differences*, 19, (3), 330-338.

Brunelli, S.M. & Berns, J.S. (2009). Anaemia in chronic kidney disease and end-stage renal disease. *Nephrology Rounds*, 7, (8) [Online]

[<http://www.nephrologyrounds.org/crus/304-076.pdf>] (Accessed 6 June 2010).

Bruner, A.B., Joffe, A., Duggann, A.K., Casella, J.F. & Brandt, J. (1996). Randomised study of cognitive effects of iron supplementation in non-anaemic iron-deficient adolescent girls. *The Lancet*, 348, (9033), 992-996.

Burden, M.J., Westerlund, A.J., Armony-Sivan, R., Nelson, C., Jacobson, S.W., Lozoff, B., Lu Angelilli, M., & Jacobson, J.L. (2007). An event-related potential study of attention and recognition memory in infants with iron deficiency anaemia. *Pediatrics*, 120, (2), e336-e345.

Carlson, J.S. & Jensen, C.M. (1981). Reliability of the Raven Coloured Progressive Matrices Test: Age and Ethnic group comparisons. *Journal of Consulting and Clinical Psychology*, 49, 320-322.

Centers for Disease Control and Prevention (1998). Recommendations to prevent and control of iron deficiency in the USA. *MMWR Morbidity, Mortality Weekly Report* [Online]

[<http://www.cdc.gov/mmwr/pdf/rr/rr4703.pdf>] (Accessed 30 June 2009).

Constenbader, V. & Ngari, S.M. (2001). A Kenya standardization of the Raven's Coloured Progressive Matrices. *School Psychology International*, 22, (3), 258-268.



Cook, J.D., Boy, E., Flowers, C. & Daroca, M-d, C. (2005). The influence of high-altitude living on body iron. *Journal of the American Society of Hematology* [Online]

[<http://bloodjournal.hematologylibrary.org/content/106/4/1441.full>] (Accessed 25 may 2011).

Coutsoudis, A., Jinabhai, C.C., Coovadia, H.M. & Mametja, L.D. (1994). Determining appropriate nutritional interventions for South African children living in informal urban settlements. *South African Medical Journal*, 84, (9), 597-600.

Department of Education. (2011). Report of the Annual National Assessments (ANA) of 2011. Department of Basic Education, RSA [Online]

[<http://www.education.gov.za/LinkClick.aspx?fileticket=1U5igeVjiqg%3D&tibid=358&mid=1325>] (Accessed 13 August 2011).

Department of Health. (2002). Regulations relating to the fortification of foodstuffs: Foodstuffs, Cosmetics and Disinfectants Act 1972 [Online]

[<http://www.doh.gov.za>] (Accessed 17 July 2011).

Dirren, H., Logman, M.H.G.M., Baclay, D.V. & Freire, W.B. (1994). Altitude correction for haemoglobin. *European Journal of Nutrition*, 48, 625-32.

Dissanayake, D.S., Kumarasiri, P.V.R., Nugegoda, D.B., & Dissanayake, D.M. (2009). The association of iron status with educational performance and intelligence among adolescents. *Ceylon Medical Journal*, 54, (3), 75-9.

Ekiz, C., Agaoglu, L., Karakas, Z., Gurel, N. & Yalcin, I. (2005). The effect of iron deficiency anaemia on the function of the immune system. *The Hematology Journal*, 5, 579-583 [Online]

[<http://online.haematologica.org/thj/2005/6200574a.pdf>] (Accessed 4 June 2011).

Eley, B.S., Sive, A.A., Shuttleworth, M. & Hussey, G.D. (2002). A prospective, cross-sectional study of anaemia and peripheral iron status in antiretroviral naive, HIV-1 infected children in Cape Town, South Africa. *BioMed Central Infectious Diseases*, 2, (3), 1-6.

Faber, M. (2007). Dietary intake and anthropometric status differ for anaemic and non-anaemic rural South African infants aged 6-12 months. *Journal of Health, Population and Nutrition*, 25, (3), 285-293.

Faber, M., Jogessar, V.B. & Benadé, A.J.S. (2001). Nutritional status and dietary intakes of children aged 2-5 years and their caregivers in a rural South African community. *International Journal of Food Science and Nutrition*, 52, (5), 401-411.

Faber, M. & Wenhold, F. (2007). Nutrition in Contemporary South Africa. *Water SA* [Online] [<http://www.wrc.org.za>] (Accessed 15 October 2010).

FAO/WHO. (1992). World declaration and plan of action for nutrition. Geneva, pp. 1-39 [Online] [[http://www.who.int/nut/documents/icn\\_declaration.pdf](http://www.who.int/nut/documents/icn_declaration.pdf)] (Accessed 16 May 2009).

Ferreira, M.U., da Silva-Nunes, M., Bertolino, C.N., Malafronte, R.S., Muniz, P.T. & Cardoso, M.A. (2007). Anaemia and iron deficiency in school children, adolescents and adults: a community-based study in rural Amazonia. *American Journal of Public Health*, 97, (2), 237-239.

Flynn, J.R. (1999). Searching for Justice: The discovery of IQ gains over time. *American Psychologist*, 54, 5-20.

Global Alliance for Improved Nutrition. (2011). South Africa maize meal and wheat flour fortification project. [Online] [<http://www.gain.mht>] (Accessed 14 July 2011).

Gerson, A.C., Butler, R., Moxey-Mims, M., Wentz, A., Shinnar, S., Lander, M.B., Mendly, S.R., Warady, B.A., Furth, S.L. & Hooper, S.R. (2006). Neurocognitive outcomes in children with chronic kidney disease: current findings and contemporary endeavours [Online] [<http://www.ncbi.nlm.nih.gov/pubmed/17061289>] (Accessed 5 January 2011).

Grantham-McGregor, S. & Ani, C. (2001). A review of studies of iron deficiency on cognitive development of children. *Journal of Nutrition*, 131, 649S-668S.

Grantham-McGregor, S. (2003). Does iron deficiency affect child development? *Pediatrics*, 122, (4), 978.

Hall, A., Bobrow, E., Brooker, S., Jukes, M., Nokes, K., Lambo, J., Guyatt, H., Bundy, D., Adjei, S., Wen, S.T., Subagio, H., Rafiluddin, M.Z., Miguel, T., Moulin, S., de Graft, J.J. et al. (2001). Anaemia in school children in eight countries in Africa and Asia. *Public Health Nutrition*, 4, (3), 749-756.

Halterman, J.S., Kaczorowski, J.M., Aligne, A., Auinger, P. & Szilagyi, P.G. (2001). Iron deficiency and cognitive achievement among school-aged children and adolescents in the United States. *Pediatrics*, 107, (6), 1381-86.

Harris, R.J. (2007). Iron deficiency: Does it really matter? *Paediatrics and Child Health*, 17, (4), 143-146. [Online]

[<http://www.sciencedirect.com/science/article/pii/S1751722207>] (Accessed 16 May 2011).

Hashizume, M., Chiba, M., Shinohara, A., Iwabuchi, S., Sasaki, S., Shimoda, T., Kunii, O., Caypil, W., Dauletbaev, D. & Alnazarove, A. (2005). Anaemia, iron deficiency and vitamin A status among school-aged children in rural Kazakhstan. *Public Health Nutrition*, 8, (6), 564-571.

Heckman, J.A. (2007). Determining point prevalence and aetiology of iron deficiency anaemia in under 5 children at Thohayandou Health Centre, Thohayandou, Limpopo Province, South Africa. Health System, Virginia Education Symposium [Online]

[[http://www.healthsystem.virginia.edu/internet/piih/ScholarAwards/ScholarApplication/Final\\_SA\\_Proposal.doc](http://www.healthsystem.virginia.edu/internet/piih/ScholarAwards/ScholarApplication/Final_SA_Proposal.doc)] (Accessed 3 February 2009).

Heckman, J., Samie, A., Bessong, P., Ntsieni, M., Hamandi, H., Kohler, M., Milam, B., Scriver, J., & Dillingham, R. (2010). Anaemia among clinically well under-fives attending a community health centre in Venda, Limpopo Province. *South African Medical Journal*, 100, 445-448.

Hemocue products. (2004) [Online].

[<http://www.hemocue.com/index.php?page=2004>] (Accessed 23 March 2009).

Idjradinata, P. & Pollitt, E. (1993). Reversal of developmental delays in iron-deficient anaemic infants treated with iron. *The Lancet*, 341, 1-4.

Jacobson, D. (2008). Prevention and treatment of iron deficiency anaemia in children. *Continuing Medical Education*, 26, 242-244.

JB Consultancy. (2002). Understanding of fortification issues in low income South African Metropolitan consumers. [Online] [<http://www.fortificationreport.pdf>] (Accessed 21 July 2011).

Jinabhai, C.C., Taylor, M., Rangongo, M.F., Mkhize, N.J., Anderson, S., Pillay, B.J. & Sullivan, K.R. (2004). Investigating the mental abilities of rural Zulu primary school children in South Africa. *Ethnicity and Health*, 9, (1), 17-36.

Kihn, T. (2005). The appropriateness of the Raven's coloured progressive matrices and its existing normative data for Zulu speakers [Online] [[http://researchspace.ukzn.ac.za/xmlui/bitstream/handle/10413/1890/kihn\\_Tarryn\\_2005pdf?sequence=1](http://researchspace.ukzn.ac.za/xmlui/bitstream/handle/10413/1890/kihn_Tarryn_2005pdf?sequence=1)] (Accessed 11 February 2011).

Knoetze, J., Bass, N. & Steele, G. (2005). The Raven's Coloured Progressive Matrices: Pilot norms for isiXhosa-speaking primary school learners in peri-urban Eastern Cape. *South African Journal of Psychology*, 35, (2), 175-194.

Konofal, E., Lecendreux, M., Arnulf, I. & Mouren, M-C. (2004). Iron deficiency in children with Attention-Deficit/Hyperactivity Disorder. *Archives of Pediatrics and Adolescent Medicine*, 158, 1113-1115.

Labadarios, D. & van Middelkoop, A.M. (1995). Children aged 6-71 months in South Africa 1994: Their anthropometric, vitamin A, iron and immunization coverage. South African Vitamin A Consultant Group [Online] [<http://www.sahealthinfo.org/nutrition/chapter6ironstatus.pdf>] (Accessed 30 February 2009).

Labadarios, D., Steyn, N.P., Maunder, E., MacIntyre, U., Swart, R., & Gericke, G.J. (2000). The national food consumption survey (NFCS): Children aged 1-9 Years. South Africa, 1999. Stellenbosch: NFCS [Online] [<http://www.sahealthinfo.org/nutrition/foodconsumption.htm>] (Accessed 13 January 2011).

Labadarios, D., Swart, R., Maunder, E.M.W., Kruger, H.S., Gericke, G.J., Kuzwayo, P.M.N., Ntsie, P.R., Steyn, N.P, Schloss, I., Dhansay, M.A., Jooste, P.L., Dannhauser, A., Nel, J.H., Molefe, D. & Kotze, T.J.W. (2008). The national food consumption survey-fortification baseline (NFCS-FB-1): South Africa, 2005. *South African Journal of Clinical Nutrition*, 21, (3), 247-263.

Lanzkowsky, B. (1995). *Manual of pediatric hematology & oncology*. (2<sup>nd</sup> edition), pp 35-50. Churchill Livingstone Inc. New York.

Lozoff, B., Jimenez, E. & Wolf, A.W. (1991). Long term developmental outcomes of infants with iron deficiency. *New England Journal of Medicine*, 325, 687-94.

Lozoff, B., Jimenez, E., Hagen, J. Mollen, E. & Wolf, A.W. (2000). Poorer behavioural and developmental outcome more than 10 years after treatment of iron deficiency in infancy. *Pediatrics*, 105, (4), E51.

Lozoff, B., Jimenez, E. & Smith, J.B. (2006). Double burden of iron deficiency in infancy and low socioeconomic status: A longitudinal analysis of cognitive tests scores to age 19 years. *Archives of Pediatrics and Adolescent Medicine*, 160, 11, 1108-1113.

Mamabolo, R.L. (2006). Can the high prevalence of micronutrient deficiencies, stunting and overweight in children at age 1 and 3 years in the Central Region of Limpopo province be explained by diet? *South African Journal of Clinical Nutrition*, 19 (3), 102-113.

Mansvelt, E.P.G. (2009). Iron Deficiency (ID) and Iron Deficiency Anaemia (IDA). *Professional Nursing Today*, 13, (1), 29-30 [Online]

[<http://www.pntonline.co.za/index.php/PNT/article/viewarticle,352>] (Accessed 13 November 2009).

McArdle, J.J., Ferrer-Caja, E., Hamagami, F. & Woodcock, R.W. (2002). Comparative longitudinal structural analysis of growth and decline of multiple intellectual abilities over the life span. *Developmental Psychology*, 38, 115-142.

Mcdowell, M.A., Fryar, C.D., Ogden, C.L. & Flegal, K.M. (2008). Anthropometric reference data for children and adults: United States, 2003-2006. National Health Statistics Reports, 10, 1-45. [Online] [<http://www.cdc.gov/nchs/data/nhsr/nhsr010.pdf>] (Accessed 3 May 2011).

Mendly, S.R. & Zelko, F.A. (1999). Improvement in specific aspects of neurocognitive performance in children after renal transplantation. *Kidney International*, 56, 318-323 [Online] [<http://www.nature.com/ki/journal/v56/n1/pdf/4495552a.pdf>] (Accessed 20 May 2010).

Miller, D.R. & Baehmer, R.L. (1990). Blood diseases of infancy & childhood. The O.C.V. Mosby Company, (6<sup>th</sup> edition), pp 170-175. St Louis, Missouri.

MI/UNICEF. (2003). Anaemia prevention and control: What works? Part II: Tools and resources. Micronutrient Initiative [Online] [[http://siteresources.worldbank.org/NUTRITION/Resources/281846-10903399908/anaemia\\_part2.pdf](http://siteresources.worldbank.org/NUTRITION/Resources/281846-10903399908/anaemia_part2.pdf)] (Accessed 12 August 2010).

Nathan, D.G. & Orkin, S.H. (1998). Nathan & Oski's haematology of infancy and childhood (5<sup>th</sup> edition) vol 1 (pp. 425-41). W.B. Saunders Company, Pennsylvania.

National Food Fortification Programme. (2008). Food Guide [Online] [<http://www.doh.gov.za>] (Access 7 July 1011).

Needlman, R.D. (2004). Growth and development: in Nelson Textbook of Pediatrics (17<sup>th</sup> edition), pp.46-49. Philadelphia: Saunders.

Neuman, W.L. (1997). Social Research methods, qualitative & quantitative approaches (3<sup>rd</sup> edition). Boston: Allyn and Bacon.

Nojilana, B., Norman, R., Dhansay, M.A., Labadarios, D., van Stuijnenburg, M.E., Bradshaw, D. & the South African Comparative Risk Assessment Collaborating Group (2007). Estimating the burden of disease attributable to iron deficiency anaemia in South Africa in 2000. *South African Medical Journal*, 97 (8), 741-46.

Oelofse, A., Faber, M., Benadé, J.G., Benadé, A.J.S., & Kenoyer, D.G. (1999). The nutritional status of a rural community of KwaZulu-Natal South Africa: The Ndunakazi Project. *Central African Journal of Medicine*, 45, (1), 14-19.

Owen, K. (1992). The suitability of Raven's standard progressive matrices for various groups in South Africa. *Personality and Individual Differences*, 13, 149-159.

Pollitt, E. (1997). Iron deficiency and educational deficiency. *Nutrition Reviews*, 55, (4), 133-141.

Powell, J.J., Jugdaohsingh, R. & Thompson, R. P. (1999). The regulation of mineral absorption in the GIT. *Proceeding of the Nutritional Society*, 58, 147-53 [Online]

[<http://www.ncbi.nlm.nih.gov/pubmed/10343352>] (Accessed 11 January 2010).

Ramakrishnan, U., Aburto, N., McCabe, G. & Martorell, R. (2004). Multimicronutrient interventions but not Vitamin A or Iron interventions alone improve child growth: results from 3 meta-analysis. *Journal of Nutrition*, 34, (10), 2592-2602.

Randall, P. (2001). South Africa to establish mandatory Food Fortification of staple food in 2002. [Online] [<http://www.scienceinafrica.co.za/2001/November/fortify.htm>] (Accessed on 25 July 2011).

Raven, J.C. & Court, J.H. (1990). *Manual of Raven's Progressive Matrices and Vocabulary Scales-Section 2: Coloured Progressive Matrices*. Oxford Psychologists Press [Online]

[<http://www.Schuhfried.com/areas-of-application/education/tests-trainings/test/cpm-ravens-coloured-progressive-matrices>] (Accessed 10 June 2009).

Rice, L., Ruiz, W., Driscoll, T., Whitley, C.E., Tapia, R., Hachey, D.L., Gonzales, G.F. & Alfrey, C. P. (2001). Neocytolysis on descent from altitude: a newly recognized mechanism for the control of red cell mass. *Annals of Internal Medicine*, 134, (8), 652-656. [Online]

[<http://www.annals.org/content/134/8/652.full.pdf>] (Accessed 29 May 2011).

Salthouse, T.A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, 103, 403-428.

Sever, Y., Ashkenazi, A., Tyano, S. & Weizman, A. (1997). Iron treatment in children with Attention-Deficit Hyperactivity Disorder: A Preliminary Report. *Neuropsychobiology*, 35, 178-180.

Sensi, L.S. & van Rensburg, S. (2005). It's all in the metals: A report on the 3<sup>rd</sup> International Metals and Brain Symposium at a combined meeting of the international brain research organisation (IBRO), the society of neuroscientist of Africa (SONA) and the collegium Internationale neuro-psychopharmacologicum (CINP) in Cape Town, South Africa, 22 April 2005. *Journal of Alzheimer's Disease*, 8, 207-208.

Sherwood, L. (2007). *Human Physiology* (6<sup>th</sup> Edition), pp 620-621. Thomson Brooks & Cole, Belmont, California.

Slickers, J., Duquette, P., Hooper, S. & Gibson, D. (2007). Clinical predictors of neurocognitive deficits in children with chronic kidney disease. *Pediatric Nephrology*, 22, 565-572 [Online] [<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1805046>] (Accessed 16 December 2010).

Soliman, A.T., Al Dabbagh, M.M., Habboub, A.H., Adel, A., Al Humaidy, N. & Abushahin, A. (2009). Linear growth in children with iron deficiency anaemia before and after treatment. *Journal of Tropical Pediatrics*, 55, (5), 324-327.

Stivelman, J. (2000). Benefits of anaemia treatment on cognitive function. *Nephrology Dialysis Transplantation*, 15, (3), 29-35 [Online] [[http://ndt.oxfordjournals.org/content/15/suppl\\_3/29.full.pdf+html](http://ndt.oxfordjournals.org/content/15/suppl_3/29.full.pdf+html)] (Accessed 30 March 2009).

Stoltzfus, R.J. (2001). Defining iron deficiency anaemia in public health terms: A time for reflection. *Journal of Nutrition*, 131, 565S-567S.



Stoltzfus, R. J., Mullany, L. & Black, R.E. (2004). Iron deficiency anaemia. In: Ezzati, M., Lopez, A.D., Rodgers, A. & Murray, C.J.L, eds. Comparative quantification of health risks: Global and regional burden of disease attributable to selected major risk factors, 1, 163-209. Geneva, Switzerland: WHO.

Sungthong, R., Mo-suwan, L., Chongsuvivatwong, V. & Geater, A.F. (2002). The effects of haemoglobin and S-ferritin on cognitive function of school children. *Asian Pacific Journal in Nutrition*, 11, (2), 177-82.

Troesch, B., van Stuijvenberg, M.E., Smuts, C.M., Kruger, H.S., Biebinger, R., Hurrell, R.F., Baumgartner, J. & Zimmerman, M.B. (2011). A micronutrient powder with low doses of highly absorbable iron and zinc reduces iron and zinc deficiency and improves weight-for-age Z-score in South African children. *The Journal of Nutrition*, 141, (2), 237-242.

UNICEF/UNU/WHO/MI. (1999). Preventing iron deficiency in women and children: Technical consensus on key issues, New York [Online]

[[http://www.inffoundation.org/pdf/prevent\\_iron\\_def.pdf](http://www.inffoundation.org/pdf/prevent_iron_def.pdf)] (Accessed 10 October 2010).

UNICEF/WHO. (1999). Prevention and control of iron deficiency anaemia in women and children. Consultation Report, Geneva, Switzerland [Online]

[[http://www.who.int/nutrition/publications/micronutrients/anaemia\\_iron\\_deficiency/UNICEF\\_WHO\\_ida\\_consultation\\_report.pdf](http://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/UNICEF_WHO_ida_consultation_report.pdf)] (Accessed 24 June 2011).

Van Stuijvenburg, M.E., Kvalsvig, J.D., Faber, M., Kruger, M., Kenoyer, D.G. & Benadé, A.J.S. (1999). Effect of iron, iodine and  $\beta$ -carotene fortified biscuits on the micro-nutrient status of primary school children: a randomised controlled trial. *The American Journal of Clinical Nutrition*, 69, 497-503.

Van Stuijvenburg, M.E., Smuts, C.M., Lombard, C.J. & Dhansay, M.A. (2008). Fortifying brown bread with sodium iron EDTA, ferrous fumarate, or electrolytic iron does not affect iron status in South African school children. *The Journal of Nutrition*, 138, 782-786.

Vass, V. (1992). Standardisation of Raven's Standard Progressive Matrices for secondary school African pupils in the Grahamstown region. Unpublished Master's Thesis, Rhodes University, Grahamstown.

Walker, S.P., Powell, C.A., Grantham-McGregor, S.M., Himes, J.H. & Chang, S.M. (1991). Nutritional supplementation and growth of stunted children: the Jamaican study. *American Journal of Clinical Nutrition*, 54, 642-648.

Walker, S.P., Wachs, T.D., Gardner, J.M., Lozoff, B., Wasserman, G.A., Pollitt, E., Carter, J.A & the International Child Development Steering Group (2007). Child development: Risk factors for outcomes in developing countries. *The Lancet*, 369, 145-57.

Wharton, B.A. (1999). Iron deficiency in children: Detection and prevention. *British Journal of Haematology*, 106, (2), 270-280.

WHO. (2000). Global Burden of Disease 2000: Iron deficiency anaemia [Online]  
[[http://www.who.int/healthinfo/statitics/bod\\_irondeficiencyanaemia.pdf](http://www.who.int/healthinfo/statitics/bod_irondeficiencyanaemia.pdf)] (Accessed 10 June 2011).

WHO. (2005). Worldwide Prevalence of Anaemia 1993-2005: WHO Global Database on Anaemia [Online]  
[[http://www.who.int/nutrition/publications/micronutrients/anaemia\\_iron\\_deficiency/9789241596657/en/index.html](http://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/9789241596657/en/index.html)] (Accessed 6 July 2010).

WHO/UNICEF/UNU. (2001). Iron deficiency anaemia: Assessment, prevention and control. A guide for programme managers [Online]  
[[http://www.int/nutrition/publications/en/ida\\_assessment\\_prevention\\_control.pdf](http://www.int/nutrition/publications/en/ida_assessment_prevention_control.pdf)] (Accessed 13 August 2010).

WHO/WFP/UNICEF. (2006). Preventing and controlling micronutrient deficiencies in populations affected by an emergency. Joint statement by the World Health Organization, the World Food Programme and the United Nations Children's Fund [Online]  
[[http://www.unicef.org/nutrition/files/Joint\\_Statement\\_Micronutrient\\_March\\_2006.pdf](http://www.unicef.org/nutrition/files/Joint_Statement_Micronutrient_March_2006.pdf)] (Accessed 4 June 2011).

Wu, A.C., Lesperance, L. & Bernstein, H. (2002). Screening for iron deficiency. *Pediatrics in Review*, 23, 171-178 [Online]

[<http://pedsinreview.aappublications.org/cgi/content/extract/23/5/171>] (Accessed 13 April 2009).



## **APPENDIX II: PATIENT INFORMATION LEAFLET**

### **Introduction:**

I am Dr Bongive Hlatshwayo from the Department of Paediatrics at the Medunsa-Dr George Mukhari Hospital Complex. I am conducting a research on the effects of iron deficiency anaemia on academic performance and cognitive function on children. You are invited to allow your child to participate in this study. If you agree, your child will be one of the 385 pupils to be selected for the study around Winterveldt primary schools.

### **Purpose of the study:**

To study the effects of iron deficiency anaemia on academic performance and cognitive function in grade II pupils from Winterveldt region.

### **What the study involves:**

All children will be screened for anaemia using a haemoglobin meter similar to the one used to check for diabetes in adults. It involves using a drop of blood from the finger prick. If your child is found to be anaemic, blood will be collected for further iron studies. All the children who are found to be iron deficient will be enrolled for school performance assessment. We will use school records and a psychometric test to compare the children with no anaemia and those with iron deficiency anaemia.

We are only enrolling children between the age of six and 10 years as the children above 10 years have higher haemoglobin levels. All children will be weighed and their heights measured so that we do not compare a bigger and taller child to a small child.

### **Ethical considerations:**

- A. Permission has been granted by the Department of Education to conduct the study. There will be no disruption of classes as the study will be conducted after school hours.
- B. The Subdistrict Head Office of the Department of Education has given permission to conduct the study.
- C. The Medunsa Research and Ethical Committee (MREC) and the school principals have been consulted and have given approval to conduct the study.
- D. The study is voluntary and a participant can be withdrawn at any time with no influence on future intervention.
- E. Publication of the findings will be confidential, that is, pupils' names will not be used but study numbers will be assigned to each participant. Data will be kept for a maximum of five years.

### **Possible risks:**

The risk of infection with blood-borne diseases will not happen as we are using one lancet prick per subject which is discarded after use. We also use aseptic procedure in collecting blood samples and the researcher is responsible for collecting blood.

### **Benefits of the study:**

The community's point prevalence of iron deficiency anaemia will be known and further steps will be taken to ensure that all children get iron supplements in their early years, like the vitamin A which is now routinely given to all young children.

If an association is found between iron deficiency anaemia and poor school performance, children will be referred for treatment to reverse these effects and your child will develop to full potential.

### **Participant's rights:**

Enrolment is voluntary and subjects can be withdrawn at any point of the study with no future influence on intervention.

All subjects are entitled to receive feedback letters throughout the study.

Pupils will receive material for use in the test like rubbers and pencils.

### **Confidentiality:**

The school principal and class teachers will not be told of the study results. All the results and the name of the pupils will be kept by the researcher. Her assistants will also have no access to this confidential information. Study numbers will be used throughout the study.

### **TRANSLATED:**

#### **Matseno:**

Ke nna Dr Bongiwe Hlatshwayo go tswa lefapheng la tsa masea mo sepetlela sa Dr George Mukhari. Re dira dipatlisiso ka ditlamorago tsa tlhaello ya minerale wa tshipi o o bakang tlhaello ya madi go go kgoreletsang bokgoni jwa go amogelo dithuto mo baneng. O lalediwa go dumela ngwana wag ago go tsaya karolo mo patlisisong e. Fa o dumela, ngwana gago e ya go nna mongwe wa ba385 ba ba tla tlhophiwang go tsaya karolo mo dikolong tsa Winterveldt.

#### **Maikaello a thuto-patlisiso:**

Re ikaella go tlhotlhomisa ditlamorago tsa tlhaello ya minerale wa tshipi mo baneng ba garata ya bobedi mo tikolong tsa Winterveldt.

#### **Thuto-patlisiso e akaretsa eng?:**

Bana botlhe bay a go tlhathlobelwa tlhaello ya madi ka go dirisa mochini o o tshwanang le o o diriswang go lekanyetsa bolwetsi jwa sukiri. Go ya go tlhabiwa monwana go tsuntsuyetsa lerothodi la madi. Fa go ka lemoga tlhaello ya madi mo ngwaneng wa gago, madi a a tsuntsulotsweng a ya go tlhatlhobelwa dipatlisiso ka ga minerale wa tshipi. Bana botlhe ba ba yang go fitlhelwa ba na le tlhaello ya minerale wa tshipi, ba ya go lekanyediwa go amogela dithuto ga bone. Re ya godirisa direkhote tsa sekolo le diteko tsa go lekanyetsa botlhale go bapisa bana bab a se nang le bokoa jwa tlhaello ya madi le bana bab a nang le jone bokoa.

Re kwadisa fela bana ba dingwana di le 6 go fitlha go 10 gonne bana ba dingwaga tse di fetang 10 ba na le ditekanyetso tse di kwa godimo tsa diteko tsa madi. Bana bothle ba ya go kalwa le go tsewa botelle gore re tle re se lekanye ngwana yo mogolwane le yo monnyane.

### **Ka tsa setho:**

- A. Lefapha la thuto le setse le kopilwe e bile le file tete go tseleletsa patlisiso. Ga go ne go nna le kgoreletso mo tsamaisong ya dithuto ya sekolo ka ge re ya godirisa na e bana ba seng mo dithutong.
- B. Komiti ya tsa Dipatlisiso ya Medunsa, mmogo le megokgo ya dikolo ba setse ba file tetelelo.
- C. Go tsaya karolo ke ka go ithaopa, e bile batsaya-karolo ba ka gogelwa morago nako nngwe le nngwe ntle le go ka salwa morago mo nakong e e tlang.
- D. Dipatlisiso di ya go dorwa ntle go senola leina la ngwana wag ago kgotsa la gago, godimo ga moo go ya diriswa dinomoro go emela leina la ngwana mongwe. Diphitlhello di ya go bolokiwa go fotha dingwana tse hlanu.

### **Matshosetsi a a ka lebellwang:**

Moatshosetsi a tshwaetso fa go gogwa madi ga a lebellwa ka ge tiriso ya nalatanyana ya go tsuntsunyetsa madi e tla be e babaletswe go dira mo ngwaneng a le mme morago e latlhiwe. Re ya go dirisa mekgwa e e babalesegileng go tsuntsunyetsa madi mme boikarabelo jotle bo mo mmatlhisising.

### **Dipoelo tsa thuto-patlisiso:**

Baagi ba ya go itse gore tlhaello ya madi ga bana go ka bakiwa ke tlhaello ya minerale wa tshipi, mme se se tla thuso go tsaya dikgato tse di maleba go bona gore bana botlhe ba fiwa metsosa e e tlhabotlang madi ba sa le bannyane jaaka ya vitamini ya A e e fiwang bana e le kgapeletso. Fa go ka fitlhelega tsamaisano magareng ga tlhaello ya minerale ya tshipi e e bakang tlhaello ya madi, le go tlhaloganya dithuto tsa sekolo ga ngwana, bana bao ba ya go kaelwa go ya go bona thuso ya kalafi go leka go busetsa morago ditlamorago tse, mme se se ya go kgontsha go gola ntle le matshosetsi a pholo.

### **Ditokelo tsa motsaya-katolo:**

Go ikwadisa ke ka go ithaopa, ka jalo batsaya-karolo ba ka gogelwa morago ntle le go tla ba tsena tsena gape mo nakong e e tlang. Batsaya-karolo botlhe ba na le tokelo ya go fiwa diphitlhello mo tsamaisong ya patlisiso ka makwalo. Batsaya-karolo ba ya go fiwa tsotlhe tsa go kwala jaaka dipensele le diraba.

### **Bosephiri/Khupamarama:**

Mokgoko le barutabana ba sekolo ga ba kitla ba bolellwa dipholo tsa patlisiso. Dipholo tsotlhe le maina a bana e ya go nna sephiri sa mmatlisisi. Mothusi wa gagwe le ena ga a na go nna le phitlhello epe ya tshedimose tso a ya sephiri.

**APPENDIX III: LETTER TO THE PARENT OF NORMAL PUPIL**

P.O.BOX 27

Medunsa

0204

Motsadi,

Ngwana wag ago o fitlhetswe a siame go ya ka di patlisiso tsa madi. A ka se tswelle pele ka thuto patlisiso ele. Re lebogela go tsaya karolo ga gwe kwa tshimalogong.

Kea leboga

Dr BPS Hlatshwayo



**APPENDIX IV: LETTER TO THE PARENT OF CONTROL PUPIL**

P.O. Box 27

Medunsa

0204

Motsadi,

Ngwana wa gago o tla tswelela pele ka thuto patlisiso. O tla fiwa diphitlello fa logato lwa bo bedi le fela. O fitlhetswe a siame mo mading fela psychologist o tla mo dirisa go le belala dithuto gore o kgana jang.

Kea leboga,

Dr BPS Hlatshwayo

APPENDIX V: LETTER TO THE PARENT OF CASE PUPIL

P.O.BOX 27

Medunsa

0204.

Motsadi,

Ngwana wagago o fitlhetswe ana le thlaelo ya madi. Re tla tswella pele ka thuto patlisiso, o tlo kwala tlhatlhobo/test. Morago ga mo o o tla romelwa kwa sepetlele go amogela kalafi ya thlaelo ya madi. Ke nna ke tla beng ke mo alafa kwa bookelong.

Kea leboga

DR BPS Hlatshwayo

**APPENDIX VI: DATA COLLECTION SHEET**

Study number (enrolment nr) -----

Demographic data:

1. Age-----

2. Weight-----

3. Height-----

4. Gender-----

Haemoglobin level----- ANAEMIA YES----- NO-----

Blood sample taken YES----- NO-----

Ferritin levels----- IDA YES----- NO-----

CRP-----

School performance:

Overall score-----

Number of terms-----

Psychometric Score (percentiles) -----

## **APPENDIX VII: The Raven's Coloured Progressive Matrices**

### Instructions

The test consists of patterns with pieces cut from each.

Each of the pieces given 1 to 6 are the right shape to fit the space in the main pattern but

Only one of them is the right pattern.

Look carefully at the pattern, only one piece is quite right, choose one that will go into the Space and circle the number of the piece.

Look again to check if your choice completes the pattern.

### Duration:

You are allowed to complete the test in 45min. Raise your hand if you do not understand the instructions.

### Translated:

Teko ya tsweletso ya nepagalo ya tlhologanyo ya bana ba garato ya 2.

Tlhagiso ka ga teko:

Teko e na le ditshwantsho kgotsa diphehene tse go ngathilweng karolwana go twa mo setshwantshong kgotsa mo phetheneng e e feletseng.

Nngwe le enngwe ya ditokana tse di tshaileng 1 go fitlha go 6 e tshwanetse go tseno mo phetheneng e tshweunyana e e mo phetheneng e e feletsang , fela, ke e le nngwe e e lebaneng.

Lebella phethene ka tlhoafalo, e le nngwe fela ya ditokana e nepagetse, tlhopa fela e e tla tsenang mo go tshwanetseng, o be o seketse nomoro/palo ya setokana.

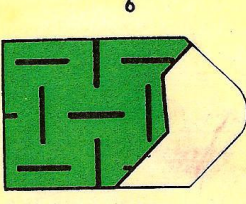
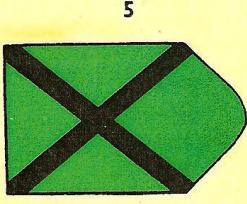
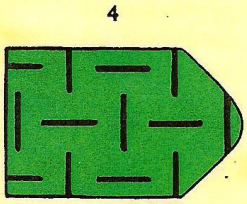
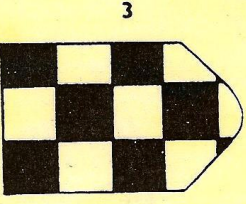
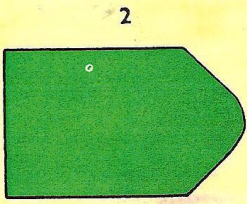
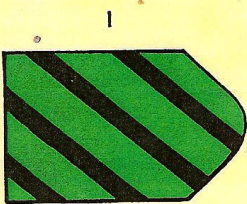
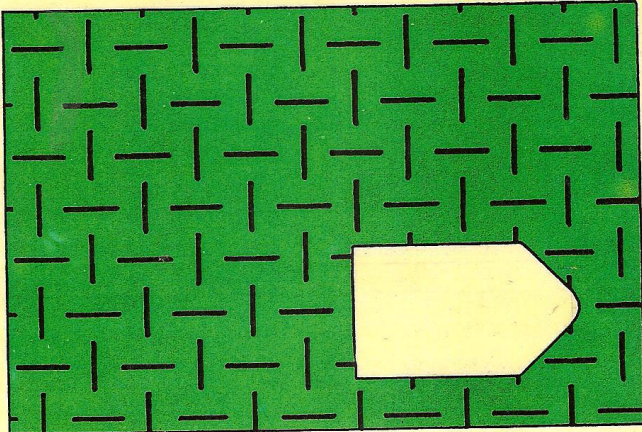
Lebisisa gape go keleka fa setokana se o se tlhophileng se feleketsa phethene.

Nako: O dumellwa go fetsa teko mo metsotsong e e 45. Emisa letsogo la gago fa o sa tlhologanye tlhaloso ya me.

EXAMPLE OF PICTURE TEST OF RCPM

— A —

A |



**APPENDIX VIII: MREC CLEARANCE CERTIFICATE:**

**UNIVERSITY OF LIMPOPO**  
Medunsa Campus



**MEDUNSA RESEARCH & ETHICS COMMITTEE**

**CLEARANCE CERTIFICATE**

P O Medunsa  
Medunsa  
0204  
SOUTH AFRICA

MEETING: 08/2009

PROJECT NUMBER: MREC/M/147/2009: PG

Tel: 012 - 521 4000  
Fax: 012 - 560 0086

**PROJECT :**

Title: The association between iron deficiency Anaemia and Academic performance of children focusing on Grade II pupils in the Winterveldt region Tshwane North, RSA

Researcher: Dr B Hlatshwayo  
Supervisor: Prof FPR de Villiers  
Department: Paediatrics  
School: Medicine  
Degree: MMed Paediatrics

**DECISION OF THE COMMITTEE:**

MREC approved the project.

DATE: 06 October 2009

  
PROF GA OGUNBANJO  
CHAIRPERSON MREC



**Note:**

- i) Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee.
- ii) The budget for the research will be considered separately from the protocol. PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.



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## APPENDIX IX: GAUTENG DOE PERMIT LETTER



UMnyango WezeMfundo  
Department of Education

Lefapha la Thuto  
Departement van Onderwys

Enquiries: Nomvula Ubisi (011)3550488

Date:	28 October 2009
Name of Researcher:	Hlatshwayo Bongiwe Princess
Address of Researcher:	948 Inswempe Street
	Nkwe Estate, Ext 18
	Rosslyn Tshwane
Telephone Number:	0125293111/0828627890
Fax Number:	0866056951
Research Topic:	The association between iron deficiency anaemia and academic performance of children, focusing on grade 2 pupils in the Winterveldt region, Tshwane North, RSA
Number and type of schools:	3 Primary Schools
District/s/HO	Tshwane North

### **Re: Approval in Respect of Request to Conduct Research**

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

Permission has been granted to proceed with the above study subject to the conditions listed below being met, and may be withdrawn should any of these conditions be flouted:

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*

---

Office of the Chief Director: Information and Knowledge Management  
Room 501, 1.11 Commissioner Street, Johannesburg, 2000 P.O.Box 7710, Johannesburg, 2000

4. A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.
5. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.
6. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.
7. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year.
8. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.
9. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
10. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
11. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.
12. On completion of the study the researcher must supply the Director: Knowledge Management & Research with one Hard Cover bound and one Ring bound copy of the final, approved research report. The researcher would also provide the said manager with an electronic copy of the research abstract/summary and/or annotation.
13. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
14. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

Pp Nomvula Ubisi  
 Martha Mashego  
 ACTING DIRECTOR: KNOWLEDGE MANAGEMENT & RESEARCH

<b>The contents of this letter has been read and understood by the researcher.</b>	
<b>Signature of Researcher:</b>	
<b>Date:</b>	



## APPENDIX X: LOCAL DOE PERMIT LETTER



**UMnyango WezeMfundo**  
**Department of Education**

*RMS 3*  
**Lefapha la Thuto**  
**Departement van Onderwys**

ENQUIRIES: Tlhoale RL  
UNIT: PP and DIMIS  
TEL. NO.: 012 725 1357

REFERENCE: Research/project  
FAX NO.: 012 702 7723

**TO: THE PRINCIPALS  
TIDIMALONG,  
PHILEMON MONTSHO AND  
REFILWE PRIMARY SCHOOLS**

**FROM: DISTRICT DIRECTOR  
TSHWANE WEST**

**DATE: 30 NOVEMBER 2009**

### **PERMISSION TO CONDUCT RESEARCH: PROJECT**

Dr BPS Hlatshwayo has been granted permission by Head Office to conduct research in the following institutions: Tidimalong, Philemon Montsho and Refilwe Primary Schools early next year. The School principals and SGB members are kindly requested to welcome the researcher.

Topic of research: "The association between iron deficiency Anaemia and Academic performance of children focusing on Grade 2 pupils in the Winterveldt region Tshwane North, RSA."  
Nature of research: MMed Paediatrics  
Name of institution: University of Limpopo  
Supervisor/Promoter: Prof. FPR de Villiers

Please ensure that minimum disruption to teaching and learning is caused.

**TS MAKOFANE  
DISTRICT DIRECTOR  
TSHWANE WEST**