BODY COMPOSITION,
ENERGY EXPENDITURE,
AND DIETARY INTAKES
IN A SAMPLE OF CHILDREN
WITH
FETAL ALCOHOL SYNDROME

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ABSTRACT

The purpose of this study was to examine body composition, energy expenditure, and dietary intakes of a sample of children (n=12) with fetal alcohol syndrome (FAS), as well as provide information on how nutritional parameters are related to growth. Body composition was determined by height, weight, head circumference, skinfolds, and bioelectrical impedance analysis (BIA) measurements. Energy expenditure was estimated by indirect calorimetry, to determine resting energy expenditure (REE), as well as the employment of a physical activity questionnaire and predictive equations. Dietary intakes were collected by three twenty-four hour recalls and three-day weighed food records, and the diets were analyzed for nutrient content using Nutritionist IV for Windows (First DataBank, The Hearst Corporation, San Bruno, California). Of the 12 subjects, 4 remained on or below the 10th percentile for height, 8 were below the 10th percentile for weight, and 7 remained on or below the 3rd percentile for head circumference. Percent body fat determined from skinfolds were compared to healthy populations of children of the same sex and Tanner stages with all group mean z-scores being negative. Bioelectrical impedance predictive equations developed for children were found to be inappropriate for this clinical population. No significant differences were found between measured REE and REE predicted from equations based on age, sex, weight, and height ($p>0.05$). Dietary intakes collected using the twenty-four hour recall method were determined to be adequate for all nutrients analyzed by Nutritionist IV, with the exception of possibly vitamin E which gave a probability estimate of inadequacy of greater than 25%. Dietary intakes determined by the weighed food record method which used a portable tape recording scale were not different from the twenty-four hour recall method, yet the use of the scale was cumbersome for the subjects and their caregivers. This sample of children with FAS continued to show growth deficiencies and low total body fat despite an adequate diet (with the exception of vitamin E) and metabolic rates were similar to that predicted for their age, sex, weight, and height.

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LIST OF ABBREVIATIONS

ABCDC - Alvin Buckwold Childhood Development Centre

ACT - activity

BIA - bioelectrical impedance analysis

BMR - basal metabolic rate

CNS - central nervous system

CP - cerebral palsy

CT - computed tomography

DXA - dual energy x-ray absorptiometry

ECW - extracellular water

FAE - fetal alcohol effects

FAS - fetal alcohol syndrome

FFM - fat free mass

FFQ - food frequency questionnaire

FM - fat mass

IQ - intelligence quotient

LBM - lean body mass

NCHS - National Center for Health Statistics

NIH - National Institute of Health

PEI - probability estimate of inadequacy

PETRA - portable electronic tape recording automated

RDA - recommended dietary allowance

REE - resting energy expenditure

RMR - resting metabolic rate

RNI - recommended nutrient intake

RQ - respiratory quotient

SD - standard deviation

SEE - standard estimate of error

TBK - total body potassium

TBW - total body water

TEE - total energy expenditure

TEF - thermic effect of feeding

LIST OF APPENDICES

1. INTRODUCTION

Behold, thou shalt conceive, and bear a son;
and now drink no wine or strong drink... (Judges 13:7).

Fetal alcohol syndrome (FAS) is a fairly new syndrome as the first reported association between maternal alcoholism and abnormal development occurred in 1973 (Jones & Smith). However, there have been several references in history that could be interpreted as such condition. In 1899, female alcoholics in a Liverpool jail had a stillbirth and infant death rate more than twice that of non-alcoholic relatives (Sullivan 1899). In early Carthage, the bridal couple were to abstain from drinking while on their wedding night to prevent conceiving a defective child (Streissguth et al. 1980).

A scarcity of nutrition information including nutritional status parameters and dietary intakes regarding individuals with FAS in Canada exists. Therefore, a study investigating anthropometry, body composition, energy expenditure, and diet is needed. Information on body composition and energy expenditure will provide a better understanding of how these parameters are related to growth. From this, nutrition counseling and education may be improved therefore enhancing the diet and nutritional care of children with FAS. Consequently, growth may be positively affected by a change in the diet and long-term effects of FAS may be reduced. As a result, high treatment costs could be potentially lowered. Nutritional intake may play a large role in the growth of FAS children, but to the best of our knowledge, a study investigating the nutritional intake of children with FAS has not been performed. In addition, assessment of body composition and energy expenditure, which relate to growth, have not been explored.

The purpose of this study is to examine nutritional intake, body composition and energy expenditure in a sample of children with FAS, as well as provide information on how nutrition is related to growth.

I hypothesize that children with FAS have different nutritional intakes, anthropometric values and body composition along with a higher energy expenditure (i.e., hypermetabolic) than that of non-clinical populations.

2. LITERATURE REVIEW

2.1 Fetal Alcohol Syndrome

Fetal alcohol syndrome, or FAS, in the newborn child is the result of maternal alcohol use during pregnancy. It is a completely preventable condition that is recognized as the leading known cause of mental retardation in the United States, surpassing Down's syndrome and spina bifida (Abel & Sokol 1987, Gottlieb 1994, Iber 1980, Osborn et al. 1993, Streissguth et al. 1991). As a defined syndrome, FAS is quite new. In 1968, a group of French investigators were the first to perform a large scale study examining characteristics of children of alcoholic parents (Lemoine et al. 1968). In 1973, Jones and colleagues (1973) at the Department of Pediatrics, University of Washington in Seattle, noticed that babies of alcoholic mothers were frequently and uniformly malformed and grew to be mentally retarded. They were the first to attach the name "fetal alcohol syndrome" to such characteristics. The word "syndrome" refers to a combination of symptoms resulting from a single cause whereas a disease has a definite pathological process.

2.1.1 Alcohol and Its Effects During Pregnancy

Alcohol can have deleterious effects on the fetus, however, the risk of FAS depends on a combination of alcohol dose (amount consumed and pattern of consumption), drinking during critical periods of development in different trimesters of pregnancy, and other factors such as poor maternal nutrition and smoking (Canada 1992a).

The most critical period for the central nervous system (CNS) development is the first 85 days of gestation. However, several animal studies suggest that effects from alcohol exposure can occur during all 3 trimesters, depending on the CNS area involved at the time (Bagg 1991). In the first trimester, alcohol interferes with organogenesis. During the second trimester alcohol contributes to mental retardation and an increased incidence of spontaneous abortion. In the third trimester there can be a significant depression of fetal growth, probably including growth of the brain (Gottlieb 1994). The gray matter of the brain has a high water content and appears to be especially vulnerable to the toxic effect of ethanol and acetaldehyde (Gottlieb 1994). If alcohol consumption is reduced during the last trimester growth outcome improves (Rosett et al. 1983).

Five mechanisms have been suggested as possible influences of fetal outcomes exposed to alcohol: 1) Impaired placental transport of essential amino acids and sugars; 2) Abnormal muscle organogenesis; 3) Fetal hypoxia due to increased oxygen consumption because of fetal ethanol metabolism and/or ethanol induced vasoconstriction of the umbilical vessels; 4) Prostaglandin metabolism secondary to ethanol-induced prostaglandin release; and 5) Alteration of maternal and fetal estrogen and growth hormone (Bagg 1991). Alcohol, and its major metabolite, acetylaldehyde, freely cross the placenta. The fetus is exposed to concentrations equal to or greater than that seen in the mother. Because the fetus cannot metabolize and excrete these products as efficiently as the mother, it is likely that the concentrations are higher and remain elevated for longer periods of time (Holzman 1983).

The effect of alcohol is influenced by a combination of: maternal nutrition or malnutrition, mother's age, body weight, health status, duration of alcohol abuse, smoking, increased stress, genetics, and other substance abuse (Abel 1995, Bagg 1991, Iber 1980, Little et al. 1990). None of these individual factors gives rise to FAS itself, but it is possible that they exacerbate the effects of heavy alcohol intake resulting in FAS (Abel 1995). FAS appears to occur only when the mother consumes a reasonably large amount of alcohol daily throughout pregnancy or with time to time binges of extreme consumption (Iber 1980). Fortunately, no deleterious effects have been observed in offspring conceived when male blood alcohol levels are elevated (Iber 1980). The level of consumption that will result in FAS has yet to be firmly established (Bagg 1991). With the right genetic match and other factors that increase vulnerability, even one drink a day may have an adverse effect on the fetus (Gottlieb 1994). Therefore, it is recommended that pregnant women and women attempting to become pregnant abstain from alcohol in any form (Gottlieb 1994). If abstinence is not feasible, it has been recommended by Forrest et al. (1991) that women should have no more than one standard drink a day (70-85g absolute alcohol a week). Health and Welfare Canada recommends that "Canadian women be supported by peers, partners and communities to avoid consuming products that contain alcohol when they suspect pregnancy and during pregnancy" (Canada 1992a).

2.1.2 Diagnosis, Characteristics, and Effects of FAS

2.1.2.1 Diagnosing FAS

The diagnosis of FAS recommended by the Research Society on Alcoholism (Austin, Texas) requires confirmation of a history of maternal alcohol abuse and that all of the following criteria are met:

a) prenatal and postnatal growth retardation (height and weight below the 10th percentile for age or gestational age [Largo et al. 1980])

b) CNS dysfunction (any neurological abnormality, developmental delay, behavioural dysfunction or deficit, intellectual impairment and/or structural abnormalities, such as microcephaly [head circumference below the third percentile] or brain malformations found on imaging studies or autopsy [Sokol & Clarren 1989])

c) characteristic cranofacial abnormalities, including microphthalmia or short palpebral fissures, and poorly developed philtrum, thin upper lip, and flattening of maxillary area (Sokol & Clarren 1989).

If the criteria is not met, there may be a diagnosis of alcohol related birth defects in which alcohol is known to be a contributing factor (Waterson & Murray-Lyan 1990) or fetal alcohol effects (FAE) when the child shows two of the three criteria for FAS (Sokol & Clarren 1989). The best time for diagnosis of FAS is between 3-10 years of age when evidence of facial dysmorphology, CNS impairment and growth deficiency are measurable and apparent (Egeland et al. 1995).

FAS is often underdiagnosed and failure to recognize FAS may hinder the appropriate social and medical services needed by the infants (Little et al. 1990). Little and colleagues (1990) studied 40 medical charts of infants born to alcohol abusers and although physical features consistent with FAS were described in their medical records, a 100% failure by hospital staff to diagnose the syndrome occurred. Part of the problem is that no single test can positively identify FAS (Osborn et al. 1993). Also, many people are hesitant to disclose information regarding their alcohol and drug use. As well, many women find it difficult to remember if they drank during pregnancy or how much they drank (Gottlieb 1994). Lack of effective communication between professionals is also an issue (Osborn et al. 1993). For example, a social worker may be aware of a history of maternal drinking but not share this information with the woman's physician. Furthermore, clinicians may be reluctant to diagnose for fear of stigmatizing the mother and child (Aase 1994).

Diagnosis is most difficult in newborns and adults as the facial characteristics are not as pronounced during these times (Aase 1994). Another problem in diagnosis arises if facial characteristics similar to those seen in FAS are attributable to the patient's age, race, or a familial characteristic. The presence of epicanthic folds and concave depression of the nasal bridge between the eyes is very common among the native Inuit population in Saskatchewan (Abel 1995). As well, this population has no growth norms, therefore estimation of growth retardation is difficult (Abel 1995).

Overdiagnosis does occur. This happens when there is too much emphasis on maternal drinking history or there is failure to recognize a different but similar disorder such as Cornelia de Lange syndrome where common characteristics include low birthweight, delayed growth, and small head size and stature (Aase 1994).

2.1.2.2 Central Nervous System Impairment

Individuals with FAS tend to have poor judgment, distractibility, and difficulty perceiving social cues (Streissguth et al. 1991). Hyperactivity, attention deficits, learning disabilities, intellectual deficits, and seizures can also exist (Streissguth et al. 1991). Most individuals with FAS score at least two standard deviations below the mean on intelligence quotient (IQ) tests (Gottlieb 1994). Conry (1990) evaluated 19 Native American children with FAS ages 6-18 years comparing them with gender and age-matched controls in order to control for differences due to cultural isolation. Children in the FAS group received significantly lower scores for sensorimotor tasks such as reaction time, nondominant finger tapping, grip strength, and motor speed as assessed using the Detroit Test of Learning Aptitude and the Beery Buktenika Test of Visual Motor Integration.

Other behavioural problems documented are poor concentration and attention, dependency, stubbornness or sullenness, teasing or bullying, crying or laughing too easily, impulsivity, lying, cheating, stealing, showing a lack of consideration, exhibiting excessive unhappiness, and periods of high anxiety (Streissguth et al. 1991). Behavior disorders that further complicate the life of the inflicted individual can be depression, irritability, social withdrawal, failure to consider consequences of actions, and inappropriate emotional responses (Streissguth et al. 1991). The behavioural problems associated with FAS have been suggested to be more debilitating than the lower IQ levels. However, it can be difficult to attribute these behaviours to this syndrome because the family environments are often unstable with such behaviours as a result (Streissguth et al. 1991)

Many of the critical diagnostic features change as the child grows older (Aase 1994). Physical features associated with FAS often changes through adolescence but the CNS impairment continues. Spohr et al. (1993) looked at prenatal alcohol exposure and long-term developmental consequences in a 10 year follow-up study of 60 patients diagnosed as having FAS. They found that most affected children can still be identified as suffering from FAS in late childhood and adolescence. Mental and developmental retardation persisted even in some patients with moderate or mild FAS. There was no significant improvement in intelligence.

2.1.2.3 Growth, Body Composition, and Energy Expenditure

Growth in the newborn with FAS is severely retarded. At birth, the FAS infant is not long enough nor weighs enough for estimating gestational age (Iber 1980). The circumference of the head is even smaller than should be for reduced size (Iber 1980). Infants with FAS are repeatedly evaluated for failure to thrive (Wright 1986) and subsequently remain more than 2 standard deviations below average for growth with weight usually more severely impaired (Clarren & Smith 1978, Iber 1980).

Studies have shown that younger children with FAS are consistently lower in length, weight and head circumference compared to normal children (Day et al. 1991, Iber 1980, Kyllerman et al. 1985, Spohr et al. 1993). Growth seldom catches up and the children remain small (Kyllerman et al. 1985, Osborn et al. 1993, Saul 1983). Microcephaly becomes more evident as the child matures, thus reflecting deficient brain growth (Osborn et al. 1993). None of the patients with severe FAS that Spohr et al. (1993) studied showed improvement in head circumference. All aspects of growth deficiencies were worse in boys than in girls. Perhaps this is due to the earlier age at which girls reach puberty. A significant and unexplained weight gain in girls was observed independent of the severity of physical malformations. Generally, these individuals grow in height at 60% the normal rate through early childhood with weight at approximately 33% the normal rate (Aase 1994). They appear unusually slender or even malnourished despite an adequate diet as observed by John Aase, a physician (Aase 1994). However, this may be explained by impaired adipose tissue deposits as a possible result of the prenatal insult to cell proliferation (Iber 1980).

These growth deficiencies persist into adolescence. After puberty, individuals with FAS tend to remain short with a small head circumference although weight often catches up (Streissguth et al. 1991, Wekselman et al. 1995). It has been documented that girls can become moderately obese in late adolescence (Streissguth et al. 1991). This was also the finding when Streissguth and colleagues (1985) performed a ten year follow up of eleven children diagnosed with FAS. Streissguth and colleagues (1991) followed up patients between five and twelve years after the original diagnostic examination if the patients were twelve years or older at the time of follow up. They noticed that males and females were equally affected on growth parameters although females who were not growth deficient for weight tended to increase adipose tissue at an earlier age than males. There may have been a slight delay in puberty for males but it did not appear to be clinically significant (Streissguth et al. 1991). Habbick et al. (in press) suggest that there could be potential for catch-up growth with a delayed pubertal growth spurt and continuance of growth when others have stopped.

No studies have been performed to extensively examine all aspects of body composition in children with FAS. Studies investigating fat free mass (FFM), water spaces, and bone mineral content have not been carried out. As well, more sophisticated and possibly more accurate and reliable methods for measuring body composition such as dual-energy x-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), and dilution techniques have not been employed in these children.

Energy expenditure in children with FAS has not been examined in relationship to their growth retardation, i.e., these children could possible be in negative energy balance due to an increase energy output. This increased energy expenditure could involve an increase resting metabolic rate (RMR) and/or increased physical activity level.

2.1.2.4 Facial Characteristics and Other Clinical Manifestations

Table 2.1 lists several facial features that commonly appear in a child with FAS:

Table 2.1. Facial characteristics seen in children with FAS.	
small head circumference	short nose
epicanthus	small midface
short palpebral fissures	flat face
eyes widely set	ears smaller and moved back
drooping eyelids	thin reddish upper lip
indistinct philtrum	low anterior hair line
low nasal bridge	

Adolescents have been observed to have grown out of some of the facial features associated with the syndrome (Spohr et al. 1993, Streissguth et al. 1991, Streissguth et al. 1985). Some of the facial features will change with age, however the flattened philtrum, shortened palpebral fissures, and epicanthal folds tend to remain (Streissguth et al. 1985). Continued growth in the following have been seen to change in the adolescent and adult facial phenotype of FAS: continued growth of the nose in 2 dimensions (height of the nasal bridge and nasal length from root to tip), continued growth of the midfacial region correcting the earlier midfacial hypoplasia, improved soft-tissue modeling of the philtrum and upper lip, and continued growth of the chin (Streissguth et al. 1991). A relationship appears to exist between the severity of the facial characteristics of FAS and the severity of impairment of mental function (Iber 1980).

Other clinical manifestations that have been reported in individuals with FAS that are not included in the diagnosis but possibly further complicate their condition are cleft palate, hirsutism, attention deficit disorder, incomplete rotation of the elbow, memory, vision, and hearing loss, seizures, and respiratory problems, among many others. Reported cardiovascular problems have included atrial and ventricular septal defects, aberrant great vessels, and tetralogy of fallot. Renal complications such as hydronephrosis, horseshoe kidneys, and aplastic, dysplastic, or hypoplastic kidneys have been present in this clinical population. As well, several gynocological problems can occur such as genital hypospadia, labial hypospadia, ureteral duplications, megaloureter, and cystic diverticula and vesicovaginal fistulas. Symptoms associated with withdrawal from alcohol, such as tremors and increased muscle tone, have been seen in the newborn infant (Powell 1981).

2.1.3 Nutritional Status and FAS

2.1.3.1 The Relationship of Maternal Nutritional Status on the Development of FAS in the Fetus

Pregnancy is a time of nutritional concern even if the pregnant woman is not an alcoholic. Some women will have low levels of nutrients stored at conception if they had several pregnancies in a short period of time, experienced poor intake for several months, or were under 20 years of age due to increased nutrient requirements for growth in their own tissues (Beagle 1981). During pregnancy, nutrient intake can be hampered because of nausea or vomiting or because of a failure to understand the importance of nutrition in the growth and development of the fetus (Beagle 1981). Also, pregnant women have an increased demand for energy or nutrients such as protein, vitamins A, B1, B2, B3, B6, B12, C, E, folate, calcium, phosphorus, iron, magnesium and zinc (Beagle 1981).

Nutritional status in the alcoholic may be compromised due to the anorexigenic effects of alcohol (Smith 1979, Sorette et al. 1980). Alcoholics can consume more than 100g of ethanol per day, which can be one half of their caloric intake; therefore, the likelihood of malnutrition and nutrient deficiencies, which also affect the fetus, is enhanced (Iber 1980). Metabolism, transport, and storage of many essential nutrients may be altered by alcohol consumption, adding to the damaging effects of alcohol (Smith 1979, Sorette et al. 1980). Malnutrition of alcoholic mothers was once thought to be the cause of FAS, but since infants of malnourished mothers who do not drink heavily do not suffer FAS, nutrition has been ruled out as a specific cause (Powell 1981). Powell may have overstated the case because no one has specifically examined the role of maternal nutrition. Therefore, alcoholic mothers who are malnourished may exacerbate the effect of alcohol on the fetus.

2.1.3.2 Nutritional Status in the Child with FAS

Alcohol withdrawal and feeding difficulties may plague the infant (Powell 1981). Fine motor problems such as poor finger atriculation, delay in establishing hand dominance, and weak grasp with delayed gross motor development may lead to serious feeding problems during the preschool years (Beagle 1981). Treatment may include special attention to feeding if the baby has cleft lip or palate (Saul 1983). "Fidgety" mealtime behaviour has been reported as typical (Landesman-Dwyer et al. 1981).

Providing infants with FAS with adequate calories and nutrients during the postnatal period does not result in "catch up" growth (Jones et al. 1976). During infancy, feeding problems, irritability, unpredictable patterns of sleeping and eating result in hard to care for babies and interfere with maternal bonding (Aase 1994). As well, most infants with FAS are hospitalized for long periods of time during the first year and this also will hamper the mother bonding with her infant. Severe and sometimes life-threatening oral feeding deficiencies have been found in some infants with FAS due to significant delays in oral motor development (Van Dyke et al. 1982). Some babies presented with limited suck patterns and were consistently noted to tire easily (Van Dyke et al. 1982). Many infants with FAS require feeding by either gastrostomy and/or nasogastric feeding for prolonged periods of time (Van Dyke et al. 1982). If this is the case, the infants do not receive normal oral feeding stimulation due to the use of the nasogastric tube from birth which may effect oral feeding development (Van Dyke et al. 1982). As well, irritation caused by the nasogastric tubes could hinder progress of oral feeding (Van Dyke et al. 1982). In one case, a mother's account of the initial feeding process was that the disinterest in food was even more frustrating than the hyperirritability (Barbour 1989). Her child never seemed to get hungry and never enjoyed eating. When she allowed him to self-regulate the feeding, he lost weight.

One study attempted to collect nutrient intake information on individuals with FAS. Day et al. (1991) looked at the effects of prenatal alcohol use on the growth of children at three years of age. For 36 months, they collected an assessment of the child's nutrition. The mothers were questioned about the number of times a day that the children ate different foods. The individual food items were categorized into four food groups: dairy products, protein, fruits and vegetables, and grains. They evaluated whether the intake of each four food groups met the recommended dietary allowance (RDA) for three year olds. The results showed that for those of low socioeconomic status, 53.2% of the children received less than the RDA for dairy; 46.3% below RDA for protein; 60.3% for fruits and vegetables; and 34.3% for grains. Although the overall diet was not adequate, they concluded that there was no significant relationship between current maternal alcohol use and the adequacy of intake of any four food groups at three years of age. As well, nutrition did not confound the relationship between prenatal alcohol use and growth at three years. These children were smaller in weight, length, and head circumference. These authors suggest that children with FAS may have a diminished capacity for growth which is not related to diet. This suggestion is supported by Aase (1994) who observed in his clinical practice (i.e., not in a scientific study) that children with FAS were slender despite an apparently adequate diet.

2.1.4 Incidence Rate

The incidence rate of this syndrome is difficult to estimate since it is not a distinct condition (Waterson & Murray-Lyan 1990). An increased awareness amongst health professionals could possibly increase the incidence dramatically. Habbick et al. (1996) concluded that the incidence rate in Saskatchewan has not fallen over the past 20 years, i.e., in 1973-77 there was a rate of 0.515 per 1000 live births and in 1988-92 the rate was 0.589 per 1000 live births. Of the 207 cases seen at the Alvin Buckwold Child Development Centre in Saskatoon, 178 (86%) were Aboriginal, 20

(9.7%) were Caucasian and in 9 cases (4.3%) the race was not documented. Other statistics determined were: 72% possessed at least one malformation, the mean intelligence quotient was 67.8 (range 35-106), 45.9% had a behavior problem, 25.6% lived with biological parents, and 27 of 108 were in a regular class at school without additional support being necessary (Habbick et al. 1996).

In 1995, Abel (1995) estimated that 0.97 in 1000 live births were found to have FAS. The highest reported incidence was found by Robinson et al. in 1987 who looked at 23 communities in British Columbia and 14 communities in the Yukon and estimated the rate of FAS and FAE in children below 16 years of age were 26 and 46 in 1000, respectively. Furthermore, they felt that this figure may have been an underestimate. The overall rate in the western world is 0.33 cases per 1000 (Abel & Sokol 1991).

Most identified cases of FAS in North America continue to be born to mothers that are black or Native, or where socioeconomic status is low (Abel & Sokol 1991). In the United States, the incidence for those of low socioeconomic status and African or Native American background are ten times higher at 2.29 in 1000 than predominant middle or upper socioeconomic status and Caucasian background at 0.26 in 1000 (Abel 1995). It is possible that the higher rates associated with certain minority groups are due to characteristics of these populations which have nothing to do with FAS (Abel & Sokol 1991). When race-related normative data are not used for diagnostic purposes, native Americans (genetic trait for epicanthic folds) and blacks have a greater likelihood of being characterized as FAS because certain features that are normal for their own reference group are atypical for whites (Abel & Sokol 1991). If there is an increased incidence in Aboriginal peoples, there are several possible explanations including cultural influences, patterns of alcohol consumption and abuse, childbearing at a later age when alcohol abuse is apt to be greater, and perhaps dietary and metabolic influences (Aase, 1981).

2.1.5 Programs for Prevention and Treatment of FAS

Economic implications for individuals with FAS have been researched. In 1987, this syndrome was estimated to cost the United States government $321 million per year (Abel & Sokol 1987). These costs are 100 times the amount spent on prevention (Abel & Sokol 1987). In 1991, Abel & Sokol (1991) estimated the incremented annual cost of treating FAS at $74.6 million. In Canada, it has been estimated that each person with FAS costs $1 million for health and social services and the educational and justice systems (Sheane 1996).

Due to prevention programs, most women now reduce their alcohol intake during pregnancy (Bagg 1991). So far, mass media strategies towards the public seem to be successful (Bagg 1991). However, the reduction in alcohol use has not resulted in a decrease in FAS cases. The greatest impact has been on more highly educated, older, light to moderate drinkers (Bagg 1991). Heavy drinkers, or those at greatest risk, are less likely to modify their consumption (Bagg 1991). Adolescents are a population group of concern due to their tendency to consume high amounts of alcohol. In 1994, close to 1.5 million American teens became pregnant (Gottlieb 1994). This population is also known to associate alcohol with sex (Gottlieb 1994). Media play an important role in shaping adolescent attitudes, values and practices, therefore they have been pressured to stop portraying alcohol consumption as sexy, romantic and machismo (Gottlieb 1994). Unfortunately, prevention efforts are not reaching these women at a high risk of drinking during pregnancy (Sheane 1996).

Professional educators must accept responsibility for an educational prevention strategy. Healthcare must be stressed before pregnancy. Many healthcare providers do not routinely ask pregnant women about alcohol use (Gottlieb 1994). Women contemplating pregnancy should be advised to avoid all alcohol from conception until birth (Iber 1980). Nutritionists can play an important role in the prevention of FAS. Nutritionists should assess carefully for a history of alcohol use and the clinical signs that may result from alcohol abuse. How much, what kind, how often and why should be asked in a dietary assessment (Beagle 1981). Open ended questions followed with questions that require direct responses are effective. Follow questions about alcohol by questions about coffee, tea or soft drinks. This may help the individual to feel more comfortable in discussing alcohol and reply more honestly (Beagle 1981). As well, the nutritionist should be familiar with the clinical features of FAS and refer the individual immediately to a physician for evaluation or help if FAS is suspected (Beagle 1981).

Research should focus on women's attitudes about alcohol, programs to reduce alcohol consumption, and the impact of FAS on individuals, families, and communities (Smitherman 1994). The following is a recommendation for research by the Government of Canada (Canada 1992a):

> The Sub-Committee recommends that Health and Welfare Canada, in cooperation with provincial and territorial health departments, design and carry out an epidemiological study to determine the incidence of Foetal Alcohol Syndrome and Foetal Alcohol Effects in Canada, among the Canadian population in general and in target sub-populations known, or suspected, to be at higher risk for such conditions.

Prevention costs are more cost effective than treatment costs; however, funds are necessary for the current and future FAS population. Early diagnosis, early intervention and systematic follow-up are key components in the management of FAS (Osborn et al. 1993). It is essential to help affected children achieve their highest level of developmental and behavioral potential by providing early interventions (Gottlieb 1994). Interventions needed are those that focus on care techniques, monitors health status and home environment, suggest alterations in care and treat problems such as hyperactivity, learning disabilities, and conduct disorders (Smitherman 1994). Most infants with FAS/FAE are placed outside the home (Smitherman 1994). Again, a recommendation for research by the Government of Canada (Canada 1992a):

> The Sub-Committee recommends that Health and Welfare Canada, in cooperation with provincial and territorial health departments, initiate a program of research to develop more effective methods for the treatment, care and training of children with Foetal Alcohol Syndrome and Foetal Alcohol Effects, so that these individuals can maximize their intellectual and employment potentials as adults in Canadian society.

Studies like the present one fulfill this mandate.

2.2 Growth Charts, Body Composition, and Energy Expenditure Measurements in Children

2.2.1 Growth Charts

Growth charts allow for the comparison of size of an infant or child to others of comparable age and sex. These reference charts provide information on weight for age, length or stature for age, weight for length or stature, and head circumference for age. These charts were developed using anthropometric data on large numbers of infants and children collected over time. Variables from growth charts are presented as percentiles. The 50th percentile is considered the average or median value for the specific population from which the data collected. Values that are plotted between the 15th and 85th percentiles are generally considered normal. Any values below the 15th or above the 85th percentiles should be evaluated.

Currently, there are no height for age, weight for age, and head circumference for age growth charts available to evaluate Aboriginal children.

2.2.2 Techniques Used to Measure Body Composition

2.2.2.1 Anthropometry

Anthropometry is the surface measurement of the body, including height, weight, skeletal build, circumferences, and skinfold thickness (Brylowski 1992). The use of skinfold measurements to predict percent body fat in children and adolescents is an acceptable and practical method (Deurenberg et al. 1990, Janz et al. 1993). The tricep skinfold has been used as a standard for undernutrition where a low measure is indicative of decreased body fat (Frisancho 1981, Nutrition Committee, Canadian Paediatric Society 1994). Fat distribution varies in the body, therefore multiple site skinfolds are better predictors of total body fat than a single skinfold (Brylowski 1992). As many as 10 sites may be measured, however much of the predictive value of the skinfolds lie in relatively few sites (Lohman 1981). There is an assumption that the majority of body fat resides in the subcutaneous regions and that there is a consistent relationship between subcutaneous and visceral fat (Jensen 1992). Regression equations have been developed from a comparison of body density measured by underwater weighing and multiple skinfold measurements (Lohman 1981). Skinfold thicknesses are measured at standardized regions using calipers (Burgert & Anderson 1979). Accuracy depends on the skill of the practitioner (Brylowski 1992). Unfortunately, careful attention to measurement sites is essential but will not rid of the considerable intra and interindividual variation which results in different predictions of body fat between examinations and examiners (Jensen 1992).

The use of skinfold measurements in an individual should only be used for comparison to a standard. These standards used should reflect the population being evaluated (Brylowski 1992). Accurate estimation of body fatness requires equations appropriate for children. Multiple skinfold measurements have been compared to body density as measured by underwater weighing and regression equations have been developed using several skinfold thicknesses to predict body density (Jensen 1992). Body density has then been used to predict percent body fat. Specific equations may be valid only for the population it was derived from. The published prediction equations are specific for the population measured which is most often healthy young men and women (Jensen 1992). Therefore, the most accurate predictions would be those made for such groups (Jensen 1992). Slaughter et al. demonstrated this in 1988 when they found that constants used to estimate fat in adults tends to overestimate body fatness in children. They criticized the equations for children that had not been cross-validated on other samples such as children that were obese, highly active or at different maturation levels. A problem that limits skinfold equations is that children are chemically immature and therefore the adult equations would overestimate body fatness and underestimate lean body weight in children (Lohman 1989, Lohman et al. 1984, Slaughter et al. 1988). Before puberty, children have more water and less bone mineral content than adults, therefore less dense fat-free mass (FFM) (Janz et al. 1993). Therefore, adult skinfold equations based on density are inappropriate for this population when predicting FFM and percent body fat. Because children vary considerably in terms of maturational levels, because they are chemically immature as compared to adults, and because the body composition of children changes considerably throughout puberty, equations that use conversion constants derived from adult values are inappropriate (Slaughter et al. 1988).

Recently, equations that take into consideration these problems have been developed and their validity has been proven upon cross-validation with other criterion measurement (Janz et al. 1993, Slaughter et al. 1988). These equations are based only on two skinfold measurements, such as triceps and calf, or triceps and subscapular, and, as such, provide satisfactory predictions of body fatness with relative ease and eliminate systematic error (Slaughter et al. 1988). Thus, due to the recent development of such equations appropriate for children, the estimation of body fatness using anthropometry has been simplified. These equations are the "standard" equations used in North America (Reilly et al. 1995). These equations were developed based on a method that involved multiple systems to estimate FFM such as body density by underwater weighing and pulmonary residual volume techniques, body water measured by deuterium oxide dilution method, and bone mineral content measured by photon absorptiometry of the right and left radius and ulna. Racial group, gender, and maturation level as determined by Tanner stages were analyzed in the formulation of the Slaughter equations. They also account for the changing relationship of skinfolds to the maturation-dependent density variations in fat-free mass. Goran et al. (1996) cross-calibrated the Slaughter equations using dual energy x-ray absorptiometry (DXA) for fat mass (FM), although on a group-mean basis there was a systematic difference of a 0.5 kg overestimate using the Slaughter equations. Janz et al. (1993) cross validated the Slaughter skinfold equations for children and found all of the equations to be reliable. They stated that as of 1993, the Slaughter skinfold equations were perhaps the best anthropometric method for estimating percent body fat and FFM in children and adolescents (Janz et al. 1993). Once percent body fat is estimated, a comparison can be made for children up to ten years of age using skinfold standards of reference children that Fomon et al. (1982) developed based on skinfold sums.

2.2.2.2 Bioelectrical Impedance Analysis

Bioelectrical impedance analysis (BIA) can be used for body composition analysis in healthy individuals and in chronic conditions in which major disturbances of water distribution are not prominent (National Institute of Health [NIH] 1994). BIA measures the impedance to flow of electricity introduced in a subject (Jensen 1992, NIH 1994, Walker et al. 1990). As current conduction in lean tissue is greater than current conduction in fat and impedance to current flow is related to body composition and dimensions, physical characteristics such as body composition can be measured in humans with the use of BIA (Walker et al. 1990). Impedance is a function of two components (vectors): the resistance (R) of the tissues, and the reactance (X) due to the capacitance of the membranes, tissue interfaces, and nonionic tissues (NIH 1994). From this estimation, FFM and body fat can then be estimated. The measurement of impedance is also an indirect technique used to estimate total body water (TBW). Indirect measures of body composition are used more extensively in population studies where it is often less critical to make fine distinctions between individuals (Jensen 1992). This technique is primarily influenced by body water; therefore, it is more a measure of FFM than of adipose tissue or FM (Jensen 1992).

In the technique, an excitation current is introduced at distal electrodes on the hands and feet, and the resistances are measured by the proximal electrodes (Jensen 1992). Usually the frequency of the current is 50 kHz when using a single frequency measure. Conductivity is high in blood and urine, intermediate in muscle, and low in bone, fat, and air. Current flows predominantly through material with high conductivity. Current paths are individual because of differences in body shape, size, electrolytes, fluid distribution, and will vary in the same person from time to time as their characteristics change (NIH 1994). A one centimetre displacement of electrodes can result in a two percent change in resistance (NIH 1994). The accuracy of resistance (Ohms) is 0.5-3% (Cornish 1997). Measurements are made with the subject lying down. Impedance values may rise sharply within the first 10 minutes after the subject assumes the supine position (NIH 1994). It is recommended that the arms and legs are abducted at a 30-45 degree angle from the trunk. Subjects should be fasted for at least 4 hours.

BIA has been validated most frequently against densitometry or isotope dilution (Cornish 1997). The prediction of TBW and the estimates of FFM and body fat using body impedance are potentially just as accurate assessments of TBW using labeled water (NIH 1994). A comparison of impedance and skinfold techniques with $H_2{}^{18}O$ dilution showed similar precision (Gregory et al. 1991).

The technique has been validated in adults but there has been less research on its use in children. However, impedance measurements have been shown to be reliable predictors in pediatric populations (Cordain et al. 1988). A comparison of

DXA, skinfold thickness and BIA was performed on 9-11 year old children (n=43) (Gutlin et al. 1996). The reliability was found to be greatest for DXA, followed by BIA and skinfold thickness measurements (Gutlin et al. 1996). Schaefer et al. (1994) compared BIA and skinfold FFM predictions to total body potassium in 112 healthy children ages 3.9 to 19.3 years and concluded that BIA predictive power is similar to that of established skinfold techniques. Houtkooper et al. (1989) performed BIA on 94 boys and girls, aged 10-14 years and concluded that resistance, together with anthropometry, is a reliable and acceptably accurate method of estimating FFM and percent body fat in children.

An equation is only useful for subjects who closely match the reference population that was used in the derivation of the predictive equations (NIH 1994). Since this technique relies on linear regression to predict FFM from ht^2/R, Cordain et al. (1988) caution when applying to populations other than those which the equation was based upon. For example, equations that are currently used may overestimate fat percentage in the very lean (Brylowski 1992), yet relatively small prediction errors have been reported for the estimation of FFM (standard estimate of error [SEE]: 1.7-3.0) (Houtkooper et al. 1996). Lohman (1989) has recommended the development of new equations for children using BIA instead of relying on equations developed from other populations.

Bioelectrical impedance analysis has the advantages of rapid, safe, and noninvasive measurements that can be taken at bedside and performed on children (Deurenberg et al. 1990, Jensen 1992). BIA appears to be a more accurate measure of FFM and percentage of body fat than body weight, height, or body mass index, and at little extra cost or difficulty but with somewhat greater complexity in measurement (NIH 1994). BIA may provide a more accurate measure of FM than do skinfold measurements; however, measurements of skinfolds and girths may provide additional useful information on body fat patterning (NIH 1994). BIA values can be affected by body position, hydration status, consumption of food and beverages, ambient air and skin temperature, recent physical activity, and conductivity of the examining table (NIH 1994). Also, validity of the data can be limited by variations in electrode position, electrode number, machine specifications and measurement protocols (NIH 1994). Body fat calculations may vary up to 10% using BIA because of different machines and methodologies used (NIH 1994). Consumption of food or beverages before BIA measurement could affect impedance by changing TBW and extracellular (ECW) volumes, however this depends on the type of food or beverage ingested and the timing of the measurements and one could hypothesize that this consumption could have little or no effect on the prediction of TBW (Kushner et al. 1996).

2.2.2.3 Other Techniques

Densitometry is a technique that can provide values for FFM and percent body fat. The method is based on the two-compartment model: fat and fat-free mass. Densitometry involves assessing body composition through measurement of density of the whole body. This is usually accomplished through hydrostatic or underwater weighing, or a combination of water displacement by body and air displacement by head. Archimedes' principle: the volume of an object submerged in water equals the volume of water the object displaces, is the basis of this technique. The equipment involved includes a tank of water large enough to contain the entire body and a scale with a chair attached that will hold the subject as the scale is lowered into the water, submerging the subject. Therefore, the subject must be willing to be submerged for long enough periods to obtain an accurate weight. It is estimated that 10% to 20% of subjects find it difficult to be weighed under water (Lee & Niemen 1996). This technique requires special expensive equipment and training for the practitioner and subject. A number of factors can affect the density of fat-free mass and therefore the accuracy of this method (Lee & Niemen 1996). Gas trapped in the gut can only be estimated (Lee & Niemen 1996). This technique is limited in children due to changes in water and mineral content of the fat-free mass in childhood and youth (Lohman 1989). This method is also unsuitable for children due to subject cooperation needed for underwater weighing. Recently, air displacement plethysmograph was found to be a highly reliable and valid method for determining percent body fat in adult humans in comparison to hydrostatic weighing (McCrory et al. 1995). This may be a promising technique for use in children; however, current equipment is only designed for adults.

Dual-energy x-ray absorptiometry (DXA) has been used to measure fat, total bone mineral, and nonbone lean tissue. The subject is scanned with photons at two different energy levels and the differential absorption of the photons is measured (Jensen 1992). Due to its low radiation dose, it is considered safe and only takes 20 to 35 minutes for a whole body scan. It requires little cooperation from the subject. A major limitation is that there are possible systematic differences between thin and obese persons due to the thickness of the body part scanned. Although there is a low radiation dose, this technique is not recommended for children when repeated measures are employed (Jensen 1992).

Another method used to analyze fat, lean tissue, and bone is computed tomography (CT). Computed tomography is an imaging technique that can produce detailed cross-sectional images of the body. This system consists of an x-ray source that is aligned opposite of radiation detectors. CT has been found to be useful in examining the distribution of subcutaneous and intraabdominal fat (Grauer et al. 1984). Disadvantages are the cost, radiation exposure, and limited access to equipment. It is not recommended for use in children due to the ionizing radiation exposure.

Magnetic resonance imaging is an imaging technique that involves in vivo chemical analysis and provides an estimate of fat and hydration. It has been used to measure the amount and distribution of intraabdominal fat. This technique has many advantages. It is noninvasive, safe (no ionizing radiation), produces high quality images, amount and distribution of fat can be assessed, and the metabolic activity of tissues and organs can be studied (Lee & Niemen 1996). A major disadvantage is the cost and, as well, the lack of availability of the equipment, especially for research purposes.

Ultrasound is also an imaging technique used to measure adipose tissue thickness. A transducer converts electrical energy into high-frequency sound and converts the sound back into electric energy (Lee & Niemen 1996). Ultrasonography has been compared with the use of skinfold calipers although the results have been mixed (Lee & Niemen 1996). Considerable skill is needed for the technician and interpretation. The advantages are that it is noninvasive, nonradioactive, safe, and portable. The disadvantages are the cost and technician skill required. It has not been validated in children.

Infrared interactance is a method that provides an estimate of total body fat. Light is reflected, absorbed, or transmitted when a material is exposed to infrared light. This is dependent on the scattering and absorption properties of the material (Lukaski 1987). A computerized infrared spectrophotometer is attached to a probe which is both an infrared transmitter and detector. The infrared light of two wavelengths is transmitted through the skin. The reflected light is then analyzed. This method is safe, noninvasive, quick, and convenient. It has, however, been reported to be inferior to skinfolds as a method for estimating body composition (Davis et al. 1989).

Total body electrical conductivity is a technique based on the principle that the degree to which a body placed in an electromagnetic field disrupts that field is closely related to the amount of fat-free mass because electrolytes within fat-free mass conduct electricity (Brodie 1988). This method requires a large solenoid coil driven by an oscillating radio-frequency current that generates an electromagnetic field (Lee & Niemen 1996). The table that the subject lies on is slowly rolled onto the coil. Changes in the electromagnetic field, measured when the subject is inside the coil and when the coil is empty, are proportional to the subject's body. Total body water, total body potassium (TBK), FFM and percent body fat can be predicted using this technique. The measurements are rapid and safe. A disadvantage is the cost of the instrument required.

Using the dilution technique, one can estimate TBW, ECW, and FFM. Fat is free of water, therefore all body water is situated in the FFM (Lee & Niemen 1996). The dilution technique is based on the assumption that fat-free tissue has an average water content of 73.2% (Lee & Niemen 1996). However, this assumption is based on studies involving limited amount of cadavers. Total body water is measured indirectly through dilution techniques. This involves a substance (tracer) of known concentration and volume given to the subject, subsequently the tracer equilibrates with the water in the subject's body, and the concentration of the tracer in the subject's blood, urine, or saliva is analyzed (Lee & Niemen 1996).

Total body water is measured using this relationship:

$$C_1V_1=C_2V_2 \quad (2.1)$$

where

C_1=concentration of tracer given,

V_1=volume of tracer given,

C_2=concentration of tracer in body fluid,

V_2=TBW.

Extracellular water (ECW) can be estimated using several methods. Subtracting ECW from TBW will allow for a calculation of FFM. Water labeled with tritium (^3H_2O), deuterium ($^2H_20$) and the stable isotope of oxygen ($H_2{}^{18}0$) are the most commonly used tracers. There are three main sources of error in measuring TBW: failure to administer an accurately measured dose, consumption of beverages by subjects during the equilibrium period, and contamination of the samples by atmospheric water before analysis (Garrow 1982). The technique involving tritium is not recommended for children due to the radiation risks. This method is also very costly.

Another method that provides an estimate of FFM is the measurement of total body potassium (TBK). Over 90% of our body's potassium is contained in FFM (Lee & Niemen 1996), however researchers disagree on the concentration. It has been determined that 0.012% of potassium is the naturally-occurring potassium-40 (^{40}K) isotope which emits a detectable amount of high-energy gamma radiation (Garrow 1982). A counter fitted with very sensitive multiple gamma-ray detectors and a computer are required (Lee & Niemen 1996). Radioactivity detected is compared to known amounts of potassium and total body potassium and lean body mass can be calculated. The presence of radioactive contamination on the subject's body and clothing from atmospheric radon gas can affect the performance of detectors (Lukaski 1987). Despite high precision (±3%) (Lee & Niemen 1996), this procedure is expensive, there is limited availability of the equipment, and high cooperation of the subject is required (Jensen 1992). The cooperation level necessary would be difficult for children.

2.2.3 Techniques Used to Measure Energy Expenditure in Children

Total energy expenditure (TEE) is usually expressed as kilocalories per unit of time and is the sum of basal metabolic rate (BMR), thermic effect of food (TEF), activity (ACT), and adaptive thermogenesis. BMR is the energy required to maintain essential body functions while lying awake, fasted 10-18 hours and at complete rest in a thermoneutral environment. This is extremely difficult to measure. Resting metabolic rate (RMR) is usually measured as a result. RMR is the energy required in an inactive and post-absorptive state, but the requirements are less standardized than for BMR. The thermic effect of feeding contributes approximately 10% of TEE (Horton 1983). Activity constitutes approximately 20-30% of TEE and is the most variable component (Horton 1983). Activity depends on the size of the individual, and the duration and intensity of the activity. Adaptive thermogenesis is defined as the body's response to a changing environmental condition and/or physiological stress. Measured in a controlled environment, adaptive thermogenesis will contribute little towards overall energy expenditure. Resting energy expenditure (REE) is the energy required for maintaining body functions and is used synonymously with RMR.

2.2.3.1 Direct Measurements

2.2.3.1.1 Direct Calorimetry

Direct calorimetry includes the measurement of all components of TEE. Individual components of energy expenditure, as well as total energy expenditure can be determined. This method involves the measurement of heat loss from the body. The subject is placed in a thermically isolated chamber and the heat dissipated is collected and measured directly as energy expended by the subject. This may require the subject to be confined within the chamber for 24 hours. Direct calorimetry is often used in small animal research; however, application in human studies is limited since large isolated chambers are required. Furthermore, the method is expensive and cumbersome. Due to the confinement of the subject in a chamber, the measurement of total energy expenditure also does not represent that of a free living subject.

2.2.3.1.2 Doubly Labeled Water

The doubly labeled water method is a direct measurement of overall energy expenditure i.e., it does not permit assessment of the separate components of TEE. This technique involves the subject drinking a known amount of labeled water with deuterium (^{2}H) and oxygen-18 (^{18}O). The subject provides urine and blood samples for 1 to 3 weeks (Lee & Nieman 1996). The deuterium is eliminated from the body as water while the ^{18}O is eliminated as water and carbon dioxide. The difference between the rates of body loss of deuterium and ^{18}O is an index of the body's carbon dioxide production (Schoeller 1990). Standard indirect calorimetric techniques are used to calculate energy expenditure with precision (3-6%) and accuracy (within 1%) (Lee & Nieman 1996, Schoeller 1990). An advantage is that this technique can be performed in free-living subjects. This method has been used extensively in children and adolescents (Bandini et al. 1997, Bandini et al. 1991, Davies et al. 1989, Goran et al. 1993, Wong 1994).

2.2.3.2 Indirect Measurements

2.2.3.2.1 Indirect Calorimetry

Indirect calorimetry can be used to measure RMR, TEF, and ACT, although ACT is not easily measured. The equipment is portable, however, a mask or hood is involved therefore restricted its use in "free living" movements. Indirect calorimetry is used for the estimation of metabolic activity through the measurement of oxygen consumption. The principle of indirect calorimetry is that the rate of energy expenditure, in terms of the body's use of carbohydrate, protein, and fat, can be calculated by determining the volume of air being consumed by the subject and by measuring the oxygen and carbon dioxide concentrations in the incoming and outflowing air (Goran et al. 1994, Westrate 1993). Values for energy expenditure in terms of resting metabolic rate and respiratory quotients can be obtained with high reproducibility using indirect calorimetry techniques employing an open-circuit ventilated hood system (Westrate 1993). With the open circuit method, the subject breathes normal room air and his/her expirations are collected or passed through a gasometer. The volume of expired air is calculated and an analysis is performed on the percentage of oxygen and carbon dioxide produced. This requires considerable calculations but has been found to be more precise than the closed circuit method. Measuring the amount of oxygen consumed and carbon dioxide produced allows for determination of the mixture of foods being metabolized.

This technique is noninvasive and gives information on the type and rate of substrate utilization with simple, accurate, and precise measures. Disadvantages of this method are the cost, the measurement time, the limited availability of the equipment, and the need for extensively trained technicians (Osborne et al. 1994). Careful calibration of equipment must be ensured to avoid errors using metabolic cart measurements (Osborne et al. 1994).

Indirect calorimetry is a technique that has commonly been used to assess resting energy expenditure in children (Bitar et al. 1995, Maffeis et al. 1993, Murphy et al. 1995, Visser et al. 1995). Bandini et al. (1995) measured RMR in premenarcheal girls and compared the measured values with several standardized equations. Their results indicated that the FAO/WHO/UNU (1985) equations based on weight are the best predictors of RMR in premenarcheal girls at different stages of development. This was also the conclusion for young, healthy children (Finan et al. 1997, Firouzbakhsh et al. 1993). However, Maffeis et al. (1993) found that the FAO/WHO/UNU predictive equation overestimated the RMR of children 6-10 years old. This finding was similar in the study performed by Molnar et al. (1995) where the FAO/WHO/UNU equations overestimated RMR in 10-16 year old obese and nonobese adolescents. Kaplan et al. (1995) found the Schofield (1985) equation using height and weight was the best predictor of REE in children with clinical nutrition problems. Azcue et al. (1996) measured REE in children with spastic quadriplegic cerebral palsy and compared their values to those estimated by the FAO/WHO/UNU predictive equations using weight and found the predictive values to be higher than that measured. However, this finding suggests that the use of predictive equations may not be appropriate in clinical populations.

2.2.3.2.2 Factorial Approaches

Components of total energy expenditure can be calculated through predictive equations. Basal metabolic rates can be estimated with predictive equations using weight, height, sex, and age as mentioned earlier i.e., FAO/WHO/UNU 1985 and Schofield 1985.

Physical activity can also be estimated through several methods. Casperson et al. (1985) define physical activity as any bodily movement produced by skeletal muscles that results in energy expenditure. The energy cost of physical activity is an important component of TEE and is highly variable. Physical activity accounts for a large portion of total energy expenditure in children and adolescents. This fact demonstrates the importance of physical activity when determining overall energy balance in children.

Several techniques have been used to assess children's physical activity such as heart rate monitors, motion sensors, observation (direct, film, video), and self-report questionnaires. It is difficult to measure activity related energy expenditure in an unobtrusive manner and therefore observation analysis, questionnaires (Goran et al. 1997), and motion sensors have been used. Direct observation is a valid procedure causing little interference (Pate 1993). It does not require equipment that may hinder movement (Puhl et al. 1990). The disadvantage is that it is costly in terms of investigator and observer time (Pate 1993). Motion sensors and heart rate monitors overcome the recall problems associated with questionnaires and are less costly than direct observation (Pate 1993). However, they can be prone to technical problems and they provide no information on specific activities or the context in which the activities are performed (Pate 1993). Caltrac (Hemokinetics, Madison, WI), an activity monitor, was designed for adults, therefore the validity of the instrument for estimating energy expenditure in children is questionable (Maliszewski et al. 1991) although it has shown significant correlations with calorimetry in female children and adolescents (Bray et al. 1994). In 1990, Mukeshi et al. (1990) did not recommend the use of Caltrac in children in epidemiological research or clinical settings.

The assessment of physical activity by questionnaire is currently the most popular and practical method of quantifying physical activity levels (Lamb & Brodie 1990). Questionnaires are simple and quick ways of assessing energy expenditure (Lamb & Brodie 1990). This technique involves relatively low subject burden, and a direct relationship has been suggested to exist between burden and performance of the test measure (Sallis 1991). Questionnaires are relatively unobtrusive (O'Hara et al. 1989) and inexpensive (Pate 1993, Sallis 1991).

Self-reports are probably the most commonly used because of the convenience of administration (Sallis 1991). However, self-reports have been found to be not useful in subjects under age 10 because of the difficulty in recalling activity (Pate 1993). Proxy reports, which are administered by a parent or teacher, are sometimes used as a supplement to the child's report (Sallis 1991). Proxy reports can be used when the subject is too young to report their own behavior (Sallis 1991). This type of report is limited by the adult's knowledge of the child's behavior (Sallis 1991). Self-report and proxy reports are relatively inexpensive and are used easily with large number, therefore are frequently used in epidemiological research (Pate 1993). Unfortunately, the validity is limited by the subject or proxy's ability to recall and report the activity (Pate 1993). Because of the subjective nature of assessing physical activity levels in this manner, researchers must consider what types of data are needed to answer questions, and must select or develop physical activity questionnaires based on these needs, as well as questionnaires that are standardized (to avoid excessive variation in perception) in order to achieve reliable and valid results (Finegan et al. 1991, Sallis 1991).

2.3 Techniques Used to Measure Nutrient Intakes in Children

2.3.1 Twenty-four Hour Recall

Twenty-four hour recall is the method most commonly used to assess actual dietary intakes (McQuaid-Cox 1990). Twenty-four hour recalls are quick, easy, and have low subject burden (McQuaid-Cox 1990). When the investigator implements a twenty-four hour recall, the individual is asked the types and amounts of food and beverages he/she consumed the day prior. The interviewee is first questioned regarding their breakfast intake with the investigator probing to assist the recall. Questions following pertain to lunch, dinner, and any morning, afternoon, or evening snacks. Details such as the preparation techniques and beverages consumed are provided. Food models can be used to assist in the estimation of portion sizes with increased accuracy. Telephoned diet recalls compared favorably with personal interview techniques (Krantzler et al. 1982, Posner et al. 1982).

Twenty-four hour recalls have their advantages and disadvantages. The advantages are that it is quick, inexpensive, easy to administer, and does not require literacy or equipment. Most importantly, it does not affect the individual's intake. Children can perform their own twenty-four hour recalls with accuracy improving with age (Whiting & Shrestha 1993). Parents have been used to recall the intakes of their children (Davidson et al. 1986). However, other studies have questioned the accuracy of recalls performed by proxy (Eck et al. 1989, Treiber et al. 1990). The main disadvantage is that this technique relies on the individual's memory and omissions can lead to an underestimation of energy intake (Lee & Niemen 1996). Both overreporting and underreporting can occur. Twenty-four hour recalls have been seen to give lower estimates of energy intake than estimated or weighed food records (Gibson 1990). Overall, repeated twenty-four hour recalls are reasonably accurate and precise and are a suitable method for assessing individual nutrient intakes of children (Whiting & Shrestha 1993).

2.3.2 Food Records

Careful records of weighed food intakes over several days provide more accurate estimates of quantity and are more likely to reflect a "usual" day's intake (McQuaid-Cox 1990). Research has shown that acceptable weighed records can be obtained from children around nine years of age (Livingstone et al. 1992). Additionally, less experience is required in the recording process than with other methods of dietary assessment such as diet history (Black et al. 1993). Unlike other methods of dietary assessment such as questionnaires or diet history, the food record does not depend on memory or perception, literacy is not required, and, as such, errors associated with these factors are absent (Black et al. 1993).

This method has been found to be the most accurate and reliable for measuring usual intake (Gibson 1990, Whiting & Shrestha 1993). However, the equipment can be expensive and requires skill for proper use. Livingstone et al. (1992) found that 7-day weighed food records tended to underestimate the food intake of adolescents. However, individuals may tend to underreport due to the recording process. It is not recommended for older children who eat a great deal away from home. As well, subject burden is higher than that of a twenty-four hour recall, therefore compliance may be lower (Gibson 1990).

Portable electronic tape recording automated (PETRA) scales have been used to assist the weighed food record method (Stephen & Deneer 1990). The food is placed on top of the scale and records the weight onto a cassette tape. The individual talks into the speaker at the front of the scale and describes what is being weighed. The cassette tape is played, the weight will appear on the attached console and the description is heard, recorded, and later analyzed. This method can improve upon reporting of intake as the subject is not aware of the weight of the food, therefore decreasing the likelihood of altering intake. As well, less literacy is needed. However, this technique can be cumbersome.

Estimated food records are written records of all food eaten over a specified time period. The subject estimates what he/she ate at that particular time, therefore not relying on memory. This method is used more frequently in group studies. If this procedure occurs over a long period of time, it can lend to a high subject burden and literacy is required (Gibson 1990). Altered food intakes can occur with this method.

2.3.3 Other Techniques

The food frequency questionnaire (FFQ) measures the number of times groups of foods are consumed over a specified period of time. This is an estimate of "usual" intake. The FFQ is quick with a low subject burden. However, this method has lower accuracy than other methods (Gibson 1990) and is not recommended for semiquantitative nutrient analysis in children (Whiting & Shrestha 1993). Kaskoun et al. (1994) determined that food-frequency questionnaires significantly overestimate energy intake in children.

The diet history method is used to estimate "usual" intake over a long period of time. This usually involves a three-day food record, a twenty-four hour recall, and a cross check food list administered by a nutritionist. It is time consuming and labour intensive. This method provides poor accuracy for semiquantitative nutrient information for children (Whiting & Shrestha 1993).

Duplicate meals and beverages consumed by the subject are collected and analyzed. This method can be costly. The duplicate meal method is accurate but not considered to be indicative of “usual” intake because the subject may alter his/her diet to reduce cost or simplify the procedure (Gibson 1990).

3. METHODS

3.1 Subjects

The children participating in the study were between the ages of 7 and 13 years who had been clinically diagnosed with fetal alcohol syndrome (FAS). This range was chosen because the children would continue to rely on their caregivers for meals. Approximately 50 caregivers of children with FAS fitting the age criteria were made aware of the research through a study information sheet which was given to them through the Alvin Buckwold Childhood Development Centre (ABCDC) in Saskatoon, Saskatchewan where the children were clients (Appendix A). The ABCDC was involved because over 200 cases had been diagnosed at the Centre; therefore, the health professionals have had contact with the caregivers and children. This was important due to the sensitive nature of this condition, i.e., a diagnosis of FAS is privileged information. It was estimated that approximately 25 caregivers and their children would be interested in participating with 15-20 children completing the study. Diagnosis of FAS was confirmed by a physician at the ABCDC.

Twelve children participated in the study. All lived in the province of Saskatchewan. None of the children were institutionalized, and the children that participated had no other health conditions aside from those associated with FAS.

Ethical approval for the study was obtained from both the Royal University Hospital, Saskatoon, and the University of Saskatchewan human ethics committees (Appendices B and C, respectively). Caregivers were required to read an information sheet and sign a consent form prior to their child's involvement in the study (Appendix D).

3.2 Study Protocol

All studies were carried out at the ABCDC or in the subject's homes, with the exception of the assessment of resting energy expenditure, which was conducted at the College of Physical Education, University of Saskatchewan, Saskatoon.

The caregiver along with the child, if able, completed a twenty-four hour recall, and was then instructed on the technique of completing a three-day weighed food record and the proper usage of the portable electronic tape recording automated (PETRA) scale. Anthropometric measurements, including skinfolds, were taken of the subject, followed by body composition measurements using bioelectrical impedance analysis (BIA). A simple questionnaire from a previous bone density study was used to assess physical activity in the subjects (Appendix E). The questionnaire was administered to the caregivers orally by the researcher (H.Dzioba [HD]). The questionnaire is limited in that it was not previously tested with this clinical population. Each caregiver was asked an identical series of questions regarding the physical activity of their child. The caregiver was asked to compare their child's activity to others the same age and gender during indoor activities, outdoor unstructured activities, and outdoor structured activities. The scale used was "much less", "less", "same", "more", and "much more". In addition, the caregiver was asked to rate the current level of physical activity relative to others the same age. The scale used was "very low", "low", "average", "high", and "very high". At all times throughout the oral questionnaire process, the caregiver was encouraged to comment further on any questions, and their perceptions, as such, of their child's physical activity level and types of activities were recorded. Questionnaires dealing with demographics, the child's food habits, medications, supplements, and overall health status as perceived by the caregiver (Appendix F) as well as the Tanner stages (Appendix G) were given to the caregiver along with the PETRA scale and an instructional binder. Upon completion of the three-day weighed food record, the researcher (HD) arranged to collect the questionnaires, instructional binder, and the PETRA scale. Assessment of energy expenditure using indirect calorimetry was conducted at a later date at the convenience of the caregiver and the child. At this time, height and weight were remeasured and these new values were used in the determination of resting energy expenditure. Certain medications could affect the outcome of results e.g. Ritalin may lower the resting energy expenditure and dietary intakes, therefore, when possible the caregiver was asked not to medicate their child before the testing process. Two additional twenty-four hour recalls were performed either in person or by telephone by the principle researcher (HD).

3.3 Measurement of Anthropometry and Body Composition

3.3.1 Anthropometry

Anthropometrical techniques were conducted according to the Anthropometric Standardization Reference Manual (Lohman et al. 1988). In addition to measurements for weight, height, and head circumference, five skinfold measurements were taken at different sites to estimate percent body fat using several equations (Appendix H).

Weight was obtained for each child using a weigh scale (Sunbeam, Toronto, Ontario) that was accurate to 0.1 kilograms. The weigh scale was calibrated with a standard known weight. Each subject was asked to stand still, with footwear removed, light clothing, and without touching anything, on the center of the scale with the feet together and hands to the side. Weight was measured in kilograms to the nearest one hundred grams.

Height was measured as standing height with the use of a steel tape measure. Each subject was asked to remove footwear and any clothing or hair pieces that would interfere with the correct positioning of the body. The subject was then asked to stand with heels together at the base of the wall, and with toes pointed outward approximately sixty degrees. Arms were to the side, legs were straight, shoulders were relaxed, and weight was spread as evenly as possible. The head was positioned in the Frankfort horizontal plane, such that the plane from the ear to the lower eye on the same side of the head was parallel to the floor and perpendicular to the wall. Both heels, the buttocks, the shoulder blades, and the back of the head were used as contact points and height was taken only when these points were sufficiently positioned against the wall. Having met these requirements, the subject was asked to inhale deeply and to maintain an erect posture against the wall. A right angle was lowered upon the highest point of the head with enough pressure to compress the hair. The measurement for height was measured in centimetres to the nearest millimetre.

Head circumference of each subject was obtained using a flexible, non-stretchable measuring tape. The subject was asked to either sit or stand, and all hair ornaments or arrangements were removed. The tape was positioned in the same plane on both sides of the head just above the eyebrows, above (but not over) the ears, and centered over the occipital prominence, such that maximum circumference was located. The tape was pulled gently but firmly to compress the hair, and circumference was measured in centimetres to the nearest millimetre. Two measurements of head circumference were taken and results averaged.

In addition to weight, height, and head circumference, five different skinfold measurements were obtained: the tricep skinfold, the bicep skinfold, the subscapular skinfold, the suprailiac skinfold, and the medial calf skinfold which are five of the most common sites used in the past on children. All skinfold measurements were obtained with the use of Harpenden calipers (Quinton Instruments, Montreal, Quebec), based on sites along the right side of the body. Once again, the technique of obtaining skinfold measurements was conducted according to the Anthropometric Standardization Reference Manual (Lohman et al. 1988). Each located site was marked prior to measurement. A flexible, non-stretchable tape was used to locate midpoints on the body. The skinfold itself was firmly held in the left hand approximately one centimeter proximal to the skinfold site, and was gently pulled away from the body. The calipers were held in the right hand perpendicular to the long axis of the skinfold. The caliper's dial faced upward for easy reading. The dial on the caliper was read three seconds after the caliper was applied. A minimum of two measurements were taken at each site, with measurements being at least fifteen seconds apart. The skinfold measurements had to be within 0.4 millimetres of each other, or a third measurement was taken. The two closest values were averaged or, in the case of equal range between the three measurements, the median value was used.

To obtain the tricep skinfold measurement, the subject was asked to stand straight with the right arm flexed ninety degrees at the elbow with the palms facing upwards. The tricep skinfold site was located on the posterior aspect of the arm, midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna (Lee & Nieman 1993, Lohman et al. 1988). The midpoint between these two processes was marked along the lateral side of the arm (Lee & Nieman 1993, Lohman et al. 1988). The skinfold site was marked at the same level of the previously marked midpoint. Standing behind the subject, the measurer (HD) grasped the skinfold with the thumb and index finger of the left hand, measured the skinfold with the calipers, and recorded the measurements.

While the subject remained standing, the bicep skinfold measurement was obtained. The midpoint of the anterior of the arm, midway between the lateral projection of the acromion process of the scapula and the inner elbow crease, was located and marked. The skinfold site was marked at the same level as the previously marked midpoint.

The subscapular skinfold measurement was obtained with the subject standing, arms at the side. The skinfold site was located by palpating the inferior angle of the right scapula and placing a mark here. The skin was grasped with the thumb and the index finger one centimetre above and medial to the site along the axis and the measurement was taken (Lee & Nieman 1993, Lohman et al. 1988).

While the subject stood with the feet together and his/her weight evenly distributed, the suprailiac skinfold measurement was obtained. The subject's right hip was exposed and the right hipbone was palpated to locate the upper ileum. The skinfold measurement site itself was located and marked just above the iliac crest at the midaxillary line. The skin was grasped by placing the thumb on the skinfold site mark and the index finger placed above and anterior to the mark. The skinfold was diagonal and led toward the pubic synthesis. The skinfold was then measured at the midaxillary line.

To obtain the medial calf skinfold measurement, the subject remained standing erect and placed the right foot on a platform so that the knee and hip was flexed approximately 90 degrees (Lee & Nieman 1993, Lohman et al. 1988). Using a flexible, non-stretchable measuring tape, the maximum circumference of the calf was determined and the medial aspect of the calf was marked. The skinfold site was located vertically, about one centimeter proximal to the marked site and measured.

The skinfold values obtained were entered into equations to estimate percent body fat. Several equations were considered using the skinfold measurements. The two equations chosen use triceps + calf skinfolds and triceps + subscapular skinfolds and were used on children and youth by Slaughter and colleagues (1988). These equations were chosen because they have been validated and used extensively on children. One of the Slaughter equations (triceps + subscapular) took into consideration the stage of puberty each male child was at the time of measurement (i.e. Tanner stage). The following equations were used:

Slaughter et al. 1988 (T+C):

Males

$$\% \text{ body fat} = 0.735(T+C) + 1.0 \qquad (3.1)$$

where

T= tricep skinfold measured in millimetres,

C= calf skinfold measured in millimetres.

Females

$$\% \text{ body fat} = 0.610(T+C) + 5.1 \qquad (3.2)$$

where

T= tricep skinfold measured in millimetres,

C= calf skinfold measured in millimetres.

Slaughter et al. 1988 (T+S):

Prepubescent White Males (Tanner stages 1 and 2)

$$\% \text{ body fat} = 1.21(T+S) - 0.008(T+S)^2 - 1.7 \qquad (3.3)$$

where

T= tricep skinfold measured in millimetres,

S= subscapular skinfold measure in millimetres.

Pubescent White Males (Tanner stage 3)

$$\% \text{ body fat} = 1.21(T+S) - 0.008(T+S)^2 - 3.4 \qquad (3.4)$$

where

T= tricep skinfold measured in millimetres,

S= subscapular skinfold measure in millimetres.

All Females

$$\% \text{ body fat} = 1.33(T+S) - 0.013(T+S)^2 - 2.5 \qquad (3.5)$$

where

T= tricep skinfold measured in millimetres,

S= subscapular skinfold measure in millimetres.

3.3.2 Bioelectrical Impedance Analysis

Bioelectrical impedance analysis was conducted using a Xitron 4000B Bio-Impedance Analyzer (Xitron Technologies, San Diego, California) which was set at 50 kHz (800uA) and calibrated before each use. Opposition to the alternating current was measured, and values were obtained for resistance and reactance. In order to proceed with the analysis, the subject was required to have been in a rested state for approximately ten minutes, not have participated in excessive physical activity for the past twelve hours or consumed any solids or beverages the past four hours, and should not have been in a state of dehydration.

In conducting the measurements, the subject was asked to lie down with the right hand and foot exposed. Sites of electrode placement on both the subject's hands and feet were cleaned with rubbing alcohol. The electrodes themselves were strips of conductive tape (RJL Bodycomp Electrodes). Two distal current-introducing electrodes were placed on the dorsal surfaces of the right hand and foot proximal to the metacarpal phalangeal and metatarsal phalangeal joints, respectively. As well, two voltage-sensing electrodes were placed at the pisiform prominence of the wrist and between the medial and lateral malleoli of the ankle. Thus, resistance and reactance to the electrical current were measured on the right side of the body. Two measurements were taken at least five minutes apart and results were averaged. Values obtained were used in a series of different predictive equations from the literature to estimate percent body fat (see section 3.6.1). The attempt of this exercise was not to directly validate BIA in a population of children with FAS, but to determine if any of the existing equations currently in the literature would be appropriate for this population. Therefore, some of the equations were expected to better fit this population with age and gender than others; however, all the data obtained from the various equations were presented.

3.4 Measurement of Resting Energy Expenditure

Resting energy expenditure (REE) was assessed by indirect calorimetry at the College of Physical Education, University of Saskatchewan, Saskatoon. The measurements were carried out by D.Jacobson, research technician, and J.Stelzer, an experienced Physical Education graduate student, with assistance provided by the researcher (HD). The calorimeter used to measure resting energy expenditure was a Vmax 29 Series Indirect Calorimeter (Sensormedics, California). A ventilated-hood, open circuit system was employed. In order to conduct the indirect calorimetric assessment, the subject was required to be in a post-absorptive state and to have refrained from physical activity for the past twelve hours. Measurement was obtained with the subject in a supine position, relaxed, and lying still. The ventilated hood was placed over the subject's head and neck. The ventilated hood was connected to a metabolic cart. The metabolic carts employed in such indirect calorimetric assessments consist of a computerized calibration and data management system, as well as an infrared carbon dioxide analyzer, a paramagnetic oxygen sensor, and a volume transducer turbine for volume measurement (Murphy et al. 1995). As an open-circuit system, a stream of air was forced across the subject's face, mixed with expired air, and was collected by a transparent plastic hood placed over the subject's head and made airtight around the neck (Westrate 1993). Fresh filtered atmospheric air was drawn into the hood and expired air was drawn out by means of an air inlet on the top of the hood and an air outlet on the side of the hood (Westrate 1993). Concentrations of oxygen consumed and carbon dioxide produced were measured at thirty second intervals. The ventilated hood itself was a gasometer, and, thus, measured the volume of oxygen consumed. The entire measurement process was considered complete when steady-state was reached or until the subject could lie still no longer. The criteria used to determine when steady state was obtained was when the carbon dioxide and oxygen readings did not fluctuate by more than 5% during a 5 minute period. Printed measurement values for the volume of oxygen consumed and the volume of carbon dioxide produced were obtained (Appendix I). An average measurement value for resting energy expenditure at steady state was recorded.

3.5 Measurement of Dietary Intake

Dietary intakes were assessed using both twenty-four hour recalls and three-day weighed food records.

3.5.1 Twenty-four Hour Recall

Information collected in the twenty-four hour recall was obtained from the caregiver of the child. If the child was old enough to capably provide the researchers (HD, J.Heshka [JH], a senior Nutrition student, L.Carter [LC], a Nutrition graduate student) with valid, direct information, then the child was involved in the assessment. All data in the twenty-four hour recall was collected with the assurance of the caregiver that the intakes for the day being assessed were "usual" for the child.

In order to assist the caregiver in the estimation of portion sizes, models were used. The models were part of the Saskatchewan Nutrition Survey Food Portions Kit (College of Pharmacy and Nutrition 1994), and included utensils, plates, bowls, mugs, cups and molds of various sizes to help determine amounts and volumes of foods consumed. The kit also contained square, uniform, polyurethane discs which could be stacked to help with the estimation of food thickness, as well as polystyrene balls of varying diameters to help estimate portion sizes of foods that are round in shape. With the assistance of the researchers, the caregiver examined the food models to accurately estimate the portions of foods consumed by the child in the specified twenty-four hour period. If the child attended school, then the child's teacher was contacted by the caregiver to verify what foods were eaten at school, whether or not additional foods not part of the child's lunch were eaten at any time throughout the school day, and whether or not the child shared lunch or snack items with other children. If the child attended school or some other facility where meal programs were offered, once again, the child's supervisor was questioned similarly about the child's dietary intake and food habits.

All information obtained through the twenty-four hour recall was recorded according to the codes given in the food portions kit. The size, amount, or volume of every utensil, plate, bowl, etc. and every polyurethane disc and polystyrene ball in the Kit had been previously determined. Thus, each food model or item in the kit had a code that corresponded with the item itself (i.e. 'B' for 'bowl'), as well as with the size of the item or the amount it represented (i.e. 'L' for 'large'). By matching the correct code with previously determined amount or volume for each code, the amounts or volumes of the food or beverages themselves could be determined. Every food or beverage consumed by the child in the specified twenty-four hour period was coded in this manner, at the time of recording with the exception of twenty-four hour recalls recorded over the telephone. Descriptions of food given over the telephone of specific dimensions that were of unknown volume or weight were later purchased and weighed for accuracy. All data from the twenty-four hour recalls were recorded manually for later nutritional analysis (Appendix J). Two week days and one weekend day were analyzed to most accurately represent a "usual" week.

3.5.2 Three-day Weighed Food Record

The exact weight of the foods consumed were obtained using PETRA scales (Cherlyn Electronics Ltd., Cambridge, England). Briefly, the basis behind the PETRA scale is that weights of foods can be obtained accurately while being recorded on an audiotape that is inserted in the PETRA scale itself. Thus, all weights recorded on the tape can then be played back using a cassette recorder while the cassette recorder is attached to a console. The name of the food, the description of the food, and the meal or time at which the food was consumed is recorded on the tape and, thus, is overheard on the cassette recorder. The weight of the food as recorded by the PETRA scale will appear, simultaneously to the tape being played. In the current investigation, proper usage of the PETRA scales was explained to the caregiver by the researchers. Rubber food models were used in a demonstration at this time. After the caregivers were instructed on the usage of the PETRA scale, they were asked to weigh a mixed meal using the food models in the presence of the researchers to ensure that they understood the procedures involved in using the scale. The caregivers were also instructed to weigh any uneaten portions in the same manner to account for food not eaten. The caregivers were given an instruction manual (Appendix K) to which they could refer in the absence of the researchers and in the event that any problems with operating the PETRA scales or weighing the food portions arose. As well, the caregivers were instructed to telephone the researcher (HD) with any questions should they arise. The weighed intakes were recorded over three days consisting of two weekdays and one weekend day. Once again, the child was encouraged to participate in the recording process if possible. Caregivers were asked to enlist the assistance of their child's teachers to ensure the accuracy of the records. The caregivers were instructed to manually record any food not weighed during this time. In addition, any homemade recipes were to be recorded and later analyzed (Appendix L). Senior Nutrition students (S.Chow [SC], F.Devereaux [FD], M.Ye [MY]) and the researcher (HD) manually recorded the types, descriptions, and weights of the food for further nutritional analysis. Foods that were consumed in standard or known quantities, such as drink boxes or puddings, were not recorded on the PETRA scale. Instead, they were recorded on a separate form provided to the caregivers (Appendix M). The information recorded on this form was added to that received by the PETRA scale for later nutritional analysis.

3.6 Data Analysis

3.6.1 Anthropometry and Body Composition

Group means for height, weight and head circumference were determined ± standard deviation (SD). Height and weight percentiles for each subject were derived from National Center for Health Statistics (NCHS) percentiles (Hamill et al. 1979). Head circumference percentiles were derived from the University of Colorado Medical Center percentile standards (McCammon 1970). Ideal weight for height was determined using prepubescent physical growth NCHS percentiles and ideal body weight percent was then calculated. A z-score is used as a transformed standardized measurement from the mean. Z-scores were determined for height and weight for each child by comparing the values obtained to the mean values from samples of children taken in studies conducted by NCHS (HES), and in American Indians from a reservation in northern Minnesota (Kroska 1965), as well as in urban native Americans from Minneapolis (Johnston et al. 1978). Z-scores were determined for height comparing each child's height to those Canadian native children studied at a Southern Ontario Reserve (K.E.Kidd, as cited in Helmuth 1983), at Tyendinaga Reserve (Partington 1966, Helmuth 1983), and at St.Regis Reserve (Pfeiffer 1982). Z-scores for height, weight, and percent body fat using both Slaughter equations were calculated based on sex and Tanner stage (Slaughter et al. 1990). Tricep and subscapular skinfolds were determined using NCHS percentiles for persons 6 months to 19 years in the United States for 1976-1980. Finally, mean percent body fat (±SD) was calculated using the Slaughter skinfold equations and compared to standards as determined by Lohman (1987).

To calculate body composition based on the data obtained using BIA, the values obtained for resistance and reactance were used in existing regression equations developed for children to calculate total body water (TBW), total body potassium (TBK), fat, fat-free mass (FFM), and percent body fat. All values were converted to percent body fat. Presently, there are no prediction equations developed on children with FAS using BIA techniques. The equations chosen had been used on children successfully and are cited in the following references: Deurenberg et al. 1990, Suprasongsin et al. 1995, Cordain et al. 1988, Deurenberg et al. 1989 (a), Deurenberg et al. 1989 (b), Valhalla Model 1990A, Segal et al. 1988, Nokadomo 1991 (Brozek et al. 1963), Houtkooper et al. 1989, Deurenberg et al. 1991, Houtkooper et al. 1992, Azcue 1992 (TBK) and Azcue 1992 (TBW). These percent body fat values were compared to those obtained from the Slaughter skinfold equations and R^2 values were determined.

3.6.2 Resting Energy Expenditure

Basal metabolic rates were estimated using equations for predicting basal metabolic rate using body weight, height, sex, and age (FAO/WHO/UNU 1985, Schofield 1985). A paired t-test was performed comparing these values to those REE values obtained by indirect calorimetry.

3.6.3 Dietary Intake

Food intake from the twenty-four hour recalls and weighed food records were analyzed using the Nutritionist IV software program (First DataBank, The Hearst Corporation, San Bruno, California) (Appendix N). Supplement use was included in the intake data. These were coded and entered by HD, JH, SC, FD, and MY, with HD reviewing all entered data for consistency. When a food item was absent from the database, a similar food was entered. Average daily intakes ± SD, the percent of the 1990 recommended nutrient intake (RNI) (Canada 1990) met, and the proportion that fell below the RNI were determined in the 12 children for energy, protein, carbohydrate, fat, iron, calcium, magnesium, phosphorus, zinc, vitamins A, E, B1, B2, B3, B12, C, D, and folate. The RNI set for fat was 73.3 g for males 7-9 years and females 10-15 years of age, 83.3 g for males 10-12 years, 93.3 g for males 13-15 years, and 63.3 g for females 7-9 years old. The RNI set for carbohydrate was 303.0 g for males 7-9 years and females 10-15 years of age, 344.0 g for males 10-12 years, 385.0 g for males 13-15 years, and 261.0 g for females 7-9 years old.

The probability estimate of inadequacy was determined using the Anderson et al. (1982) method as described by Gibson (1990) (Appendix O). This method is used to predict the number of individuals within a group that will have nutrient intakes below their own requirement; therefore, estimating the population at risk for specific nutrients (Gibson 1990). A paired t-test was used to compare the absolute values of nutrients using both the twenty-four hour recall and three-day weighed food record methods.

The number of food exchanges were determined through Nutritionist IV using the Food Exchange System (American Diabetes Association, Inc. and the American Dietetic Association). This Food Exchange System is used to simplify controlling for energy consumption, especially carbohydrate and is used mainly in the diabetic population. There are six major exchange lists: Starch/Breads, Meats, Vegetables, Fruits, Milk, and Fats. Foods on the same exchange lists provide, on average, a similar number of calories, and grams of carbohydrate, protein, and fat. Again, a paired t-test was employed to compare the two methods regarding the food exchanges.

4. RESULTS

4.1 Demographics

The ages of the 12 subjects (8 boys and 4 girls) ranged from 7.00 to 13.50 years with the mean age 10.46 ± 2.06 years. Tanner stages ranged from 1 to 4, with 10 of the 12 subjects in prepubescency (Stages 1 and 2), 1 subject pubescent (Stage 3) and 1 postpubescent (Stage 4). Nine of the children were of Aboriginal descent and 3 were Caucasian (Table 4.1). Only 3 children were not currently taking any medication and 8 were taking medications for attention deficit disorder. In relation to their caregivers, 6 were in foster care, 4 were adopted, and 2 children were in the care of their biological mother.

When caregivers were asked how active their child was compared to other children the same age and sex, 1 answered "very high", 4 replied "high", 4 for "average", and 3 answered "low" (Table 4.1). No one replied "very low". All subjects were currently living in Saskatchewan at the time of data collection (Figure 4.1).

4.2 Anthropometry and Body Composition

4.2.1 Anthropometry

The mean height of the children was 135.7±12.0 cm with 4 children remaining on or below the 10th percentile for age (Table 4.2). The mean weight of the children was 27.2±8.1 kg with 8 remaining below the 10th percentile for age (Table 4.2). The mean head circumference of the children was 50.6±1.5 cm with 7 remaining on or below the 3rd percentile for age (Table 4.2). For the children that had heights below 145 cm for boys (n=6) and 137 cm for girls (n=3), ideal height for weight was plotted. The remainder of subjects had heights beyond the scope of the graphs, i.e., those boys above 145 cm and girls below 137 cm in height. The mean percentage of ideal body weight for the 9 subjects plotted was 84±13%. Only 1 subject was above 100% their ideal weight for height (Table 4.3). Z-scores were determined using data

Table 4.1. Characteristics, medication use, and physical activity level as perceived by the caregivers of children participating in the study (n=12).

SUB #	SEX	AGE[1] (years)	TANNER STAGE[2]	RACE	MEDICATION	PHYSICAL ACTIVITY[3]	RELATION TO CAREGIVER
hp01	Male	7.00	1	Treaty Indian	Ritalin Dixarit	high	Foster Child
hp02	Male	11.25	1	European/ New Zealander	None	high	Adopted
hp03	Female	9.50	1	Caucasian	Ritalin Clonidine Asendin	average	Biological
hp04	Female	13.00	4	Caucasian/ Aboriginal	Triphasil	low	Foster Child
hp05	Male	9.50	1	Native	None	average	Foster Child
hp06	Male	11.50	1	Native	Cylert Apo-Clonidine	average	Foster Child
hp07	Male	13.25	3	Cree	Ritalin	low	Biological
hp08	Male	13.50	2	Cree	Ritalin	high	Adopted
hp09	Female	9.50	1	Cree	Ritalin	very high	Adopted
hp10	Male	8.25	1	Caucasian	Clonidine	high	Foster Child
hp11	Female	10.00	1	Indian	None	average	Adopted
hp12	Male	9.25	1	Native	Ritalin Clonidine	low	Foster Child

1 The mean age of the children was 10.46 ± 2.06 years.
2 Prepubescency is represented by Tanner stages 1 and 2, pubescency by stage 3, and postpubescency by stages 4 and 5.
3 Caregiver's response to: "Rate your child's level of physical activity compared to other children the same age and sex."
Scale: very low, low, average, high, very high.

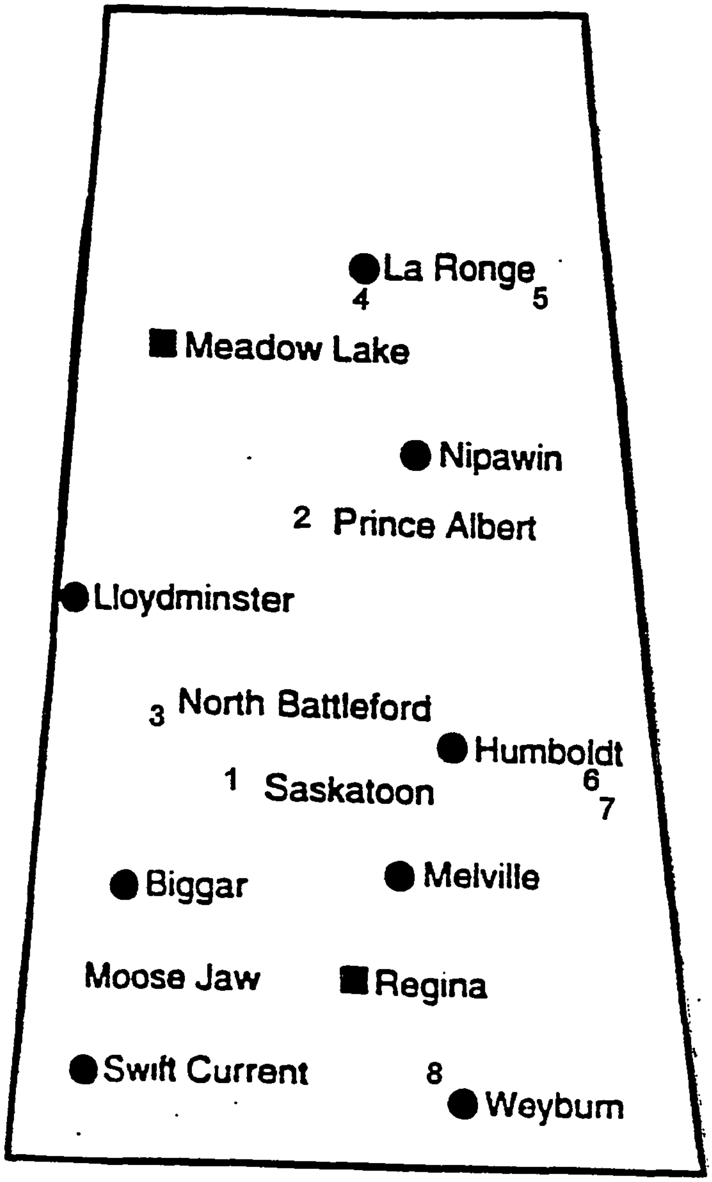

Figure 4.1. Location of subjects across Saskatchewan.

1 Subjects hp01, hp02, and hp10 were from Saskatoon.
2 Subject hp03 was from Prince Albert.
3 Subject hp04 was from Battleford.
4 Subjects hp05 and hp06 were from Air Ronge.
5 Subject hp07 was from Deschambault Lake.
6 Subjects hp08 and hp09 were from Kelvington.
7 Subject hp11 was from Okla.
8 Subject hp12 was from McTaggart.

Table 4.2. Height (HT), weight (WT), and head circumference (HC) with corresponding percentiles in the sample of children with FAS (n=12).

SUB #	HT[1] (cm)	WT[1] (kg)	HC[2] (cm)
hp01	110.0 (<5)	15.5 (<5)	49.0 (<3)
hp02	144.5 (50)	31.0 (10>25)	51.9 (25>50)
hp03	134.5 (25>50)	35.0 (75)	49.3 (<3)
hp04	150.4 (10>25)	41.0 (25>50)	51.5 (25>50)
hp05	137.7 (90>95)	22.7 (10>25)	50.7 (3)
hp06	139.2 (10>25)	25.5 (<5)	51.5 (3)
hp07	149.2 (10>25)	34.1 (5)	51.4 (<3)
hp08	148.1 (5>10)	36.4 (5)	53.4 (25>50)
hp09	127.1 (10)	20.9 (<5)	50.3 (25>50)
hp10	124.5 (25)	19.5 (<5)	48.3 (<3)
hp11	137.0 (25>50)	25.5 (5>10)	50.7 (25>50)
hp12	126.4 (10)	19.5 (<5)	49.0 (<3)
MEAN (SD)	135.7 (12.0)	27.2 (8.1)	50.6 (1.5)

1 Height and weight percentiles derived from National Center for Health Statistics (NCHS) percentiles (Hamill 1979).
2 Head circumference percentiles derived from the University of Colorado Medical Center percentile standards (McCammon 1970).

Table 4.3. Weight (WT), ideal weight (WT) for height (HT), and corresponding ideal body weight (WT) percentages for 9 subjects whose heights were below 145 cm for boys (n=6) and below 137 cm for girls (n=3).

SUB #	WT (kg)	IDEAL WT for HT (kg)	IDEAL BODY WT (%)
hp01	15.5	18.75	83
hp02	31.0	36.50	85
hp03	35.0	29.75	118
hp05	22.7	31.25	73
hp06	25.5	32.50	78
hp09	20.9	25.00	84
hp10	19.5	24.25	80
hp11	25.5	31.50	81
hp12	19.5	25.00	78
MEAN (SD)	23.9 (6.1)	28.28 (5.42)	84 (13)

Ideal weight for height determined using the 50th percentile from the prepubescent physical growth NCHS percentiles (Hamill 1979). Ideal body weight percent was calculated by dividing the child's weight by their ideal weight for height and multiplying by 100.

collected on urban native Americans from Minneapolis (Johnston et al. 1978), American Indians from Red Lake, Minnesota (Kroska 1965), and the United States national probability samples from the National Center for Health Statistics (Hamill et al. 1972, Hamill et al. 1973). The mean z-scores for height using the above mentioned studies were -0.70 ± 0.70, -0.50 ± 1.20, and -1.18 ± 0.96, respectively (Table 4.4). The mean z-scores for weight were all at least one standard deviation below the mean (-1.47 ± 0.68, -1.57 ±1.20, and -1.25 ± 0.67, respectively) as shown on Table 4.5. Z-scores for height using data collected on Canadian Native children from 4 previously mentioned studies were determined (Table 4.6). All of the mean z-scores were negative with the exception of the Southern Ontario study performed in 1934.

Mean percent body fat predicted using tricep and subscapular skinfold values was 13.51 ± 5.84% and using tricep and calf skinfold values was 12.75 ± 6.36% (Table 4.7). No significant difference was found for percent body fat when comparing the two equations (p=0.26). Corresponding standards determined by Lohman (1987) were also provided on Table 4.7. The standards were identical for each subject regardless the skinfolds used with the exception of subject hp03 who was determined to be only "moderately high" when tricep + subscapular skinfolds were used as opposed to "high" when tricep + calf skinfolds were used. As well, subject hp03 was the only subject above optimal. In both cases, half of the subjects were considered to have "low" body fat for their age and sex. Eleven children were below the 50th percentile for the tricep skinfold and 8 were below the 50th percentile for the subscapular skinfold (Table 4.8).

Table 4.9 shows z-scores calculated for height, weight and percent body fat using data collected from male and female prepubescent, pubescent and postpubescent children (Slaughter et al. 1990). All mean z-scores were negative.

4.2.2 Bioelectrical Impedance Analysis

Several equations using BIA values were used to estimate percent body fat. Table 4.10 describes these equations and the subjects used in the original studies. The ranges of percent body fat and R^2 values comparing the BIA percent body fat

Table 4.4. Z-score values comparing the heights of children with FAS (n=12) to those the same age and sex in 3 different samples.

SUB #	Minneapolis	Red Lake	HES
hp01	-1.68	-2.75	-3.51
hp02	-0.27	0.42	-0.17
hp03	-0.30	0.45	-0.14
hp04	-0.49	N/A	-1.20
hp05	0.16	1.42	N/A
hp06	-1.01	-0.81	-0.93
hp07	-0.71	N/A	-1.16
hp08	-0.80	N/A	-1.29
hp09	-0.57	-0.89	-1.22
hp10	-1.72	-0.87	-1.64
hp11	-0.52	-0.23	-0.53
hp12	-1.50	-1.22	N/A
MEAN (SD)	-0.70 (0.70)	-0.50 (1.20)	-1.18 (0.96)

Z-scores determined using data collected on urban native Americans from Minneapolis (Johnston et al. 1978), American Indians from Red Lake, Minnesota (Kroska 1965), and the United States national probability samples from the National Center for Heath Statistics (HES) (Hamill et al. 1972, Hamill et al. 1973). If no corresponding value for a particular sex and age was provided, N/A was entered.

Table 4.5. Z-score values comparing the weights of children with FAS (n=12) to those the same age and sex in 3 different samples.

SUB #	Minneapolis	Red Lake	HES
hp01	-2.06	-3.03	-2.24
hp02	-1.18	-1.06	-0.88
hp03	-0.01	1.15	0.53
hp04	-0.65	N/A	-0.92
hp05	-1.68	-1.40	-1.25
hp06	-1.69	-2.21	-1.54
hp07	-1.41	N/A	-1.36
hp08	-1.22	N/A	-1.16
hp09	-1.39	-1.91	-1.54
hp10	-2.55	-2.56	-1.69
hp11	-1.65	-1.26	-1.18
hp12	-2.19	-1.87	-1.72
MEAN (SD)	-1.47 (0.68)	-1.57 (1.20)	-1.25 (0.67)

Z-scores determined using data collected on urban native Americans from Minneapolis (Johnston et al. 1978), American Indians from Red Lake, Minnesota (Kroska 1965), and the United States national probability samples from the National Center for Heath Statistics (HES) (Hamill et al. 1972, Hamill et al. 1973). If no corresponding value for a particular sex and age was provided, N/A was entered.

Table 4.6. Z-score values comparing the heights of children with FAS (n=12) to those the same age and sex in 4 different studies.

SUB #	Southern Ontario 1934	Tyendinaga 1966	St.Regis 1981	Tyendinaga 1982
hp01	N/A	-2.48	-2.80	-1.78
hp02	1.02	0.19	0.22	0.12
hp03	0.47	0.39	0.69	-0.90
hp04	-0.70	-2.28	-1.15	-0.58
hp05	4.56	0.33	0.54	0.39
hp06	0.44	-0.83	-0.62	-0.59
hp07	0.25	-1.61	-0.78	-0.62
hp08	0.15	-1.79	-0.90	-0.73
hp09	-0.62	-2.25	-1.43	-2.10
hp10	0.00	-0.66	-1.45	-1.21
hp11	0.37	-0.20	-0.75	-0.21
hp12	-1.72	-1.73	-1.44	-2.07
MEAN (SD)	0.38 (1.57)	-1.07 (1.08)	-0.82 (0.97)	-0.86 (0.81)

Z-scores determined using data collected on Canadian Native children for a Southern Ontario Reserve of Iroquois and Ojibwa Natives from 1934 (K.E.Kidd, as cited in Helmuth 1983), Tyendinaga Mohawk Reserve (Partington 1966), St. Regis Reserve (Pfeiffer 1982) and Tyendinaga Reserve (Helmuth 1983). If no corresponding value for a particular sex and age was provided, N/A was entered.

Table 4.7. Percent body fat estimated by Slaughter et al. 1988 skinfold equations using the sum of tricep+subscapular and tricep+calf skinfolds with corresponding standards as determined by Lohman (1987).

SUB #	BODY FAT[1] (%)	SUM OF SKINFOLDS[1] (mm)	STANDARD[1]	BODY FAT[2] (%)	SUM OF SKINFOLDS[2] (mm)	STANDARD[2]
hp01	8.75	9.2	low	7.76	9.2	low
hp02	13.18	13.5	optimal	14.74	18.7	optimal
hp03	23.74	26.7	moderately high	27.98	37.5	high
hp04	20.92	22.6	optimal	16.45	18.6	optimal
hp05	8:33	8.8	low	6.37	7.3	low
hp06	8.22	8.7	low	7.39	8.7	low
hp07	11.48	13.5	optimal	10.85	13.4	optimal
hp08	15.13	15.5	optimal	13.13	16.5	optimal
hp09	12.19	12.6	low	12.97	12.9	low
hp10	8.54	9.0	low	7.91	9.4	low
hp11	22.69	25.1	optimal	19.74	24.0	optimal
hp12	8.97	9.4	low	7.69	9.1	low

1 - Tricep + subscapular skinfold sums were used. Mean % body fat = 13.51±5.84.
2 - Tricep + calf skinfold sums were used. Mean % body fat = 12.75±6.36.

The following equations were used, depending on the child's sex and Tanner stage:

Prepubescent White Males (Tanner stages 1 and 2)
$\% \text{ body fat} = 1.21(T+S) - 0.008(T+S)^2 - 1.7$
Pubescent White Males (Tanner stage 3)
$\% \text{ body fat} = 1.21(T+S) - 0.008(T+S)^2 - 3.4$
All Females
$\% \text{ body fat} = 1.33(T+S) - 0.013(T+S)^2 - 2.5$

where

T=tricep skinfold measured in millimetres,
S=subscapular skinfold measured in millimetres.

Males
$\% \text{ body fat} = 0.735(T+C) + 1.0$
Females
$\% \text{ body fat} = 0.610(T+C) + 5.1$

where

T=tricep skinfold measured in millimetres,
C=calf skinfold measured in millimetres.

Table 4.8. Tricep and subscapular NCHS skinfold percentiles in the sample of children with FAS (n=12).

SUB #	TRICEP PERCENTILE (%)	SUBSCAPULAR PERCENTILE (%)
hp01	<5	25>50
hp02	25>50	25>50
hp03	50>75	75>85
hp04	15>25	50>75
hp05	<5	25>50
hp06	5>10	10>15
hp07	15>25	25>50
hp08	25>50	50>75
hp09	5	25>50
hp10	<5	15>25
hp11	25>50	50>75
hp12	10>15	15>25

Tricep and subscapular skinfolds determined using NCHS percentiles for persons 6 months to 19 years in the United States in 1976-1980 (National Center for Health Statistics 1987).

Table 4.9. Z-score values for height, weight, and percent body fat of children with FAS (n=12) compared to a healthy control group.

SUB #	HEIGHT	WEIGHT	% BODY FAT (TRI + SUB)	% BODY FAT (TRI + CALF)
hp01	-3.78	-2.90	-0.98	-1.21
hp02	0.54	-0.40	-0.35	-0.12
hp03	-1.01	0.00	0.17	0.68
hp04	-1.95	-1.97	-0.46	-1.21
hp05	-0.31	-1.74	-1.04	-1.32
hp06	-0.13	-1.29	-1.05	-1.17
hp07	-0.59	-1.42	-0.51	-0.59
hp08	0.99	0.47	0.14	-0.35
hp09	-2.07	-2.20	-1.22	-1.12
hp10	-1.96	-2.26	-1.01	-1.10
hp11	-0.66	-1.48	0.05	-0.31
hp12	-1.73	-2.26	-0.95	-1.13
MEAN (SD)	-1.06 (1.31)	-1.46 (1.01)	-0.60 (0.51)	-0.74 (0.61)

Z-scores determined using data collected on children based on sex and Tanner stage (Slaughter et al. 1990).

Table 4.10. Equations using BIA data from a sample of children with FAS (n=12) to estimate percent body fat, the criteria the equations were tested on, the percent body fat range, and the R^2 values determined using the two Slaughter skinfold equations.

REFERENCE	EQUATION	CRITERIA (1)	RANGE (%body fat)	R^2 (2)	R^2 (3)
Deurenberg et al. 1990	FFM=(0.438*10^4)*H^2/R+0.308*W+1.6*S+7.04*H-8.5 (H=m, R=Res, W=kg, S=1 if M, =0 if F)	Boys and girls 7-25 y old, n=246 SEE=2.39 kg R=0.99	9.0-30.3	0.36	0.34
Suprasongsin et al. 1995	FFM=0.524*Ht^2/R+0.415*Wt-0.32 (Ht=cm, R=Res, Wt=kg)	normal children, children with various endocrine disorders, and young adults, aged 8-26 y, n=56	2.6-19.1	0.16	0.13
Cordain et al. 1988	FFM=0.81*Ht^2/R+6.86 (Ht=cm, R=Res)	16 F & 14 M, aged 9-14 y SEE=4.1 kg R^2=0.69	-18.9-20.8	N/A	N/A
Deurenberg et al. 1989(a)	FFM=(0.43*10^4)*H^2/R+0.354*W+0.9*S (H=m, R=Res, W=kg, S=1 if M, =0 if F)	33 M & 31 F, aged 8-11 y SEE=1.31 kg R^2=0.89	13.6-31.5	0.49	0.42
Valhalla Model 1990A	Fat=Wt-(0.58*Ht^2/R+0.24*Wt+2.7) (Wt=kg, Ht=cm, R=Res)	Children (age<15y) n=NA	0.6-24.7	N/A	N/A
Segal et al. 1988	(M) FFM=22.66827+0.00132*ht-.04394*resistance+0.30520*mass-0.16760*age (F) FFM=14.59453+0.00108*ht-.02090*resistance+0.23199*mass-0.06777*age (ht=cm, resistance=ohms, mass=kg, age=years)	94 Chinese boys and girls, aged 11-17y	73.9-209.4	N/A	N/A
Nokadomo 1991 Brozek et al. 1963	(M) D = 1.1650-0.1093* (WxI)/H^2 (F) D = 1.1193-0.0684*(WxI)/H^2 (D=Density, W=kg, I=Res, H=cm) %BF=(4.201/D-3.813)x100	583 healthy children, aged 9-10 y 633 healthy children, aged 12-13 y	13.1-27.8	0.19	0.14

Table 4.10 continued on the next page.

Table 4.10. continued

REFERENCE	EQUATION	CRITERIA (1)	RANGE (%body fat)	R^2 (2)	R^2 (3)
Deurenberg et al. 1989(b)	(F) FFM = 0.762*Ht^2/R+4.20 (M) FFM = 0.488*Ht^2/R+0.345*Wt-0.16 (Ht=m, R=Res, Wt=kg)	41 F, aged 11-16 y SEE=2.8 kg R^2=0.90 59 M, aged 11-16 y SEE=2.1kg R^2=0.94	65.9-89.8	N/A	N/A
Houtkooper et al. 1989	FFM=0.58*Ht^2/R+0.24Wt+2.69 (Ht=cm, R=Res, Wt=kg)	41 F & 53 M, aged 10-14 y SEE=2.0 kg R^2=0.93	0.7-24.7	N/A	N/A
Deurenberg et al. 1991	FFM=(0.406*10^4)*Ht^2/R+0.360*Wt+5.580*Ht+0.56*Sex-6.48 (Ht=m, R=Res, Wt=kg, Sex=1 if M, =0 if F)	446 F & 361 M, aged 7-83 y SEE=1.7 kg R^2=0.97	11.8-30.5	0.19	0.18
Houtkooper et al. 1992	FFB-DW=0.61RI+0.25Wt+1.31 (RI=H^2/R, H=cm, R=Res, Wt=kg)	Whites 10-19 y old, n=225 SEE=2.1 kg R^2=0.95	2.5-24.8	0.32	0.27
Azcue 1992 (TBK)	TBK=-0.328+2.07*H^2/R (H=cm, R=Res) (M) LBM=TBK*0.4353 (F) LBM=TBK*0.47058	n=67 M and F, aged 1.8-62 y old SEE=6.6 kg R^2=0.93	2.0-29.6	0.03	0.02
Azcue 1992 (TBW)	TBW=2.99+0.649*H^2/R (H=cm, R=Res) LBM=TBW/0.732	n=101 M and F, aged 1.8-62 y old SEE=2.301 R^2=0.94	-15.0-21.7	N/A	N/A

(1) Criteria includes the sex, age, race, and number of subjects included in the original studies. Also provided under criteria are SEE's, R^2's and R's, if available.
(2) R^2 values using the Slaughter et al. 1988 (T+S) skinfold equation.
(3) R^2 values using the Slaughter et al. 1988 (T+C) skinfold equation.
If the percent body fat range included a value that was less than 2% or if a value was greater than 50%, N/A was entered. No significant correlation between BIA and the Slaughter skinfold equations were found.

values to the percent body fat values obtained using the Slaughter skinfold equations are shown. No R^2 value was calculated (i.e. N/A) if the range included a calculated fat value less than 2% or greater than 50%.

4.3 Resting Energy Expenditure

Eight of the 12 subjects participated in the measurement of REE. The others could not have the measurement taken due to the cost and/or time needed to travel to Saskatoon. Subjects hp07, hp08, and hp09 took Ritalin before the testing. Respiratory quotients (RQ) values ranged 0.85 - 1.00 with a mean RQ of 0.95±0.05 (Table 4.11). The mean REE was 1077 kcal/day (±313) and the mean REE estimated by predictive equations were as follows: FAO/WHO/UNU = 1128±179 kcal/day, Schofield using weight = 1115±179 kcal/day, and Schofield using weight and height = 1122±176 kcal/day (Table 4.11). No significant difference between the two methods was found ($p>0.05$).

4.4 Diet

Tables 4.12, 4.13, 4.14, and 4.15 give absolute values of nutrients along with means and standard deviations averaged from three twenty-four hour recalls and three weighed food records for energy and macronutrients, minerals, fat soluble vitamins, and water soluble vitamins, respectively. There were no significant differences between the two diet collection methods for all nutrients analyzed with the exception of calcium ($p=0.03$) and phosphorus ($p=0.05$). However, energy ($p=0.13$), protein ($p=0.11$), carbohydrates ($p=0.06$), magnesium ($p=0.14$), vitamin E ($p=0.13$), and vitamin B3 ($p=0.13$) lean towards significance. The percentage of the RNI met for each individual and the mean percentages for the group from the twenty-four hour recalls and weighed food records are shown in Tables 4.16 and 4.17, respectively. In Table 4.16, the group mean percentage did not meet the RNI for energy (95%), carbohydrates (97%), and fat (79%). When using the weighed food record method, again, the group mean percentage did not meet the RNI for energy (84%), carbohydrates (83%), and fat (96%), as well as vitamin E (65%). The percentage of subjects below the RNI for each of the nutrients for each method is provided in

Table 4.11. Resting energy expenditure (REE) measured and estimated by FAO/WHO/UNU equations using weight (WT) and Schofield equations using weight (WT) and weight and height (WT-HT) with the corresponding measured respiratory quotient (RQ) (n=8).

SUB #	REE MEASURED (kcal/day)	RQ MEASURED	REE FAO/WHO/UNU WT (kcal/day)	REE Schofield WT (kcal/day)	REE Schofield WT-HT (kcal/day)
hp01	418	0.92	847	856	862
hp02	1045	0.88	1194	1207	1217
hp03	1271	0.85	1287	1197	1183
hp04	1422	0.91	1246	1241	1243
hp07	965	0.95	1248	1261	1274
hp08	1280	1.00	1288	1302	1310
hp09	969	0.95	969	911	931
hp10	1243	0.99	938	947	959
MEAN (SD)	1077 (313)	0.95 (0.05)	1128 (179)	1115 (179)	1122 (176)

Resting energy expenditure (REE) and respiratory quotient (RQ) measured through indirect calorimetry on 8 of the subjects. REE estimated by the 1985 FAO/WHO/UNU and Schofield predictive equations using weight and height and weight. No significant difference was found between the energy expenditures for the two methods (measured vs. predicted) using a paired t-test ($p>0.05$).

The following prediction equations were used:
FAO/WHO/UNU BMR (kcal/day)
Males 3 to 10 years: 22.1W + 495
10 to 18 years: 17.5W + 651
Females 3 to 10 years: 22.5W + 499
10 to 18 years: 12.2W + 746
where W = weight in kilograms

Schofield BMR using weight (MJ/24h)
Males 3 to 10 years: 0.095wt + 2.110
10 to 18 years: 0.074wt + 2.754
Females 3 to 10 years: 0.085wt + 2.033
10 to 18 years: 0.056wt + 2.898
where wt = weight in kilograms

Schofield BMR using weight and height (MJ/24h)
Males 3 to 10 years: 0.082wt + 0.545ht + 1.736
10 to 18 years: 0.068wt + 0.574ht + 2.157
Females 3 to 10 years: 0.071wt + 0.677ht + 1.553
10 to 18 years: 0.035wt + 1.948ht + 0.837
where wt = weight in kilograms, ht = height in metres

Table 4.12. Absolute values of nutrients as a three day average using the twenty-four hour recall (24h) and weighed food record (PETRA) methods for energy (NRG) and the macronutrients protein (PTN), carbohydrates (CHO), and fat in the sample of children with FAS (n=12).

SUB #	NRG kcal 24h	NRG kcal PETRA	PTN g 24h	PTN g PETRA	CHO g 24h	CHO g PETRA	FAT g 24h	FAT g PETRA
hp01	2629	1926	89	50	411	326	79	52
hp02	2475	2221	89	82	350	312	83	77
hp03	1893	1197	65	45	246	158	74	45
hp04	2715	2328	89	69	409	356	88	76
hp05	2061	1613	57	60	317	203	72	63
hp06	2509	1282	77	44	366	187	90	41
hp07	2525	2573	85	56	370	372	83	104
hp08	2819	2264	94	89	369	247	112	105
hp09	1548	2154	46	58	211	272	60	95
hp10	2096	2457	92	102	258	287	80	104
hp11	2089	1728	84	83	230	193	93	71
hp12	1255	1766	48	65	181	255	38	57
MEAN (SD)	2218 (483)	1959 (448)	76 (18)	67 (19)	310 (81)	264 (69)	79 (18)	74 (23)

Nutrient values obtained using the two methods of dietary intake collection were compared by paired t-tests:
NRG: p=0.13, PTN: p=0.11, CHO: p=0.06, FAT: p=0.49.

Table 4.13. Absolute values of nutrients as a three day average using the twenty-four hour recall (24h) and weighed food record (PETRA) methods for minerals: iron (Fe), calcium (Ca), magnesium (Mg), phosphorus (P), and zinc (Zn) in the sample of children with FAS (n=12).

SUB #	Fe mg 24h	Fe mg PETRA	Ca mg 24h	Ca mg PETRA	Mg mg 24h	Mg mg PETRA	P mg 24h	P mg PETRA	Zn mg 24h	Zn mg PETRA
hp01	26	11	401	655	314	230	1348	986	11	6
hp02	14	17	973	1022	302	298	1555	1358	9	9
hp03	24	8	528	407	138	125	1008	655	15	6
hp04	18	21	945	1150	409	358	1767	1607	14	16
hp05	15	8	573	1059	281	214	1158	1183	11	7
hp06	18	10	753	433	340	179	1635	853	12	5
hp07	18	17	272	440	188	243	971	1086	8	7
hp08	23	21	874	1219	296	278	1587	1517	13	13
hp09	10	19	399	741	132	200	670	927	6	10
hp10	13	20	922	1453	314	276	1718	1496	13	10
hp11	13	14	719	961	260	205	1465	1303	11	10
hp12	9	13	701	704	154	175	1032	919	7	12
MEAN (SD)	17 (5)	15 (5)	672 (237)	854 (342)	261 (88)	232 (63)	1326 (351)	1158 (301)	11 (3)	9 (3)

Nutrient values obtained using the two methods of dietary intake collection were compared by paired t-tests:
Fe: p=0.45, Ca: p=0.03, Mg: p=0.14, P: p=0.05, Zn: p=0.22.

Table 4.14. Absolute values of nutrients as a three day average using the twenty-four hour recall (24h) and weighed food record (PETRA) methods for the fat soluble vitamins in the sample of children with FAS (n=12).

SUB #	VIT A RE 24h	VIT A RE PETRA	VIT D µg 24h	VIT D µg PETRA	VIT E mg 24h	VIT E mg PETRA
hp01	653	496	4.6	2.9	6	5
hp02	1862	1422	6.8	7.2	7	3
hp03	2269	306	7.4	0.9	17	2
hp04	1243	2082	7.0	8.8	4	7
hp05	716	605	4.7	7.1	4	3
hp06	731	513	5.5	4.6	3	4
hp07	520	713	2.8	2.8	6	8
hp08	1153	733	6.6	2.5	16	7
hp09	643	1090	3.1	6.2	8	4
hp10	1216	2274	8.6	6.6	9	8
hp11	620	640	7.4	6.6	5	3
hp12	848	439	7.4	5.5	2	4
MEAN (SD)	1040 (545)	943 (651)	6.0 (1.8)	5.1 (2.4)	7 (5)	5 (2)

Nutrient values obtained using the two methods of dietary intake collection were compared by paired t-tests:
VIT A: p=0.67, VIT D: p=0.30, VIT E: p=0.13.

Table 4.15. Absolute values of nutrients as a three day average using the twenty-four hour recall (24h) and weighed food record (PETRA) methods for the water soluble vitamins in the sample of children with FAS (n=12).

SUB #	VIT B1 mg 24h	VIT B1 mg PETRA	VIT B2 mg 24h	VIT B2 mg PETRA	VIT B3 mg 24h	VIT B3 mg PETRA	VIT B12 µg 24h	VIT B12 µg PETRA	VIT C mg 24h	VIT C mg PETRA	FOLATE µg 24h	FOLATE µg PETRA
hp01	3.5	2.0	2.0	1.4	20.3	14.6	3.2	1.9	249	355	404	504
hp02	1.9	1.8	2.3	2.6	22.0	26.3	3.7	3.0	199	78	319	286
hp03	2.0	0.8	2.2	0.9	22.0	10.3	5.9	2.1	195	93	358	95
hp04	2.4	2.7	2.7	2.7	24.8	21.4	4.5	7.0	235	359	341	552
hp05	1.2	1.8	1.7	1.7	15.8	10.0	1.9	3.4	72	45	217	94
hp06	1.8	1.4	2.2	1.1	18.6	13.0	2.4	1.5	63	58	214	135
hp07	1.2	2.0	1.6	1.8	28.8	19.4	2.0	1.3	108	94	254	226
hp08	2.2	1.4	2.6	1.9	26.5	16.3	5.1	3.4	116	110	282	173
hp09	1.0	1.5	1.2	2.0	12.4	16.6	2.3	5.3	71	219	95	197
hp10	2.1	1.7	2.7	2.6	16.7	19.8	5.9	4.3	68	52	188	180
hp11	1.8	1.8	2.2	2.5	17.4	21.9	5.0	6.2	108	50	197	328
hp12	1.3	2.0	1.6	1.3	10.2	11.7	3.4	3.5	88	141	155	131
MEAN (SD)	1.9 (0.7)	1.7 (0.5)	2.1 (0.5)	1.9 (0.6)	19.6 (5.6)	16.8 (5.1)	3.8 (1.5)	3.6 (1.8)	131 (69)	138 (113)	252 (91)	242 (151)

Nutrient values obtained using the two methods of dietary intake collection were compared by paired t-tests:
VIT B1: p=0.58, VIT B2: p=0.27, VIT B3: p=0.13, VIT B12: p=0.73, VIT C: p=0.79, FOLATE: p=0.79.

Table 4.16. Percentage of recommended nutrient intakes as a three day average using the twenty-four hour recall method for energy (NRG), protein (PTN), carbohydrate (CHO), fat, iron (Fe), calcium (Ca), magnesium (Mg), phosphorus (P), zinc (Zn), vitamins A, E, B1, B2, B3, B12, C, D, and folate in the sample of children with FAS (n=12).

SUB #	NRG	PTN	CHO	FAT	Fe	Ca	Mg	P	Zn	VIT A	VIT E	VIT B1	VIT B2	VIT B3	FOLATE	VIT B12	VIT C	VIT D
hp01	119	341	135	108	325	121	313	269	157	93	91	385	181	126	448	324	995	182
hp02	98	260	101	99	173	152	232	222	94	233	90	188	178	122	265	371	796	272
hp03	95	225	92	109	302	136	129	191	214	322	289	247	216	155	382	587	781	294
hp04	123	205	135	120	170	135	251	211	156	155	53*	262	248	154	215	446	830	278
hp05	93	217	104	97	184	119	281	231	154	102	54*	134	151	98	241	194	288	185
hp06	100	227	106	107	225	120	261	233	136	91	39*	177	169	103	178	239	252	218
hp07	90	174	96	88	182	41*	101	107	63*	57*	61*	109	111	144	145	196	360	112
hp08	100	191	95	120	234	107	159	176	106	128	175	196	186	132	161	508	387	264
hp09	81	178	80	93	130	69	132	134	86	91	141	128	114	88	106	231	282	122
hp10	95	355	84	109	167	200	314	343	182	173	130	230	245	104	208	585	273	343
hp11	94	234	75	127	163	99	192	183	120	77	67	202	195	109	151	503	429	297
hp12	57*	184	59*	52*	112	147	153	206	103	121	24*	143	144	63*	172	335	353	296
MEAN	95	223	97	79	197	120	210	209	131	137	101	200	178	116	223	377	502	238

Those asterisked (*) depicts less than 67% of their RNI was met.

Table 4.17. Percentage of recommended nutrient intakes as a three day average using the weighed food record method for energy (NRG), protein (PTN), carbohydrate (CHO), fat, iron (Fe), calcium (Ca), magnesium (Mg), phosphorus (P), zinc (Zn), vitamins A, E, B1, B2, B3, B12, C, D, and folate in the sample of children with FAS (n=12).

SUB #	NRG	PTN	CHO	FAT	Fe	Ca	Mg	P	Zn	VIT A	VIT E	VIT B1	VIT B2	VIT B3	FOLATE	VIT B12	VIT C	VIT D
hp01	87	190	107	70	140	93	229	197	84	70	76	227	125	91	559	190	1421	117
hp02	88	240	90	92	209	113	229	194	99	177	40*	179	196	146	238	303	310	286
hp03	54*	124	52*	60*	97	37*	92	81	65*	38*	35*	84	83	64*	73	205	373	34*
hp04	105	150	117	103	162	114	199	189	175	260	98	301	247	133	325	703	1195	353
hp05	73	229	66*	86	101	151	214	236	95	86	45*	204	150	62*	104	340	180	282
hp06	51*	128	54*	49*	125	48*	137	121	56*	63*	54*	135	84	72	112	147	231	185
hp07	91	114	96	111	166	40*	131	120	59*	79	86	177	128	96	129	128	311	111
hp08	80	182	64*	112	209	110	150	168	108	81	73	130	134	81	99	341	366	98
hp09	113	223	104	149	240	105	200	185	143	155	71	192	198	118	219	531	875	248
hp10	111	392	94	141	245	207	275	299	148	324	119	186	238	123	200	432	209	265
hp11	78	231	63*	96	170	87	151	162	109	79	37*	197	227	136	251	616	198	264
hp12	80	251	84	78	161	100	175	183	174	62*	51*	222	122	73	145	354	563	219
MEAN	84	205	83	96	169	100	182	178	110	123	65*	186	161	100	204	358	519	205

Those asterisked (*) depicts less than 67% of their RNI was met.

Table 4.18. The percentages that did not meet the RNI for each nutrient ranged from 0% to 67% using the twenty-four hour recall method, and ranged from 0% to 92% using the weighed food record method. Table 4.19 shows the probability estimate of inadequacy (PEI) for each of the methods. The PEI's for the nutrients ranged from 0% to 47.4% using the twenty-four hour recall method, and ranged from 0% to 69.8% when the weighed food record was used. Vitamin E was the only nutrient to receive a value with a PEI above 25% using both methods of diet collection. This may be due to the nutrient database, therefore vitamin E was analyzed in different foods using Nutritionist IV. As an example, when two tablespoons of peanut butter was entered into Nutritionist IV, no value for vitamin E was given. The USDA website (http://www.nal.usda.gov/fnic/cgi-bin/list_nut.pl) gives a value of 3.2 mg of vitamin E for two tablespoons of peanut butter; therefore, the Nutritionist IV database does not analyze for vitamin E adequately.

In Tables 4.20 and 4.21, the total number of food exchanges, according to the Food Exchange System, were averaged for each subject over the three days using the twenty-four hour recall and weighed food record methods, respectively. Differences between the two methods regarding food exchange intake were not significant (Starch/Breads p=0.19, Vegetables p=0.38, Fruit p=0.66, Milk p=0.33, Meats p=0.39, Fats p=0.34).

Only one subject (hp03) took any vitamin/mineral supplements when diet was collected by the twenty-four hour recall method. No supplement use by the subjects was recorded during the period diet was collected by the weighed food record method. This may be because the caregivers forgot to do so, or perhaps there simply was no supplement use by the children at this time.

Table 4.18. Percentage of subjects below the recommended nutrient intake as a three day average using the twenty-four hour recall (24H RECALL) and weighed food record (PETRA) methods for energy (NRG), protein (PTN), carbohydrate (CHO), fat, iron (Fe), calcium (Ca), magnesium (Mg), phosphorus (P), zinc (Zn), vitamins A, E, B1, B2, B3, B12, C, D, and folate.

METHOD	NRG	PTN	CHO	FAT	Fe	Ca	Mg	P	Zn	VIT A	VIT E	VIT B1	VIT B2	VIT B3	FOLATE	VIT B12	VIT C	VIT D
24H RECALL	67	0	58	42	0	25	0	0	25	42	67	0	0	25	0	0	0	0
PETRA	75	0	75	58	8	42	8	8	50	58	92	8	17	58	17	0	0	17

Table 4.19. Probability estimate of inadequacy (%) as a three day average using the twenty-four hour recall (24H RECALL) and weighed food record (PETRA) methods for energy (NRG), protein (PTN), carbohydrate (CHO), fat, iron (Fe), calcium (Ca), magnesium (Mg), phosphorus (P), zinc (Zn), vitamins A, E, B1, B2, B3, B12, C, D, and folate.

METHOD	NRG	PTN	CHO	FAT	Fe	Ca	Mg	P	Zn	VIT A	VIT E	VIT B1	VIT B2	VIT B3	FOLATE	VIT B12	VIT C	VIT D
24H RECALL	13.8	0	20.4	12.7	0	14.7	0	0	10.9	15.3	47.4#	0	0	7.8	0	0	0	0
PETRA	35.3#	0	41.7#	28.2#	0.6	28.2#	0.6	2.6	27.0#	39.9#	69.8#	2.6	5.2	30.8#	6.3	0	0	8.9

Those marked (#) depict an inadequate intake defined as a probability of 25% or greater (Gibson 1990).

Table 4.20. Food groups categorized by the Food Exchange System as a three day average using the twenty-four hour recall method.

SUB #	Starch/ Breads	Vegetables	Fruit	Milk	Meats	Fats
hp01	16.5	0.5	8.0	0.7	4.1	14.5
hp02	15.0	1.7	3.3	2.4	4.6	14.7
hp03	8.2	1.1	6.6	0.7	5.3	11.1
hp04	18.6	1.5	4.6	2.2	3.4	15.9
hp05	12.6	0.0	4.8	1.9	1.9	12.5
hp06	16.5	0.0	4.2	2.0	2.9	15.8
hp07	16.7	0.9	1.4	0.6	7.8	11.5
hp08	15.9	4.0	4.4	1.2	6.6	18.1
hp09	9.7	1.1	2.5	0.6	2.9	9.8
hp10	10.6	0.5	2.1	4.2	4.6	14.5
hp11	9.4	0.9	1.5	2.7	5.5	15.4
hp12	8.0	0.6	1.8	2.5	1.4	6.8
MEAN	13.1	1.1	3.8	1.8	4.3	13.4

No significant difference was found between the exchange categories for the two methods of dietary intake collection using a paired t-test.

Table 4.21. Food groups categorized by the Food Exchange System as a three day average using the weighed food record method.

SUB #	Starch/ Breads	Vegetables	Fruit	Milk	Meats	Fats
hp01	10.6	0.6	8.6	1.2	1.6	9.4
hp02	16.6	0.4	1.6	2.5	3.7	12.9
hp03	5.4	1.2	4.8	0.0	3.6	6.1
hp04	12.8	1.8	7.9	1.8	2.9	13.1
hp05	7.6	1.0	2.5	3.1	2.4	10.6
hp06	9.9	0.9	1.3	1.2	2.0	6.6
hp07	20.5	0.2	3.7	0.6	2.5	17.3
hp08	12.6	0.4	2.7	0.6	7.4	16.0
hp09	8.8	0.6	3.9	1.5	3.7	16.2
hp10	12.7	1.6	2.0	3.0	5.7	16.8
hp11	9.6	0.0	1.0	1.8	6.4	9.6
hp12	11.9	0.0	2.0	1..5	3.1	9.4
MEAN	11.6	0.7	3.5	1.6	3.8	12.0

No significant difference was found between the exchange categories for the two methods of dietary intake collection using a paired t-test.

5. DISCUSSION

This is the first study which examined the nutritional status of a sample of children (n=12), seven to thirteen years of age, with fetal alcohol syndrome. The purpose was to collect nutrition, body composition, and energy expenditure information in children with FAS and to examine if relationships exist between the heights, weights, and the body composition in these children and a negative energy balance, i.e., does an increased energy expenditure and/or inadequate dietary intake relate to their retarded growth? Anthropometric and bioelectric impedance measurements were performed to determine total body fat. Resting energy expenditure was measured using indirect calorimetry and predictive equations based on age, sex, weight, and height. The dietary intakes of the children were determined by two methods: three-day weighed food records and three twenty-four hour recalls.

Criteria for diagnosis of FAS includes retarded growth. Head circumference below the third percentile and height and weight below the tenth percentile are required for a diagnosis of FAS, although some of these characteristics have been shown in studies to disappear as the child ages (Streissguth et al. 1991, Streissguth et al. 1985, Wekselman et al. 1995). Of the 12 subjects in the current study, 4 remained on or below the 10th percentile for height, 8 were below the 10th percentile for weight, and 7 remained on or below the 3rd percentile for head circumference. Therefore, the majority of this sample of children continued to suffer from growth retardation. Percent body fat determined from skinfolds were compared to a healthy population the same sex and Tanner stages with all group mean z-scores being negative. Thus, the sample of children in this study had characteristics that suggest physiological abnormalities or nutritional deficiencies. Another purpose was to compare methods for determining body composition. Current bioelectrical impedance predictive equations developed for children in the literature were found to be inappropriate for this clinical population. No significant differences were found between measured REE and REE predicted from equations based on age, sex, weight, and height. Dietary intakes collected using the twenty-four hour recall method were determined to be adequate for all nutrients analyzed, with the exception of possibly vitamin E. Dietary intakes determined by the weighed food record method which used a portable tape recording scale were not different from the twenty-four hour recall method, yet the use of the scale was cumbersome for the subjects and their caregivers. The majority of this sample of children with FAS continued to show growth deficiencies and low total body fat despite an adequate diet (with the exception of vitamin E) and metabolic rates were similar to that predicted for their age, sex, weight, and height.

5.1 Subjects and Study Protocol

The number of subjects that data was collected on was below the goal of 15-20, being 12 in total. The researcher (HD) was not permitted to contact any subjects until the ABCDC reached the family and consent was given. Therefore, it was difficult to determine reasons for non-response. For those that replied and later refused to participate, the reasons given were that they were too busy, the child had been moved to another foster home or adopted, or that their child was "okay now". The age range for participation was to be those children under thirteen years of age since it was desirable to have the child dependent on the caregiver for all nutrition consumed. As the child becomes adolescent, less reliance on the caregiver for meal preparation occurs (Eck et al. 1989). The age range was expanded up to 14 years of age to include as many subjects as possible. This did not pose a problem because these children (n=2) continued to be dependent on their caregiver for all meals.

Improvement of the recruiting process could possibly be accomplished by contacting Native groups, such as health centres and schools on reserves, due to the high incidence of FAS in northern Saskatchewan. Advertisement of the study with the cooperation of Chief and Council on reserves would be better received by the communities. Other avenues would include contacting social services, Indian Child Family Services, and alcohol abuse groups. This syndrome, however, has a sensitive nature and often is kept confidential; therefore, these suggestions may not be plausible.

Murphy et al. (1988) suggested that in studies with limited time and/or resources to assess a child's physical fitness, a parent's response to a single multiple choice question can provide a useful estimate of a child's fitness (as measured by maximal volume of oxygen consumed). There was a large subject burden in the current protocol; therefore, physical activity was assessed by a few questions posed to the caregiver. Goran et al. (1997) infer that children with greater fat mass spend less time in recreational physical activity. If the opposite were true, the majority of these children should have scored at least "high" on the question posed to the caregivers, which was not the case (Table 4.1). Due to the varied response, no conclusion can be made regarding the physical activity of this population group as compared to "normal" children. A comment that was made on more than one occasion was that it was difficult for the caregiver to compare their child with others of similar age because their child often associated with children of younger age, perhaps due to their mental capacity.

The comments recorded by the caregivers on the types of activities these children participated in were varied. Reponses such as "ride 'em toys", "cricket", "watching TV", "bowling", "frog hunting", "trampoline", "trapping", "fishing", "snowmobiling", "leading horses", and "catching mice" were provided. The activities the children were involved in depended on the environment they lived in, i.e., reserve, farm, city, etc. Therefore, this sample of children represented a heterogeneous population. The questionnaire employed has not been validated in this population; however, one cannot rule out differences in physical activity in children with FAS versus "healthy" children based on the results.

5.2 Anthropometry and Body Composition

5.2.1 Anthropometry

By the anthropometrical criteria for the diagnosis of FAS, only one of the 12 subjects (hp01) would be diagnosed with full-blown FAS at the time of the study (Table 4.2). The others seemed to have "grown out of it", specifically regarding height, where only 4 subjects remain on or below the 10th percentile. However, only 2 subjects (hp02 and hp04) did not meet any of the anthropometrical criteria. In reference to weight, subject hp03 was the only subject above her calculated ideal weight for height (Table 4.3) and was the only child above the 50th percentile for weight at the 75th percentile (Table 4.2). This was also demonstrated when the children where compared to other Aboriginal children; that is, the Aboriginal children in the study did not improve significantly in growth parameters. Subject hp03 was the only subject above average for weight (Table 4.5). Perhaps this was a direct result of subject hp03's diet. The majority of the foods that this child consumed were highly processed, ready-to-eat foods. Another contributing factor could be genetics, which was not looked at.

Although each subject was diagnosed with FAS at some point during his/her lifetime, this may not be the diagnosis if evaluated now. This was consistent with the findings of Egeland et al. (1995) who determined the ideal ages for diagnosis to be 3-10 years of age. In the current study, both height and weight mean z-scores were below average with weight more severely affected than height. The heights of children in this study group were compared with Canadian Native children and, again, the z-scores were negative (with the exception of a 1934 study [K.E.Kidd, as cited in Helmuth 1983], z-score = 0.38 ± 1.57) as illustrated in Table 4.6. Height, weight, and percent body fat (using both Slaughter equations) were found to be below "normal" (Table 4.9). This was reflected also in the skinfold measurement where the majority of subjects were below the 50th percentile for both the tricep and subscapular skinfolds (Table 4.8).

When making a comparison of the tricep skinfolds to urban native Americans in Minneapolis (Johnston et al. 1978), only 2 of the subjects (hp03 and hp11) had a greater skinfold value. As well, when subscapular skinfolds were compared to this group, only 3 of the subjects (hp03, hp04, and hp11) had a greater skinfold measurement. This was in coherence with the previously mentioned results of subject hp03's increased weight.

The height, weight, head circumference, and skinfold growth charts used were derived from populations over 25 years ago. The head circumference growth charts were developed from 236 children of middle and upper class, predominantly of Northern European extraction who were followed longitudinally during the years 1933 to 1966 (McCammon 1970). The data used to develop the height and weight growth charts was collected between 1929 and 1974. Consideration must be taken into account when using standards mostly derived from a Caucasian population due to the large percentage of Aboriginal children in this study. However, when this sample group was compared to children studied in more recent Aboriginal populations, the children with FAS remained below average for height and weight.

5.2.2 Bioelectrical Impedance Analysis

Walker et al. (1990) performed anthropometrical and BIA measurements on 129 stunted and 32 non-stunted children (9-24 months) and found that resistance was significantly higher in stunted children suggesting there were differences in body composition and/or shape. This difference in body composition was hypothesized for this study group. Houtkooper et al. (1992) developed predictive equations for FFM using healthy Caucasian children and youth ages 10-19 years; however, they stated that the effects of extreme fatness or leanness, ethnicity, alteration in hydration, premeasurement exercise, and eating may increase the magnitude of prediction errors over the SEE (standard estimate of error) values found in their study. These factors may have influenced the results when the equation was used with this population group.

Several predictive equations previously validated in children were used to predict percent body fat. The R^2 values ranged from 0.0208 to 0.494 (Table 4.10); therefore, there was no significant correlation between the BIA and Slaughter skinfold equations. The R^2 values examining a possible correlation between percent body fat values estimated using skinfold and BIA data were low. One would expect an R value of greater than 0.8 for a significant correlation to be present; therefore, an R2 value of 0.64 or greater is required. Other studies have produced R values of greater than 0.9 when examining correlations of methods (Azcue et al. 1996, Gregory et al. 1991). The original objective was to compare different methods of measuring body fat; therefore, several BIA equations were used. These equations were not employed on the population from which they were derived; however, in a more closely fitted population such as Cordain et al. 1988, Deurenberg et al. 1989(b), and Houtkooper et al. 1989 where children of similar age were studied, each of these equations produced a value of percent body fat either below 2% or greater than 50% body fat.

Further research must be carried out in this population group for a regression equation to be derived.

5.3 Resting Energy Expenditure

Several studies have been conducted comparing energy expenditure in lean and obese children. DeLany et al. (1995) found no significant difference in RMR of prepubertal children with similar FFM values. Maffeis et al. (1991) found no significant difference in BMR of prepubertal children. However, Bandini et al. (1990) found that BMR was significantly higher in obese adolescents. Goran et al. (1994) stated that RMR in adults is influenced by FFM and FM and is significantly higher in men than in women. They found this to be true for young boys as well. They determined that FFM, gender, and FM are the important determinants of RMR in children. Bogardus et al. (1986) believe that much of the difference in RMR between people can be explained by variations in total lean body mass. Soares-Wynter and Walker (1996) compared measured RMR in stunted and non-stunted children and found that the stunted children had significantly lower RMR, but not after controlling for lean body mass (LBM) suggesting that the stunted children's smaller LBM accounted for the lower RMR.

In the children participating in the current study, no significant difference was found between measured REE and predicted REE (Table 4.11); therefore, these children did not have accelerated metabolic rates. This was unlike other clinical populations, such as children with cerebral palsy (CP) (Azcue et al. 1996) and Down syndrome (Luke et al. 1994), where their RMR was found to be lower than that of the general population. The short stature and low IQ seen in children with Down syndrome is comparable to that of FAS, however Down syndrome children tend to be heavier than reference children.

The hypothesis of hypermetabolism in children with FAS was based on the children being slender in appearance; however, hypermetabolism was not explained by the indirect calorimetry result. Any errors that occurred in the measurement of REE would typically result in an overestimate of REE due to the restlessness of the subjects during the measurement. If the overestimate was corrected, this would further decrease the total energy expenditure values. Therefore, another approach which captures the free-living individual may give a better estimate of TEE. An example of such a technique would be the doubly labeled water technique. To determine the effect of medication on REE, such as Ritalin, a study measuring REE while the subjects are on and off medications could be conducted.

The REE measured for subject hp01 was half of what was predicted (Table 4.11). The caregiver did not want to subject the child to another measurement; therefore, one can only speculate on the reason for such value. The most obvious source of error would be the calibration of the equipment used. One could hypothesize that the subject did not reach a "true" steady state. The researcher (HD) observed the subject to be "petrified" by the testing process and therefore remained still throughout the during of the testing resulting in an almost immediate steady state.

Respiratory quotients (RQ) values ranged 0.85 - 1.00 with a mean RQ of 0.95±0.05. These values are high for fasted individuals, thus there could possibly be an abnormality that suggests that these children take longer to start metabolizing fat stores or perhaps they have larger glycogen stores.

5.4 Dietary Intake

5.4.1 Twenty-four Hour Recall

The twenty-four hour recall method has been used to analyze nutrient intakes of children (Whiting et al. 1995). Caregivers of the children were asked to complete a twenty-four hour recall with the assistance of their child when possible. Only 2 of the subjects were below 67% of their RNI for more than one nutrient (Table 4.16). Subject hp07 had a low intake of calcium, zinc, and vitamins A and E, perhaps due to a low intake of milk products. Subject hp12 had a low intake of energy, carbohydrate, fat and vitamins E and B3. This may attributed to the low energy intake over those 3 days (57% of his RNI). Subject hp12 was taking the drug ritalin at the time of consumption. A possible side-effect of this drug is appetite suppression (Efron et al. 1997, Stein et al. 1996); however, this effect is short term and these children have been taking this medication long-term. The only other nutrient with a low intake was vitamin E which was low in 5 of the subjects. This can be explained by the inadequacy of the vitamin E analysis provided by Nutritionist IV. Using the twenty-four hour recall method, more than half the group did not meet their RNI for energy, carbohydrate, and vitamin E (Table 4.18). A dietary study of Hopi Native American elementary students demonstrated RDAs were met for all vitamins and minerals with the exception of vitamin D, calcium and zinc (Brown & Brenton 1994). When nutrient intakes of American children (2 to 10 years of age) were assessed by Albertson et al. (1992), more than 50% of the population had intakes of calcium, vitamin B6 and zinc below the RDA level. Physical activity, nutrient intake, and body composition in 10 year old French children were investigated and they concluded that active children consumed significantly more energy than their less active peers (Deheeger et al. 1997).

Findings from the current study showed an inadequate intake (defined as 25% or greater) for vitamin E only (Table 4.19) based on the probability estimate of inadequacy. Lesser risk (PEI greater than 15%) was observed for vitamin A and carbohydrates. Similar results have been documented in children. Evers & Hooper (1995) studied nutrient intake of 7 to 9 year old children in economically disadvantaged communities in Ontario and discovered that the median nutrient intakes exceeded the RNI's with the exception of energy, calcium, and vitamin A. Whiting et al. (1995) analyzed the dietary intakes of children age 8 to 15 years living in Saskatoon and inadequate intake was observed for vitamin A and zinc, with girls also showing an inadequate intake for calcium, folate, iron, and vitamin B2. Lesser risk was observed for folate and calcium in boys and vitamin B1 in girls.

The subjects' intakes according to food exchanges using the Food Exchange System are shown in Table 4.20. The Vegetable and Fruit groups were combined to modify the food groups similar to that of Canada's Food Guide to Healthy Eating (Canada 1992b). The similarities in serving sizes between the Food Exchange System and Canada's Food Guide to Healthy Eating are listed.

Milk Products:

1 cup milk (exchange) vs. 1 cup milk (Can.)

¾ cup yogurt (exchange) vs. ¾ cup yogurt (Can.)

Vegetables & Fruit:

1 small to medium fruit (exchange) vs. 1 medium fruit (Can.)

½ cup canned or fresh fruit (exchange) vs. ½ cup fresh, frozen, canned fruit (Can.)

½ cup cooked vegetables (exchange) vs. 1 medium vegetable
½ cup juice (exchange) vs. ½ cup juice (Can.)
1 cup raw vegetables* (exchange) vs. ½ cup fresh, frozen, canned vegetables (Can.)
*corn, peas, potatoes, and winter squash are considered a starch choice
The recommended number of servings for the Vegetables & Fruit group is 5-10 servings per day. The recommendation for children 4-9 years old is 2-3 servings of Milk Products per day while it is recommended that youth ages 10-16 years consume 3-4 servings per day. Ten of the twelve children did not meet their recommendation of Milk Products. The majority of subjects did not consume at least 5 servings of vegetables and fruit as a three day average. This was also the finding when the weighed food record method was used. This was consistent with the findings of Whiting et al. (1995). The mean number of servings of Milk Products in this sample was lower than that of the children studied in Whiting et al. (1995), however, the Vegetables & Fruit group mean servings were higher in the current study when the twenty-four hour recall method was employed.

5.4.2 Three-day Weighed Food Record

In examining Tables 4.12, 4.13, 4.14, and 4.15 the weighed food record consistently provided nutrient values lower than those derived from the twenty-four hour recall method. Presently, there are four methods to determine misreporting of dietary intake: monitoring weight, comparing energy intake to energy expended by doubly labeled water, 24-hour urinary nitrogen excretion, and using predetermined cut-off values. Goldberg et al. (1991) set cut-off values, derived from whole-body calorimeter and doubly labeled water measurements, that determine whether reported energy intakes are a plausible measure of the food consumed during the actual measurement period. These cut-offs are based on sample size and duration of measurements, and are expressed as a multiple of BMR. The cut-off value for n=1 and four days of dietary intake is 1.10 x BMR if BMR is measured, and 1.06 x BMR if BMR is predicted using the Schofield equations with 95% confidence limits (Goldberg et al. 1991). Ratios of energy intake to REE measured and BMR predicted were calculated. The only subject that fell below these cut-offs was hp03 when the weighed food record method was used. This suggests that her dietary intake was underreported, or perhaps she was losing weight. Change of weight was not determined in the subjects; however, the period of time the diet information was collected did not coincide with the day REE was measured, therefore monitoring weight was not warranted.

The weighed food record procedure was not as successful as the twenty-four hour recall method. For unknown reasons, a few of the records were incomplete, i.e., there was not enough information on the tape to detail a three day record. As well, the numbers on the console flashed extremely quickly at times, making it difficult for the recorder to determine the weight of the food. This may have been due to improper weighing technique, a faulty tape, or problems with the PETRA scale or console recording. Each PETRA scale was calibrated before use, therefore reducing the likelihood of error due to mechanical error. For these reasons, the three-day food record was not combined with the twenty-four hour recall data for further analysis. Furthermore, the RNI's were not met as well using the PETRA scales as when the twenty-four recalls were performed. This could be expected due to the difficulties of the collection of a complete three days. Six subjects did not meet two-thirds of their RNI's regarding two or more nutrients. Subject hp03 had a low intake of energy, carbohydrate, fat, calcium, zinc, and vitamins A, E, B3, and D. Incomplete data retrieval was a likely explanation for the overall low energy intake. Subject hp05 had a low intake of carbohydrate and vitamins E and B3. Subject hp06 had a low intake of energy, carbohydrate, fat, calcium, zinc, and vitamins A and E. Again, this was most likely due to a low energy intake. Subject hp07 had low calcium and zinc intake values and this may have been contributed to a low intake of milk products. Subject hp11 had a low intake of carbohydrate and vitamin E while subject hp12 had low vitamins A and E intake values. Using the weighed food record method, vitamin E was low in 6 of the subjects but this is likely attributed to the Nutritionist IV database.

More subjects did not meet their RNI's when using the weighed food record method (Table 4.18). More than half of the group did not meet their RNI's for energy, carbohydrate, fat, zinc, and vitamins A, E, and B3. The proportion of subjects not meeting the RNI's were higher in the weighed food record method except for those nutrients where all subjects met or exceeded their RNI's such as protein and vitamins B12 and C. Inadequate intake was observed for energy, carbohydrate, fat, calcium, zinc, and vitamins A, E, and B3 (Table 4.19). Once again, the improper use of the scale and recording procedure could explain the results.

The nutrient analysis is only as good as the nutrition database used. Nutritionist IV did not adequately analyze for vitamin E. The 1990 recommended nutrient intakes (RNI's) are derived from the average nutrient intake plus two standard deviations. This is strictly a recommendation and by no means is the requirement for all of these children. Presently, Dietary Reference Intakes are in the development process; however, there is no official consensus on how to utilize these references at this time, therefore, RNI's were used as the recommendation. The food groups as recommended by Canada's Food Guide to Healthy Eating are also general guidelines to be used by the public. Each child is different and requires different nutrients in differing quantities.

This sample group appeared to have intakes of nutrients that were adequate but remain below average for height, weight, and percent body fat. Their diet proved to be "adequate" according to RNI's , but perhaps this is not a "healthy" diet. We do not know the requirements of nutrients for individuals with FAS. Specific nutrients may be higher or lower than that of the "normal" population. After evaluating the children's diets according to the Milk and Vegetable & Fruit groups in Canada's Food Guide to Healthy Eating, it was apparent that their diets lack variety. Also, the children may be intaking adequate nutrients but the bioavailibility of these nutrients may be hampered; therefore, the children would not be utilizing the nutrients needed effectively.

5.5 Limitations

Limitations of a study must be addressed. First, the method of the recruitment of subjects was limiting. No contact was permitted until the caregiver agreed to participate. This led to a small sample group; therefore, caution must be used when making conclusions in this study group and not to generalize to the FAS population. Second, the BIA method did not work in this study group, at least with the current equations in the literature. Only one REE measurement was taken, and therefore it was difficult to interpret suspicious values such as that measured for subject hp01. The physical activity questionnaire led to no obvious trend. The diet analysis was hampered for two reasons; the Nutritionist IV software program did not analyze for vitamin E appropriately, and the PETRA scale technique was not performed properly by all participants. The Nutritionist IV vitamin E information is developed from the United States Department of Agriculture Handbook No. 8, Composition of Foods, Raw, Processed, Prepared. This handbook does not provide values for vitamin E for all foods; therefore Nutritionist IV has an incomplete database in regards to vitamin E. This is the first study in the College of Pharmacy and Nutrition at the University of Saskatchewan to use the Nutritionist IV database and, therefore, this discrepancy was not realized until now.

Future research would include possible solutions to these limitations. A nation-wide study would increase the sample size. Several measurements of REE could possibly confirm our results. Total energy expenditure could be measured using the doubly labeled water technique, therefore analyzing all components of energy expenditure. A more thorough assessment of physical activity could be undergone. With a larger sample size, one could validate the BIA technique for this population. Other body compartments such as lean body mass and total body water could be investigated. Finally, further diet investigation is encouraged.

5.6 Conclusions

The majority of the children in the sample had some indicator of growth retardation present, i.e., remained on or below the 10th percentile for height and weight and the 3rd percentile for head circumference. All z-scores for height, weight, and percent body fat were negative (with the exception of the 1934 study [K.E.Kidd, as cited in Helmuth 1983] for height). The current BIA equations used to estimate percent body fat were inappropriate for this population. No significant difference was found between REE measured and REE predicted.

The diet of this sample was adequate according to group mean RNI's with the exception of vitamin E which was most likely due to the nutrition database used and thus was not a true inadequacy. As well, the diet of the sample of children followed the recommendation of calories contributed to overall energy intake provided by the macronutrients, i.e., 50-60% of total energy contributed from carbohydrates, 13-15% from protein, and 30% from fat (Canada 1990). The nutrient intakes measured by the two methods of diet collection leaned towards a significant difference and one would expect to see a significant difference with a larger sample size.

In conclusion, the children with fetal alcohol syndrome who participated in this study continued to have low body fat and growth deficiencies despite an apparent adequate diet. As well, the metabolic rates were similar to that predicted for their age, sex, and weight. This group was heterogeneous with the only common factors being their age and an FAS diagnosis at some point during their lives. The severity of FAS varied, along with their living environments and medication use. Future research should involve stricter criteria such as similar medication use or heights and weights falling under a specific percentile. Therefore, more investigation is required to determine the reasons for the growth impairment in children with FAS.

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