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Body composition, physical activity and C-reactive protein in children: The PLAY Study

B Harmse, B.Sc. Dietetics

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Abstract

Obesity is currently the most common and costly nutritional problem in developed countries and ten percent of the world's school-aged children are estimated to be overweight to some extent. Low-grade systemic inflammation is increasingly emerging as a significant component of the metabolic syndrome. Youth in lower income families are particularly vulnerable because of poor diet and limited opportunities for physical activity. In developing countries obesity among youth is rising among the urban poor, possibly due to their exposure to Westernised diets coinciding with a history of undernutrition. The aim of this study was to assess the association between serum CRP and physical activity and to assess the association between serum CRP and body composition in black high-school children from a township in the North West Province (NWP), South Africa.

Methods and results: The study group consisted of 193 school children between the ages 13 to 18 years (78 boys and 115 girls) residing in Ikageng, the township outside of Potchefstroom in the North West Province, South Africa. Children were from a black ethnic group, living in a poor socio-economic setting. Demographic and body composition measurements were taken and fasting blood samples were drawn for serum C-reactive protein (CRP) measurements. The difference between serum CRP of overfat versus girls with a normal fat percentage was non-significant ($p = 0.46$). Boys with body fat percentage >20% (n=16) had a mean serum CRP of 1.42 ± 2.16 mg/L and for boys with a normal fat percentage (n=53) mean serum CRP was 0.89 ± 1.62 mg/L. The Mann-Whitney U-test for the difference between mean CRP of the two groups of boys was $Z=1.39$, $p = 0.16$ (no significant difference), but with a trend of higher serum CRP concentration in the boys with higher % body fat. For the boys, the only positive partial correlation was between serum CRP and triceps skinfold ($r=0.327$, $p=0.045$). In the girls' group no statistically significant partial correlations were found between CRP and body composition variables. There was no significant difference between serum CRP concentrations of the three physical activity categories of girls. Interestingly, there was an inverse correlation between percentage body fat

and fitness in the boys' group (r=-0.509 and p= 0.008). The difference in log CRP between activity groups showed a trend of lower serum CRP with higher physical activity in the girls.
Conclusion: This study showed no statistically significant associations between serum CRP and body composition, except for the positive correlation between triceps skin fold and serum CRP in boys, or CRP and physical activity, but clear trends were noted of an inverse association between CRP and physical activity in the girls.

Key words:
C-reactive protein, inflammation, physical activity, youth, adolescent, metabolic syndrome, body composition

Opsomming

Vetsug is tans die duurste en mees algemene voedingsprobleem in ontwikkelde lande, en daar word geskat dat tien persent van die wêreld se kinders van skoolgaande ouderdom tot 'n mate oorgewig is. Laer-graad sistemiese inflammasie word al hoe meer genoem as 'n betekenisvolle komponent van die metaboliese sindroom. Tieners in lae-inkomste families is veral vatbaar omdat hulle minder geleenthede tot fisiese aktiwiteit en minder optimale eetgewoontes ondervind. In ontwikkelende lande is obesiteit in arm stedelike groepe aan die toeneem, moontlik as gevolg van blootstelling aan die Westerse dieet na 'n geskiedenis van ondervoeding in die verlede. Die doel van die studie was om die assosiasie tussen serum C-reaktiewe proteien (CRP) en fisiese aktiwitiet en ook die verhouding tussen CRP en liggaamsamestelling te bepaal onder 'n groep hoërskool leerlinge uit 'n informele nedersetting in Ikageng, buite Potchefstroom in die Noordwes provinsie van Suid Afrika.
Metodes en resultate: Die studie-groep het bestaan uit 193 skoolkinders tussen die ouderdom van 13 en 18 jaar (78 seuns en 115 dogters) wat woonagtig is in Ikageng, buite Potchefstroom in die Noordwes Provinsie,

Suid-Afrika. Die swart kinders was van 'n lae-inkomste groep. Demografiese en liggaamsamestelling metings is geneem en vastende bloedmonsters is geneem vir serum CRP metings. Die verskil tussen serum CRP van oor-vet teenoor meisies met 'n normale vet persentasie was nie statisties betekenisvol nie (p = 0.46). Seuns met 'n vet persentasie >20% (n=16) het 'n gemiddelde CRP van 1.42 ±2.16 mg/L, en vir seuns met 'n normale vet persentasie (n=53) was die gemiddelde serum CRP 0.89 ±2.16 mg/L. Die Mann-Whitney U-toets vir die verskil tussen die log CRP van die twee seuns groepe was Z=1.39, P=0.16 (nie betekenisvol), maar daar was 'n tendens van hoër CRP waardes in seuns met 'n hoër persentasie liggaamsvet. Vir die seuns was die enigste betekenisvolle positiewe korrelasie tussen CRP en die triseps velvou (r=0.327, p=0.045). By die meisies was daar geen betekenisvolle parsiële korrelasies tussen CRP en veranderlikes van liggaamsamestelling nie. Daar was geen betekenisvolle verskil tussen CRP vir verskeie aktiwiteitsvlakke in die meisies nie, maar daar was 'n omgekeerde korrelasie tussen vetpersentasie en fisiese fiksheid in die seuns (r=-0.509, p= 0.008). Daar was wel 'n tendens van laer CRP met verhoogde aktiwiteit by die meisies.

<u>Samevatting:</u> Daar was geen statisitese betekenisvolle assosiasies tussen serum CRP en liggaamsamestelling, buiten die positiewe korrelasie tussen CRP en triseps velvou van die seuns, of CRP en fisiese aktiwiteit in hierdeie studie nie, maar duidelike tendense word gesien van 'n omgekeerde verwantskap tussen fisiese aktiwiteit en CRP in die meisies.

Kernwoorde:

C-reaktiewe proteien, inflammasie, fisiese aktiwiteit, jeug, adolessent, metabolise sindroom, liggaamsamestelling.

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Such confidence as this is ours through Christ before God. Not that we are competent in ourselves to claim anything for ourselves, but our competence comes from God. 2 Corinthians 3:4-5

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Chapter 1: Introduction

Content of introduction

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1.1. Background

South Africa is a developing country where both undernutrition and overnutrition is seen. The prevalence of obesity is high among adult black women, whilst low in children (Kruger, 2005:1153; Steyn *et al.,* 2005). According to Monyeki *et al.* (1999:287), obesity is not only common in South African female adults, but also in female adolescents. In 2002 the First South African National Youth Risk Behaviour Survey stated that the prevalence of overweight among high school children was 17% and obesity 4% (Medical Research Council of South Africa, 2002:12).

Obesity is currently the most common and costly nutritional problem in developed countries with ten percent of the world's school-aged children estimated to be overweight to some extent (Molnár and Livingstone; 2000:S45). The metabolic syndrome (MS), a cluster of 5 biological markers that together predict the development of cardiovascular disease and type 2 diabetes, is now increasingly emerging among children and adolescents (Nemet *et al.*, 2003:148). Low-grade systemic inflammation is increasingly emerging as a significant component of the MS (Klein-Platat *et al.*, 2005:1178).

Youth in lower income families are particularly vulnerable because of poor diet and limited opportunities for physical activity (PA) (Lobstein *et al.*, 2004: 5). In developing countries, obesity among youth is most prevalent in wealthier sections of the population, but is also rising among the urban poor in these countries, possibly due to their exposure to Westernized diets coinciding with a history of undernutrition (Lobstein *et al.*, 2004: 5). Lambert *et al.* (2004:1762) concluded that the metabolic correlates of excess weight, including a state of low-grade systemic inflammation, are detectable early in life.

This study was performed as part of the PLAY study, which investigated the effects of physical activity in children. The PLAY study (acronym for PhysicaL Activity in the Young) was a parallel intervention study consisting of an experimental as well as a control group with the intervention group having been subjected to a physical activity intervention.

The study group consisted of 193 (78 boys and 115 girls) school children between the ages 13 to 18 years, attending one of two schools (Seiphemelo Secondary School or Boitshoko High School) in Ikageng, a township outside of Potchefstroom in the North West Province, South Africa. A nutrition advisor from the District Health office selected these schools because it was most likely to find undernourished children in these schools.

The sample comprised children from a black ethnic group living in a poor socio-economic setting. The type of housing utilised by the population group is mainly galvanized/zinc or brick houses with a partial water and electricity supply. Subjects in the different schools were in the similar growth phase and socio-economic status and their eating habits and physical activity levels were also similar.

In South Africa there is a need for data regarding the status of childhood overweight, the metabolic syndrome and the cardio-vascular risk, with many studies focusing on only one or two risk factors. In this study, the focus was on gathering information in such a manner that the relevant conclusions could be made regarding body composition, physical activity, CRP as a marker and ultimately the metabolic syndrome and the risk for cardiovascular disease in high school aged children.

1.2. Goals

The goals of the study were

- To assess the association between serum CRP and physical activity in black children aged 14 - 18 from a township in the North West Province (NWP), South Africa
- To assess the association between serum CRP and body composition in black children aged 14 - 18 from a township in the NWP, South Africa.

1.3. Hypothesis

The following hypotheses were formulated for this study:

- There is a negative association between serum C-reactive protein concentration and habitual physical activity in black adolescents from a township school in the NWP, South Africa
- C-reactive protein is positively associated with body composition measures of overweight (especially in terms of body fatness) in black adolescents from a high school in a township in the NWP, South Africa.

1.4. Structure of this mini-dissertation

This mini-dissertation is divided into six chapters. The introductory section is aimed at stating the problem, introducing the reader to the study group and placing the setting of the study in perspective, whilst the literature review is a summary of current peer reviewed literature available on the topic and relevant studies that have been done, followed by the methodology and results obtained. The author concludes with a discussion of results and the significance of the outcomes in light of current literature, followed by the conclusion.

1.5 Contributions of the author

The author played a part in the organisation of the study on ground level and assisted in the collection of demographical data. She also assisted in obtaining anthropometrical measurements (skin folds) and manually computerising data. Interacting with the subjects as well as assisting with interviews on the school premises gave the author the opportunity to attain insight into the circumstances and daily activities of the children.

Chapter 2: Review of literature

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2.1. Introduction

Obesity is currently the most common and costly nutritional problem in developed countries (Molnár & Livingstone; 2000:S45) and ten percent of the world's school-aged children are estimated to be overweight to some extent (Lobstein *et al.,* 2004: 4).

The prevalence of overweight is rising significantly in most parts of the world, although dramatically higher in economically developed regions (Jebb *et al.,* 2003: 461; Lobstein *et al.,* 2004: 4). The rapidity of this increase implicates environmental rather than genetic factors (Lobstein *et al.,* 2004:5), although one cannot exclude the correlation between genes and the environment (Berkey *et al.*, 2003: 836; Guo *et al.*, 2000:1634).

The metabolic syndrome (MS), a cluster of 5 biological markers that together predict the development of cardiovascular disease and type 2 diabetes, is now increasingly emerging among children and adolescents (Nemet *et al.*, 2003:148). Hypertension, insulin resistance, central adiposity, hypertriglyceridemia and decreased values of high-density lipoprotein cholesterol are regularly measured in clinical medicine, but they seem to have little in common mechanistically (Phinney, 2005:115).

Low-grade systemic inflammation is increasingly observed as a significant component of the MS (Klein-Platat *et al.*, 2005:1178). Different cytokines and chemical messengers, which induce their effects individually or in interaction with each other, constitute the main regulators of the inflammatory process (Klein-Platat *et al.*, 2005:1178).

Among these cytokines, IL – 6, a pro-inflammatory cytokine produced by different cells, adipose tissue amongst others, is over expressed in adults with MS (Visser *et al.*, 2001:e13) and in obese adolescents (Visser *et al.*, 2001:e13). The findings linking inflammation and the MS may either make this picture more complex or provide a mechanistic link between these indexes (Phinney, 2005:115).

Elevated plasma lipid levels are a characteristic of obesity, infection and other inflammatory states. Hyperlipidemia in obesity is in part causal to the induction of peripheral tissue insulin resistance and dyslipidemia contributes to the development of atherosclerosis (Wellen & Hotamisligil, 2005:112)

Youth in lower income families are particularly vulnerable because of poor diet and limited opportunities for PA (physical activity). In developing countries, obesity among youth is most prevalent in wealthier sections of the population, but is also rising among the urban poor in these countries, possibly due to their exposure to Westernized diets coinciding with a history of undernutrition (Lobstein *et al.,* 2004: 5).

2.2. Adolescent physiology and body composition

2.2.1. Physical growth and maturation

Adolescence is an important period in development and significant somatic growth and maturation of secondary sexual characteristics are evident during this time. The onset of puberty is believed to occur as a consequence of a change in the pituitary-gonadal axis resulting in a dramatic rise in testosterone in boys and estrogen in girls. Evaluation of growth based on chronological age alone can be inaccurate and misleading due to marked variability in the timing of maturational changes (Cole *et al.*, 2000:1240; Lobstein *et al.*, 2004:36).

Obese youth characteristically have accelerated growth initially, e.g. in advanced height and bone age, but their pubertal growth spurt is less pronounced, resulting in a reduction in height centile and ultimately adult heights no different from their non-obese counterparts (Lobstein *et al.*, 2004:36).

The pubertal growth spurt is associated with significant changes in body composition (Guo *et al.*, 2000:1633), where girls tend to accumulate more fat than boys. Menarche usually occurs shortly after the peak in height velocity in girls (Kruger, 2005:1153). The rise in serum oestradiol relates temporarily to breast enlargement, widening of the hips and an increase in body fat.

2.2.2. Measures of overweight in childhood and adolescence

Anthropometry is widely used in surveys as an indicator of nutritional and health status. It is especially important during adolescence as it allows evaluation of physical and maturational growth as well as health risks during this critical stage of development (Al-Sendi *et al.*, 2003:367).

Characterisation of BMI-trends and other indicators of body fatness during childhood and adolescence is important so that strategies can be developed to control and prevent overweight and to ensure accurate assessment of body composition (Al-Sendi *et al.*, 2003:368).

BMI as a measure of body fatness in adolescence is influenced by maturation status, race and the distribution of body fat. The relationship between percentage body fat and BMI is dependant on the stage of maturation (for equivalent BMI, lower percentage of body fat in more sexually mature than less sexual mature), race (from an equivalent BMI, whites have a higher percentage body fat than blacks), and waist:hip ratio or waist circumference (for equivalent BMI, central obesity is associated with a higher percentage body fat than peripheral obesity) (Lobstein *et al.,* 2004:36).

Overweight prevalence is significantly higher in early maturers of all racial groups and early maturation is associated with a greater risk of obesity during both adolescence and adulthood (Lobstein *et al.,* 2004:36). Overweight boys tend to mature later than their non-overweight counterparts. Although early sexual maturation is associated with overweight in girls, in boys the reverse seems to be case, with the prevalence of overweight and obesity higher in late maturers than in early maturers (Lobstein *et al.,* 2004:25).

Cole *et al.* (2000:1243) established the international cut-off points for body mass index for overweight and obesity by sex between 2 and 18 years, obtained by averaging data from Brazil, Great Britain, Hong Kong, Netherlands, Singapore and the United States (Cole *et al.* 2000:1243). For the purposes of this review, data for ages 10 to 18 are presented in Table 1.

2.2.3 Genetic and environmental influences on adolescent growth and development

Population variations in growth are the result of an interaction between genetic and ethnic factors as well as a variety of environmental influences, including socio-economic status and health status (Al-Sendi *et al.*, 2003:374). It is a common impression that school children from non-Caucasian backgrounds living in Westernised societies have a greater propensity for developing obesity than white Caucasian children, but when socio-economic circumstances and parental education are taken into account, the differences may not be great. In the USA for example, African-American and Hispanic Americans appear to contribute more to the obesity epidemic, with more rapid rates of change in their populations than the white American population (Lobstein *et al.,* 2004:42).

Table 1: International cut - off points for body mass for overweight and obesity by sex between 10 and 18 years, defined to pass though body mass index of 25 and 30 kg/m^2 at age 18 (As defined by Cole *et al.* 2000:1243)

	Body mass index 25 kg/m^2		Body mass index 30 kg/m^2	
Age (years)	Males	Females	Males	Females
10	19.84	19.86	24.00	24.11
10.5	20.20	20.29	24.57	24.77
11	20.55	20.74	25.10	25.42
11.5	20.89	21.20	25.58	26.05
12	21.22	21.68	26.02	26.67
12.5	21.56	22.14	26.43	27.24
13	21.91	22.58	26.84	27.76
13.5	22.27	22.98	27.25	28.20
14	22.62	23.34	27.63	28.57
14.5	22.96	23.66	27.98	28.87
15	23.29	23.94	28.30	29.11
15.5	23.60	24.17	28.60	29.29
16	23.90	24.37	28.88	29.43
16.5	24.19	24.54	29.14	29.56
17	24.46	24.70	29.41	29.69
17.5	24.73	24.85	29.70	29.84
18	25	25	30	30

2.2.4 Gender differences in adolescent body composition

Sexual development is an important factor influencing anthropometric measurements in body composition during adolescence (Al-Sendi *et al.*, 2003:376). During adolescence, gender differences and age variations become apparent in fat mass, fat-free mass and regional body fat distribution. The rate of increase in BMI is related to high adult BMI levels in both genders during adolescence, but more so in men than in women (Guo *et al.*, 2000:1633). While body fat increases until the age of 17 years in girls, it starts decreasing around the age of 13 in boys.

Adolescence is one of the most vulnerable periods for the development of overweight and obesity (Kruger *et al.*, 2004:564; Lobstein *et al.*, 2004:37). Although the mechanism is unclear, it is possible that fat distribution patterns established during adolescence play a role. Reports suggest that boys have higher WHR values than girls, reflecting a more centralised fat distribution in boys (Al-Sendi *et al.*, 2003:376). Boys tend to deposit fat centrally and lose fat peripherally as they mature, creating a picture predictive of diabetes, heart disease, hypertension and hyperlipidemia in adults (Lobstein *et al.*, 2004:37).

Conversely, lean body mass increases steeply up to the age of 19 years in boys whereas in girls it stagnates at age 15 (Al-Sendi *et al.*, 2003:376). Boys tend to have larger BMI's than girls and the rate of change in BMI is larger in boys than girls (Guo *et al.*, 2000:1634). Interestingly, Guo *et al.* (2000:1634) found that the maximum BMI attained at post-pubescence is strongly associated with the degree of fatness in adulthood.

2.3. Prevalence of obesity among children and adolescents

The National Health and Nutrition Examination Survey II, conducted in the USA during the period of 1988 – 1994, found that 11% of children and adolescents 6 to 17 years of age were overweight, reflecting a body mass index above the 95th percentile relative to gender and age-specific national reference data (Salbe *et al.,* 2002:299). A report on the initial results of the 1999 National Health and Nutrition Examination Survey indicated that prevalence rates had increased even further in the USA to 13% of children aged 6 to 11 years and 14% of adolescents aged 12 to 19 years (Ford *et al.,* 2001:486; Salbe *et al.,* 2002:299).

South Africa is a developing country where both undernutrition and overnutrition is seen. The prevalence of obesity is high among adult black women, whilst low in children (Kruger, 2005:1153). Stunting is a very common nutritional disorder in South Africa and local research has shown that there may be a link between stunting and the development of overweight or obesity (Jinabhai *et al,* 2003:358; Kruger *et al.,* 2004:564; Monyeki *et al.*, 1999:287; Mukuddem-Petersen & Kruger, 2004; Steyn *et al.,* 2005:4).

According to Monyeki *et al.* (1999:287), obesity is not only common in South African female adults, but also in female adolescents. In 2002 the First South African National Youth Risk Behaviour Survey stated that the prevalence of overweight was 17% and obesity 4% (Medical Research Council of South Africa, 2002:12). This survey was a cross-sectional prevalence study amongst secondary school learners in South Africa. The study sample comprised of Grade 8-11 (aged 13-19) learners from government schools in 9 provinces in South Africa (Medical Research Council of South Africa, 2002:11), that is 188 schools and 10 699 learners throughout the country. These data also showed that the co-existence of stunting and being overweight is a public health problem among adolescents in SA.

2.4. Consequences of childhood obesity

Many obese children, especially adolescents, tend to stay obese or overweight as adults and it has been suggested that 33% of adult obesity starts in childhood (Forshee *et al.*, 2004:463; Molnár & Livingstone; 2000:S46). Obesity during childhood seems to increase the risk of subsequent morbidity, whether or not obesity persists into adulthood (Graf *et al.*; 2005:291, Molnár & Livingstone; 2000:S46), with obese children being at an increased risk of metabolic and cardiovascular disorders later in life (Jebb *et al.,* 2003; Nemet *et al.*, 2003:148). Generally known obesity-related disorders are heart disease, diabetes, certain cancers, gall bladder disease, osteoarthritis and endocrine disorders and these are on the increase in young adult populations (Lobstein *et al.,* 2004: 4).

atherosclerotic cardiovascular disease (Cook *et al.*, 2000:140; Sothern, 2004:704) and in recent years CRP-values, as measured by a high-sensitivity assay (hs-CRP), have been recognised as a useful and sensitive predictor of the future risk of MI and stroke. *De novo* hepatic synthesis starts rapidly after initial stimulus, with serum concentrations rising above 5mg/L by about 6 hours and peaking around 48 hours (Hiura *et al.*, 2003:541).

Pepys and Hirschfield (2003:1805) note that CRP values cannot be used diagnostically, but should be interpreted with full knowledge of all other clinical and pathological results.

An advantage of using CRP is that no fasting is needed before measurement (Genest *et al.*, 2003:5). Duplicate measures, preferably 2 weeks apart are recommended and the lower value should be regarded as the most reliable value (Genest *et al.*, 2003:5, Misra, 2004:478). The plasma half-life of CRP is about 19 hours and is constant under all conditions of health and disease, so that the sole determinant of circulating CRP is the synthesis rate (Pepys & Hirschfield, 2003:1805).

Upon interpretation of CRP-values, low inflammation risk is defined as a level less than 1 mg/L; average risk is 1.0-3.0 mg/L and high risks are values 3-10mg/L (Genest *et al.*, 2003:5; Kushner *et al.*, 2006: 166.e18; Verma *et al.*, 2004:1915). Tests should be repeated and the patient examined for the sources of infection and inflammation (Genest *et al.*, 2003:5).

2.5.2 CRP and Obesity

There is an increasing link between basal inflammation, MS and obesity (Wellen *et al.,* 2005:1112). The release of IL-6 from the visceral (Isasi *et al.,* 2003:332) adipose tissue may induce low-grade systemic inflammation in subjects with increased body fat. This may explain the association between BMI and CRP levels (Wu *et al.*, 2003:97). CRP may be indirectly associated with TNF-□, IL-6 and BMI. These phenomena could also explain why obesity was associated with clinically raised CRP levels in both genders (Wu *et al.*, 2003:98).

Overall adiposity is an important determinant of serum CRP in adults and in children with different ethnicities (Barbeau, 2002:415; Sothern, 2004:704; Wärnberg, 2004:559). A correlation of CRP with IR, independent of body mass index, has also been reported in children (Sothern, 2004:704). Vikram *et al.* (2004:1340) found that hs-CRP correlates well with measures of generalised as well as abdominal obesity in adolescents.

It is well known that CRP levels in adults rise with aging, smoking, progression of hypertension and BMI (Hiura *et al.*, 2003:541). It has been proven that weight loss and the improvement of IR leads to decreases of CRP levels and also of event risk in adults. However, the limited number of studies on children causes uncertainty in its clinical significance in inflammation of the young (Hiura *et al.*, 2003:542; Misra, 2004:478; Wärnberg *et al.,* 2004:559).

CRP is also correlated with insulin resistance (IR) in adults (Lee *et al.*, 2004:101; Recasens *et al.*, 2005:112). CRP and obesity is correlated in adults (Maachi *et al.*, 2004:993) and Hiura (2003:541) proved that there are elevated levels of CRP in obese boys.

Results from the Third National Health and Nutrition Examination Survey (NHANES III) showed that CRP concentrations were significantly elevated among children with a BMI > 85th percentile. Excess body weight may be associated with a state of chronic low-grade inflammation in boys and girls (Ford *et al.*, 2001:486). Wu *et al.* (2003:94) also revealed that children in the fourth quartile CRP groups were heavier and had significantly higher BMI's and lower HDL levels than children with non-detectible CRP levels, suggesting that elevated CRP levels might be associated with CVD risk factors in 12-16 year olds. Vikram *et al.* (2003, 305) found that overweight measured by BMI, waist circumference and triceps skinfold thickness correlates with increased CRP. Wärnberg *et al.* (2004:599) confirmed these findings.

The inflammatory properties of IL-6 and tumour necrosis factor (TNF) may play certain roles in the stimulation of acute-phase protein production in the liver, which may regulate plasma CRP levels (Wu *et al.*, 203:97).

2.6. Dietary fatty acids and inflammation

Although fatty acids (FAs) have been implicated in the development of chronic inflammatory conditions, e.g. insulin resistance and obesity, much research is needed in the relation between insulin resistance, obesity, inflammatory activity and dietary FA's (Fernandez-Real *et al.*, 2003:1362).

Links between adiposity and MS are known, but other factors (like diet) are also thought to contribute (Fernandez-Real *et al.*, 2003:1362; Klein-Platat *et al.*, 2005:1178). Unsaturated FA's and n-3 FAs in particular, are receiving increasing attention as potential anti-inflammatory agents (Fernandez-Real *et al.*, 2003:1362).

Previous ideas on adipose tissue were that it is metabolically inert tissue, serving only as a depot for energy substrate and insulation, but one now knows that it is metabolically functional (Nemet *et al.*, 2003:148). Recent investigations have focused on a family of adipose derived cellular mediators (adipocytokines), including TNF-□ and IL-6. The importance of these agents is that they are produced by the fat cells and are known to regulate a host of physiological processes directly tied to carbohydrate and fat metabolism and the development of obesity complications such as diabetes and atherosclerosis (Nemet *et al.*, 2003:148).

Studies of diet or plasma FA composition in children, mostly obese children, focused mainly on lipid variation and not on low-grade inflammation

(Samuelson, 2001:333). Studies on children and young adolescents may furnish new insight into the early mechanisms of MS because they are free of lifestyle confounders such as smoking, drug therapy use and alcohol consumption (Blendea, 2005:1338; Klein-Platat *et al.*, 2005:1178).

Fernandez-Real *et al.* (2003:1366) showed that dietary FA's seem to be highly linked to inflammatory activity. They found this to be especially true in subjects with an increased body fat mass. The percentage of saturated FA's and n-6 FA's were significantly associated with circulating IL-6, whereas the percentage of n-3 FA's correlated negatively with CRP in overweight subjects. A study conducted by Arya *et al.* (2006: 865) among urban Asian Indian adolescents on CRP and dietary fatty acids also showed that saturated FA intake is associated with high CRP values. Sialic acid has been proven to be a marker of obesity-related diseases by acting as an integrated marker of the activity of acute phase proteins (Browning *et al.*, 2004:1004). In the same way as CRP, sialic acid has been shown to be associated with and a predictor of cardiovascular disease and type II diabetes. Interestingly, sialic acid has been proven to predict features of the MS independently of BMI in adult women, but no research has been done in adolescents (Browning *et al.*, 2004:1004).

The associations of the percentage FA's and IL-6 need to be interpreted in the context of the atherosclerotic process, as inflammation in the vessel wall plays an essential part in the initiation and progression of atherosclerosis (Fernandez-Real *et al.*, 2003:1367). Atherosclerosis can be defined as an immune process initiated by endothelial activation and inflammation which progresses by the involvement of the environmental and genetic factors (Ezgü *et al.,* 2005:1384). Damage to the cell vessel wall leads to endothelial cell disruption, resulting in exposure of the underlying vascular smooth muscle cells.

Endothelial and smooth muscle cells produce IL-6, and IL-6 gene transcripts are expressed in human atherosclerotic lesions. Prospective studies indicate that increased IL-6 and CRP on the one hand and FA composition on the other hand are associated with IR, type 2 diabetes and cardiovascular events. Being overweight modulates the relations of FA's to inflammatory markers (Fernandez-Real *et al.*, 2003:1362).

2.7. Physical activity

2.7.1. Role of physical activity in the development of overweight

Overweight in individuals of any population is the result of long-term positive energy balance (Björntorp, 2001:1006; Molnár & Livingstone, 2000:S46). Energy balance in humans must follow the laws of thermodynamics. The general equation for the energy balance in man is: energy intake = energy expenditure + energy stored (Molnár & Livingstone, 2000:S46). Investigations indicate that the cause of obesity lies in behavioural and environmental changes involving large sections of populations. Studies have shown a negative correlation between PA and body fatness (Molnár & Livingstone, 2000:S45). It was suggested that decreased PA or increasing inactivity is probably the main factor accounting for the reduction in total energy expenditure, leading to positive energy balance and increased prevalence in obesity (Molnár & Livingstone, 2000:S45). Egger and Swinburn (1997:779) concluded that even incidental activity can increase energy expenditure and intensity of activity also plays a role.

Apart from the direct thermogenic effect, exercise increases resting metabolic rate, thermogenic effect of food, fat oxidation and may reduce caloric intake (Molnár & Livingstone, 2000:S53). However, PA should not be seen as the sole agent to induce negative energy balance. It has been suggested that children who engage in regular PA are most likely to become active adults and that there is a behavioural tracking of activity levels from childhood to adulthood (Fulton *et al.*; 2004:581, Molnár & Livingstone, 2000:S53).

The rationale behind the motivation of PA in adolescents is thus to establish exercise as a lifelong habit, teach relevant skills, develop components of physical fitness such as muscle strength, flexibility and endurance, reduce the prevalence of obesity, reduce the risk of osteoporosis and coronary heart disease later in life and increase self-esteem (Fulton *et al.*; 2004:581, Molnár & Livingstone, 2000:S52; Roberts, 2000:35).

2.7.2 Physical activity and metabolic profile

Body fatness and central body fat distribution are related to an adverse risk profile in youth (Ball *et al.*, 2003:392; Al-Sendi *et al.*, 2003:367) and reports suggest that PA exerts a positive effect for risk factors of chronic disease. A higher degree of cardio-respiratory fitness has shown to relate to a healthier metabolic profile in children (Ball *et al.*, 2003:392).

PA may protect against heart disease by improving lipid profile, maintaining blood pressure and controlling body weight (Fulton *et al.*, 2004:581; Molnár & Livingstone, 2000:S52). It is also generally accepted that physically active children have better cardiovascular risk profiles than the non-active ones and that PA plays a key role in the prevention and treatment of obesity through its metabolic effects (Fulton *et al.*; 2004:581; Molnár & Livingstone, 2000:S53). It has long been known that weight and IR is strongly correlated (Reinehr & Andler, 2004:111). PA also improves IR in both obese and non-obese youth and weight loss improves insulin sensitivity and decreases hyperinsulinemia, although obese children who maintain weight loss continue to show elevated insulin levels in spite of improved glucose tolerance (Lobstein *et al.,* 2004:26). Isasi *et al.* (2003:332) showed in a study that mean fitness level was higher in boys than in girls but that CRP levels did not differ between boys and girls and fitness level was inversely correlated to CRP in boys.

2.7.3 Physical activity and urbanisation

Much has been written in the literature on the nutrition transition brought on by the urbanisation and Westernisation of communities over the years (Kruger *et al.*, 2004:565), but a subject receiving very little attention is the "PA transition" (Forshee *et al.*, 2004:463). Physical inactivity is currently reducing the quality of life of tomorrow's adults (Roberts, 2000:33).

Adult weight loss is associated with a reduction in the markers of vascular inflammation and IR (Esposito *et al.*, 2003:1799). Weight reduction in adolescence could slow the progression of metabolic risk factors identified with CVD and type 2 diabetes (Hagarty *et al.*, 2004:481). Berkey *et al.* (2003:839) showed that an increase in total recreational activity over a one-year period was associated with a relative BMI decline in adolescents.

2.8. Clinical recommendations for PA and physical fitness

Public health recommendations often address whole communities at large (macro-environment), whilst clinical community-directed recommendations usually pertain to the individual patient and his/her family (micro-environment) (Egger & Swinburn 1997: 479; Fulton *et al.*, 2004:582).

Overweight youths in particular may need to be targeted by recommendations, as they have a greater risk of developing adverse