

CALCIUM AND VITAMIN D
INTAKE OF CHILDREN AND ADOLESCENTS WITH ASTHMA

By

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By

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This thesis is dedicated to children and adolescents with asthma with the hope that through research the quality of their lives will be improved.

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LIST OF ABBREVIATIONS

AI – Adequate Intake

BDP – beclomethasone dipropionate

BMC – bone mineral content

BMD – bone mineral density

BM – bone mass

BMI – body mass index

BUD - budesonide

CaSR – calcium sensing receptor

CF – cystic fibrosis

CSFII – Continuing Survey of Food Intakes by Individuals

d - day

DBP – vitamin D-binding protein

DPI – dry powder inhaler

DRI – Dietary Reference Intake

EAR – Estimated Average Requirement

EIA – exercise-induced asthma

FEF_{25-75%} – forced expiratory flow at 25-75% forced vital capacity

FEV₁ – forced expiratory volume in 1 second

FFQ – food frequency questionnaire

FVC – forced vital capacity

g – grams

GI – gastrointestinal

IOM – Institute of Medicine

IU – International Unit

kcal – calories

LTRA – leukotriene receptor antagonist

MDI – metered dose inhaler

mcg – micrograms

mg – milligrams

NAEPP – National Asthma Education and Prevention Program

NHANES – National Health and Examination Survey

NHLBI – National Heart, Lung, and Blood Institute

nmol/l – nanomoles per liter

PBM – peak bone mass

PEF – peak expiratory flow

PFT – pulmonary function test

PTH – parathyroid hormone

RDA – Recommended Dietary Allowance

SD – standard deviation

UF – University of Florida

UL – Tolerable Upper Intake Level

U.S. – United States

USDA – United States Department of Agriculture

V_{50} – airflow at 50% of vital capacity

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Asthma is a chronic inflammatory disease of the airways that currently affects 6.1 million children under the age of 18 years. Parents of children with asthma commonly avoid or eliminate foods from their children's diets in an attempt to reduce the onset of asthmatic symptoms. Milk and dairy products are the foods most often reported to be eliminated or avoided, although studies do not support a connection between milk intake and a reduction in pulmonary function. Inadequate milk and dairy products consumption could have an adverse effect on the intake of calcium and vitamin D, nutrients associated with favorable bone growth and development. Other factors that may affect bone health and future risk for osteoporosis in this population include restricted physical activity and corticosteroid use. No studies have examined the calcium and vitamin D intake of children and adolescents with asthma, which was the purpose of this study. It was hypothesized that asthmatic children and

adolescents do not meet the adequate intake (AI) for calcium and vitamin D and that they consume less calcium than what has been reported in national survey data from children of the same age. Subjects with asthma were recruited from the Pediatric Pulmonary Center Asthma Clinic and the UF Research Asthma Lab. Three-day food records were collected and analyzed for calcium and vitamin D intake using Food Processor. Calcium and vitamin D intake was compared to the AI and to data for an age-matched reference population (i.e., Continuing Survey of Food Intakes of Individuals, CSFII). The 3-day mean dietary calcium intake for the 1 to 3 year old group was significantly less ($p = 0.001$) than that of the age-matched reference population. The 3-day mean dietary calcium intake for the 9 to 18 year old age group was significantly lower than the AI ($p = 0.02$). Vitamin D intake met the AI for all age groups, and no differences were detected between the vitamin D intake of subjects with asthma compared to the respective age group using the CSFII database. Dietitians and other healthcare providers should encourage adequate consumption of milk and dairy products in children and adolescents with asthma with the goal of ensuring adequate calcium intake and reducing future risk for osteoporosis in this vulnerable population.

CHAPTER 1 INTRODUCTION

Asthma is a chronic inflammatory disease of the airways (1-3) that currently affects 6.1 million children under the age of 18 years (1). It is the leading serious chronic illness among children (4), and recent increases in asthma prevalence have been steepest among the young (5).

A potential concern for pediatric asthma patients is the future risk for osteoporosis. Adequate intake of calcium and vitamin D and regular physical activity are essential for normal growth, development, and maintenance of bone. Inadequate calcium and vitamin D intake, limited physical activity, and corticosteroid use are important factors that can affect bone formation and bone health in children with asthma, thus affecting bone mineral density (BMD), stature, achievement of peak bone mass (PBM), and risk for osteoporosis later in life. Several research groups (2,6-8) have reported that avoidance or elimination of dairy products (6,7), low physical activity (8,9), use of oral corticosteroids (2), and long-term use of inhaled corticosteroids (2) are seen among children and adolescents with asthma. Inadequate milk and dairy products consumption could have an adverse effect on the intake of calcium and vitamin D, nutrients associated with favorable bone growth and development. The calcium and vitamin D intake of pediatric patients with asthma has not been reported previously in the literature, and it is possible that due to avoidance or elimination of milk and dairy products from their diets, their intake of these nutrients are less

than the AI levels set by the Institute of Medicine (IOM). Evaluating the adequacy of calcium and vitamin D intake in the pediatric asthma population will help to identify whether there is a need for targeted intervention strategies to improve the intake of these nutrients with the goal of reducing the risk for osteoporosis later in life.

Hypotheses

It was hypothesized that children and adolescents with asthma 1) do not meet the AI for calcium and vitamin D 2) consume less calcium than what has been reported in national survey data from children of the same age, and 3) consume a different amount of total milk and dairy products and specific types of dairy products than reported in national survey data from children of the same age.

Specific Aims

The specific aims of this study were to determine calcium and vitamin D intake of children and adolescents with asthma using a 3-day food and supplement diary and to compare their intake of these nutrients to the AIs for each age category (i.e., 1 to 3, 4 to 8, and 9 to 18 years) and to compare calcium intake of our pediatric asthma population to survey data from the 1994 to 1996 and 1998 CSFII. Another specific aim was to compare dairy product consumption of our pediatric asthma population to survey data from the 1994 to 1996 and 1998 CSFII.

CHAPTER 2 BACKGROUND AND LITERATURE REVIEW

Asthma

Overview

Asthma is a reversible, recurrent obstructive lung disease (3) that currently affects 6.1 million children under the age of 18 years (1). Approximately 9 million U.S. children under the age of 18 years have been diagnosed with asthma, and boys are more likely to be diagnosed with asthma than girls (10). In 2002, 4.2 million children under the age of 18 years suffered an asthma attack or episode (1,10). It is the leading serious chronic illness among children (4,11), and recent increases (55% from 1980 to 1996) (4) in asthma prevalence have been steepest among the young (5). Asthma is the third leading cause of hospitalization among children under the age of 15 years and causes 14.6 million lost school days annually, making it the leading cause of school absenteeism attributed to chronic conditions (1).

The working definition of asthma developed by the National Heart, Lung, and Blood Institute (NHLBI) is a

chronic inflammatory disorder of the airways in which many cells and cellular elements play a role, in particular, mast cells, eosinophils, T lymphocytes, neutrophils, and epithelial cells. In susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and cough, particularly at night and in the early morning. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment. The inflammation also causes an associated increase in the existing bronchial hyperresponsiveness to a variety of stimuli. (2, p.11)

Recent observations indicate that reversibility of airflow obstruction may be incomplete in some individuals with asthma (12).

Etiology

Numerous factors may play an important role in the etiology of asthma, some of which may increase the risk for developing asthma and others which may provide protection against asthma. According to the NHLBI, atopy, which is an IgE-mediated allergic response to common aeroallergens, is the strongest identifiable factor associated with increased risk for developing asthma (13).

There also is a strong genetic component to the development of asthma.

Therefore, the propensity for developing asthma is influenced by genetic and environmental factors and interactions among these factors.

Factors that may decrease the risk for developing asthma include exposure to various aeroallergens early in life, certain early childhood bacterial and viral infections (i.e., pneumonia, respiratory syncytial virus, *M. tuberculosis*, measles, hepatitis A, etc.), exposure to other children (e.g., presence of an older sibling and early enrollment in childcare), less frequent use of antibiotics, farming environment (i.e., contact with barn animals), breast feeding (breast milk protection), season of birth (i.e., spring), and nutrition (e.g., intake of polyunsaturated fatty acids, omega-3 fatty acids, etc.) (2,3,14,15).

Pathophysiology

In general, asthma occurs as a result of the interaction between genetic predisposition and certain environmental triggers that result in peribronchial inflammation (3). The major pathophysiologic features of asthma include “denudation of airway epithelium, collagen deposition, edema, mast cell

activation, and inflammatory cell infiltration” (2, p.11). Inflammation results in bronchial hyperresponsiveness, airflow limitation, respiratory symptoms, acute bronchoconstriction, airway edema, mucus plug formation, airway wall remodeling, and disease chronicity (13). Bronchial hyperresponsiveness, an exaggerated bronchoconstrictor response to a stimulus such as an allergen or irritant, occurs as a result of thickening of the airway wall (13,14). The chronic, persistent airway inflammation that occurs in asthma is caused by activation of recruited and resident immune cells that initiate a persistent level of cell damage and an ongoing repair process (13,14).

During an asthma exacerbation or episode, the airways become narrow as a result of a series of events that include swelling of the airway lining, tightening of the airway muscles, and increased secretion of mucus in the airway (1). As a result, individuals experience coughing, wheezing, and difficulty breathing (16). Although asthma symptoms are often triggered by allergens such as a pollen, mold, animal dander, feathers, dust, food, or cockroaches, it also can be triggered by respiratory infections, colds, vigorous exercise, cold air, sudden temperature changes, cigarette smoke, excitement, stress, or exercise (1). Asthma episodes or exacerbations may resolve spontaneously or following treatment with medication (14).

Diagnosis

Important information to gather in order to diagnose asthma in children includes onset and history of symptoms; description of a typical episode; conditions associated with onset of symptoms; type and pattern of symptoms; perception of severity; physical examination of the head, neck, upper respiratory

tract, chest, and skin; hyperexpansion of the thorax; wheezing during normal breathing; prolonged phase of forced exhalation; increased nasal secretion; mucosal swelling; nasal polyps; and atopic dermatitis/eczema (3,13,14). In children 5 years of age and older, diagnostic tests such as spirometry and bronchoprovocation challenge are used in addition to the history and physical examination to diagnose asthma. In children younger than 5 years, it is difficult to objectively measure lung function using spirometry, so diagnosis is primarily based on symptoms, physical examination, and response to therapy (15).

Spirometry, or pulmonary function testing (PFT), is the best method for evaluating lung function in patients who may have asthma. Spirometry can detect several physiological abnormalities that occur in asthma, such as decreased airflow and lung volumes, increased work of breathing, increased airway responsiveness to stimuli, and variability of airway flow (14). The results of PFT are used to diagnose and categorize the severity of asthma in children over 5 years of age and adults. These include forced expiratory volume in 1 second (FEV_1), ratio of FEV_1 to forced vital capacity (FEV_1/FVC), and forced expiratory flow during the middle portion of exhalation ($FEF_{25-75\%}$). Forced expiratory volume in 1 second is defined as the volume that is exhaled in the first second in liters per second (3). This measurement provides pulmonologists with information about large to medium sized airways (3). Forced vital capacity is the maximum volume of air that can be exhaled after maximal inhalation (14). The ratio of FEV_1 to FVC measures general airway obstruction (3). Forced expiratory flow during the middle portion of exhalation, is the average flow of air during the

middle portion of the FVC and provides pulmonologists with information about the small airways (3). In children 5 years of age and older, an FEV₁ below 80% of predicted is diagnostic for asthma (2). An increase in FEV₁ of more than 12% following use of a short-acting bronchodilator also is diagnostic for asthma (2,3).

Another method that can be used to diagnose asthma is a bronchoprovocation challenge. This method is useful for evaluating children 5 years of age and older who have a chronic cough and/or vague exercise intolerance, but do not display a change in FEV₁ in response to short-acting bronchodilators (14). A bronchoprovocation challenge is performed by slowly administering a low dose of a challenging agent (i.e., an irritant, bronchoconstrictor chemical, an antigen, etc.) into the airway until a 20% decrease in FEV₁ from baseline is achieved or the highest predetermined dose of challenging agent is reached (14).

Asthma is classified as mild intermittent, mild persistent, moderate persistent, or severe persistent. Severity is based on the frequency and occurrence of symptoms during the day and night in infants and children 5 years of age and younger (2). In children over 5 years of age and adults, the degree of asthma severity is based on frequency and occurrence of symptoms during the day and night as well as FEV₁ measurements (2).

Monitoring

Asthma can be monitored by PFTs, airway challenge, peak flow monitoring, asthma exacerbation history, signs and symptoms, quality of life, pharmacotherapy, patient-provider communication, and/or patient satisfaction (2). The methods used to monitor asthma are spirometry and peak flow

monitoring. Unfortunately, because spirometry and peak flow monitoring are largely effort dependent, it is difficult to objectively monitor lung function in infants and children under 5 years of age (15). As a result, monitoring asthma in this age group is largely based on asthma symptoms, the need for a rescue bronchodilator and oral corticosteroid therapy, and emergency room visits or hospitalizations (15).

Pulmonary Function Testing (Spirometry). Spirometry is often conducted every 3 months during a regular pulmonary visit. A change of 1 standard deviation (SD) in any of the pulmonary function measures (i.e., FEV₁, FEV₁/FVC ratio, and FEF_{25-75%}) is considered significant (14). If the change in one or more of the pulmonary function measures is significant, adjustments to the type or dose of medication(s) are made.

Peak Flow Monitoring. Peak flow monitoring is another way to monitor asthma and aid in its management. Peak expiratory flow (PEF) is a measure of the most rapid flow of air during a forced expiration and it provides pulmonologists with information about the function and condition of larger airways (3). Compared to spirometry, peak flow monitoring is considered to be a less technological approach; however, it is an objective, quantifiable, reproducible, and sensitive measure of airway obstruction that changes dramatically during the early stages of an asthma exacerbation (2,3,14).

Asthma Management

Medical Management

According to the NHLBI, the goals of therapy in asthma control include minimal or no chronic symptoms during the day or night, minimal or no

exacerbations, no limitations on activities, no school missed by the child or work missed by the parent as a result of asthma symptoms, minimal use of short-acting inhaled β_2 -agonists, and minimal or no adverse effects from medications (2). Medical management of asthma focuses on decreasing airway inflammation to minimize airflow obstruction and asthma symptoms (2,15). There are two main categories of medications used to manage asthma: reliever medications and controller medications (Table 1).

Asthma is managed through a stepwise approach based on severity of the disease. The preferred and alternative treatments used to manage asthma in children 5 years and younger and older than 5 years are outlined in Tables 2 and 3, respectively. During an asthma exacerbation, the focus shifts toward controlling and relieving the smooth muscle airway spasms using reliever medications (14).

Reliever medications are short-acting bronchodilators such as short-acting β_2 -agonists and anticholinergics and anti-inflammatory medications, including systemic corticosteroids (2,3). These are used to relieve acute bronchoconstriction (3). They are effective in treating acute asthma exacerbations, but do not prevent an exacerbation from occurring (3). The short-acting β_2 -agonists can be administered in an oral, nebulized, or metered dose inhaler (MDI) form. Anti-inflammatory medications, such as systemic or oral corticosteroids, also are used to relieve asthma symptoms; however, they are not intended for daily use and are reserved for acute asthmatic episodes (3). Long-

Table 1. Medications used to treat or prevent asthma symptoms.

Medication Category	Mechanism of Action	Examples
<u>Reliever Medications:</u>	Use: treatment of acute asthma exacerbations	
Short-acting β_2 -agonist	Dilate airways by relaxing bronchial smooth muscle	Albuterol (Ventolin [®] , Proventil [®]), Pirbuterol (Maxair [™] Autohaler [™]), Bitolterol, Levalbuterol, Salmeterol (Serevent [®])
Anticholinergic	Dilate airways by relaxing bronchial smooth muscle	Ipratropium (Atrovent [®])
Systemic (oral) corticosteroid	Reduce airway inflammation	Prednisone, prednisolone, methylprednisolone
<u>Controller Medications:</u>	Use: long-term control of asthma	
	Reduce frequency of acute asthma exacerbation	
Inhaled Corticosteroid	Reduce airway inflammation Decrease transport of fluid across the capillaries Decrease mucus production	Fluticasone (Flovent [®]), Budesonide (Pulmicort [®]), Beclomethasone (Beclvent [®] , Qvar [®] , Vanceril [®]), Flunisolide (Aerobid [®]), Triamcinolone (Azmacort [®])
Long-acting β_2 -agonist	Relieve airway constriction	Salmeterol (Serevent [®] discus [®]), Formoterol (Foradil [®])
Leukotriene modifier	Decrease inflammation by reducing the production or blocking the action of leukotrienes	Montelukast (Singulair [®]), Zafirlukast (Accolate [®]), Zileuton

Sources: (1-3,17)

Table 2. Long-term control medications for infants and children with asthma 5 years of age and younger.

Asthma Severity Classification	Long-term Control Medications	
Severe persistent	<u>Preferred treatments:</u> High-dose inhaled corticosteroid and long-acting inhaled beta ₂ -agonist	<u>If needed:</u> Oral corticosteroid
Moderate persistent	<u>Preferred treatments:</u> Low-dose inhaled corticosteroid (medium-dose, if needed) and long-acting inhaled beta ₂ -agonist or, Medium-dose inhaled corticosteroid	<u>Alternative Treatments:</u> Low-dose inhaled corticosteroid (medium-dose, if needed) and leukotriene receptor antagonist or theophylline
Mild persistent	<u>Preferred treatment:</u> Low-dose inhaled corticosteroid	<u>Alternative Treatments:</u> Cromolyn or leukotriene receptor antagonist
Mild intermittent	No daily medication needed	

Source: (2)

term use of these medications should be avoided due to the side effects associated with them (3).

Controller medications aid in long-term control of asthma and are used to reduce peribronchial inflammation and frequency of acute asthma exacerbations (3). They are taken on a daily basis, regardless of symptoms, and are available in a nebulized, MDI, or dry powder inhaler (DPI) form (3). The controller medications include anti-inflammatory agents such as inhaled corticosteroids, leukotriene modifiers, mast cell stabilizing drugs, and long-acting

Table 3. Long-term control medications for children with asthma over 5 years of age and adults.

Asthma Severity Classification	Long-term Control Medications	
Severe persistent	<u>Preferred treatment:</u> High-dose inhaled corticosteroid and long-acting inhaled β_2 -agonist	<u>If needed:</u> Oral corticosteroid
Moderate persistent	<u>Preferred treatments:</u> Low- to medium-dose inhaled corticosteroid and long-acting inhaled β_2 -agonist	<u>Alternative Treatments:</u> Increase inhaled corticosteroid up to medium-dose range; or low-to-medium dose inhaled corticosteroid and leukotriene modifier or theophylline
Mild persistent	<u>Preferred treatment:</u> Low-dose inhaled corticosteroid	<u>Alternative Treatments:</u> Cromolyn, leukotriene receptor antagonist, nedocromil, or sustained release theophylline
Mild intermittent	No daily medication needed	<u>Severe exacerbations:</u> Oral corticosteroid

Source: (2)

bronchodilators (Table 1) (18). Inhaled corticosteroids, which are intended for daily use, are the most effective controller medications available; therefore they are the most preferred medication for asthma control when pharmacotherapy is indicated (2,3,18). Long-acting β_2 -agonists are not the preferred treatment for asthma, but may be used concomitantly with inhaled corticosteroids in moderate and severe persistent asthma to control nighttime and exercise induced symptoms (2,17). Similar to long-acting β_2 -agonists, leukotriene modifiers serve as an alternative to inhaled corticosteroids and can be used in combination with

inhaled corticosteroids for the treatment of mild persistent asthma (2). Although they are not as effective as inhaled corticosteroids, they are effective in controlling asthma in approximately two-thirds of the population with asthma (3).

The preferred medical therapy for children 5 years of age and younger includes low-dose inhaled corticosteroids, administered using a nebulizer, DPI, or a MDI with a holding chamber, with or without a face mask (2). Alternative therapies include cromolyn or a leukotriene receptor antagonist (LTRA) (2). A low-dose inhaled corticosteroid also is the preferred medication for children over 5 years of age and adults (2). Alternative therapies include cromolyn, LTRAs, nedocromil, or sustained release theophylline (2).

Environmental Management

Altering the indoor and outdoor environment is another way to aid in the management of asthma. Indoor environmental management may include decreasing or eliminating allergens, mold, insects (i.e., house dust mites, cockroaches), animals (domestic and pests), or irritants (i.e., tobacco, perfumes and scents, household cleaners, wood-burning fireplaces, heating and air conditioning), or controlling humidity in the home, school, and office (3). Outdoor environmental management may include decreasing or eliminating exposure to cold or exercise (3).

Dietary Management

Parents of children with asthma commonly avoid or eliminate foods from their children's diets in an attempt to reduce the onset of asthmatic symptoms (6). Milk and dairy products are the foods most often reported to be eliminated or avoided (6), although studies do not support a connection between milk intake

and a reduction in pulmonary function (19-21). Restriction or avoidance of milk and dairy products consumption could have an adverse effect on the intake of calcium and vitamin D, nutrients associated with favorable bone growth, development, and maintenance. Inadequate calcium and vitamin D intake, as well as restricted physical activity and oral corticosteroid use, place children and adolescents with asthma at risk for osteoporosis.

Calcium

Structure and Function

Calcium is the most abundant divalent cation in the human body, and 99% of calcium is found in bones and teeth, mainly in the form of hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) (22-25). The remaining 1% of calcium in the body is present in intracellular and extracellular fluids, muscle, and other tissues (22). In general, calcium plays a vital role in normal growth, development, and maintenance of bone and other calcified tissues (22). Other functions of calcium include blood clotting, nerve conduction and transmission, muscle contraction, enzyme regulation, hormone release, vision, mediating vascular contraction, vasodilation, and glandular secretion (22,24,25).

During bone formation and mineralization, calcium enters bone fluid from blood in the free, ionized form (i.e., Ca^{2+}) or as a calcium salt (i.e., $\text{Ca}_3(\text{PO}_4)_2$) (24). It is thought that during the process of bone mineralization, osteoblasts secrete a substance onto the bone surface to enhance calcium precipitation. Calcium, in the form of a calcium salt, binds to the bone surface and is laid down on collagen to form bone.

Within the intracellular compartment of the body, calcium acts as a second messenger to activate physiological responses (25). It functions in activating these physiological responses by binding to specific proteins such as calmodulin and troponin C (24). The binding of calcium to calmodulin activates enzymes that serve to function in smooth muscle contraction, glycogenolysis, and other functions. When calcium binds to troponin C, skeletal muscle contraction is stimulated (24).

In the extracellular compartment, which includes blood, lymph, and body fluids, calcium is present primarily in the free, ionized form, but also can be bound to albumin or globulin, or complexed to phosphate, citrate, or other anions (24,25). Extracellular calcium serves as a source of ionized calcium for the skeleton and cells (25).

Digestion and Absorption

In order for calcium to be digested, it must be in the free, ionized form. Calcium derived from food and supplements is in the form of insoluble salts, and calcium must be released from these salts for proper absorption (24). Absorption of calcium occurs throughout the small intestine by one of two processes. The first process, which takes place primarily in the duodenum and the proximal jejunum, is transcellular, saturable, and requires energy (i.e., active transport) (24,25). It is under homeostatic control, involves a calcium-binding protein, and is regulated by calcitriol ($1,25(\text{OH})_2\text{D}_3$), making it a vitamin D-dependent process (24,25). This route of absorption occurs at low (<400 mg) and moderate calcium intakes, during periods of growth, and during pregnancy and lactation (22,24). The second process of absorption, which takes place primarily in the

jejunum and ileum, is nonsaturable, passive, paracellular, not under homeostatic control, and dependent on the amount of calcium available in the intestinal lumen (22,24,25). As a result, the more dietary calcium ingested, up to a certain threshold, the greater the amount of calcium absorbed through this route (24). Approximately 25 to 35% of dietary calcium is absorbed through both of these routes combined. In addition, it is thought that a modest amount of calcium is absorbed in the large intestine through the release of calcium from bacteria after ingestion of some fermentable fibers such as pectin.

There are several dietary factors that may influence calcium absorption. Dietary components that increase the absorption of calcium include vitamin D, sugars such as lactose, sugar alcohols such as xylitol, inulin, fructooligosaccharides, and protein (23-25). The presence of food in the gastrointestinal (GI) tract also improves calcium absorption as does the calcium content of a meal (22,25). Dietary components that may decrease absorption of calcium include oxalate or oxalic acid; nonfermentable fiber such as the fiber found in wheat bran, hemicelluloses, phytate or phytic acid; divalent cations and other minerals such as magnesium or zinc; caffeine; unabsorbed dietary fatty acids; and a low dietary calcium/phosphorus intake ratio (22-26). This reduction in calcium absorption can occur through several mechanisms including decreased transit time, binding, chelation, competition for absorptive sites, and the formation of insoluble salts (24). Overall, calcium absorption ranges from 20 to 50% (24).

Transport

Calcium is transported through the blood bound to proteins, complexed, or in the free, ionized form. Approximately 40% of calcium in the blood is bound to proteins (i.e., albumin and prealbumin), 10% is complexed to sulfate, phosphate or citrate, and 50% is found in the free, ionized form (24).

Homeostasis

Calcium homeostasis is tightly controlled both intracellularly and extracellularly. Extracellular homeostasis (i.e., blood calcium) is maintained primarily through the actions of three hormones: parathyroid hormone (PTH), calcitriol, and calcitonin (24). Additionally, a calcium-sensing receptor (CaSR or CaR), which is found in the parathyroid gland, thyroid gland, distal nephron, GI tract, skin, brain, and in osteoblast cell lines, is involved in calcium homeostasis (25,27).

When blood calcium concentration is low, a PTH-vitamin D-dependent process returns blood calcium concentration to normal by increasing calcium absorption, renal tubular reabsorption, and bone resorption (25). When low concentrations of ionized calcium are detected by the CaSRs of the parathyroid gland, intact PTH is released (27). The release of PTH affects the kidneys and bones (24). In the kidney, PTH stimulates the synthesis and activation of calcitriol, the active form of vitamin D, which induces reabsorption of calcium in kidneys (24,28). Calcitriol also upregulates the production of calbindin by binding to the nuclear receptors of enterocytes thereby stimulating transcription of the gene that encodes calbindin (24). Increased calbindin production is associated with increased calcium absorption from the GI tract. In the bone, PTH interacts

with receptors on osteoblasts to signal osteoclasts to break down bone and release calcium into the blood by way of calcium pumps. As a result of these actions, the blood calcium concentration is returned to normal.

When the blood calcium concentration is high, ionized calcium binds to the CaSR on the parathyroid gland to induce a conformational change and PTH secretion is inhibited (25). As a result, PTH cannot activate calcitriol. Instead, calcitonin is secreted, which serves to decrease calcium absorption by inhibiting vitamin D activation, increasing urinary calcium excretion in the kidney, and decreasing bone resorption by inhibiting osteoclasts from metabolizing bone (24,25,28). As a result of these actions, the blood calcium concentration is returned to normal.

Intracellular calcium homeostasis is maintained through the action of ATP-dependent calcium pumps and calcium storage in the mitochondria, endoplasmic reticulum, nucleus, and vesicles (24). Calcium pumps transport Ca^{2+} out of the cell to maintain low intracellular concentrations within the cell or to the mitochondria for storage until it is needed by the cell. To control the calcium concentration in the cytoplasm, calcium may be transported from extracellular sites into the cell by a sodium-calcium exchange.

Deficiency

Calcium deficiency may occur as a result of inadequate intake, poor absorption, or excessive losses. The consequence of a calcium deficiency is a decrease in bone mass (BM), which may lead to osteopenia and eventually osteoporosis if bone loss continues (24,29-32). The loss of BM associated with

the development of osteoporosis results in increased bone fragility and increased fracture risk (33).

Risk for calcium deficiency is higher in vegetarians or individuals who are lactose intolerant or have high protein and fiber intakes. Other factors that contribute to calcium deficiency include fat malabsorption, immobilization, which promotes calcium loss from the bones, decreased GI transit time, or short-term use of thiazide diuretics (22,24).

Status Assessment

Methods used to determine calcium status include measurement of serum calcium and serum ionized calcium. Serum calcium, which includes protein-bound, complexed, and ionized calcium, is very tightly regulated and is affected by albumin status so it is not a good indicator of calcium status (24). Serum ionized calcium is reflective of abnormal calcium metabolism when albumin status is normal, but a correction factor must be applied when serum albumin is low.

Dietary Reference Intakes (DRIs)

Dietary Reference Intakes are nutrition-based reference values that can be used for planning and assessing diets (22). Those that pertain to calcium are the AI and Tolerable Upper Intake Level (UL).

Adequate Intake (AI)

The AI is defined as the “observed or experimentally derived intake by a defined population or subgroup that, in the judgment of the DRI Committee, appears to sustain a defined nutritional state, such as normal circulating nutrient values, growth, or other functional indicators of health” (22, p.25). An AI, rather

than a Recommended Dietary Allowance (RDA), is used when sufficient data are not available to establish an Estimated Average Requirement (EAR) (22). The AI is the amount of a nutrient that is “expected to meet or exceed the amount needed to maintain a defined nutritional state or criterion of adequacy in essentially all members of a specific healthy population” (22, p.25). The AI for calcium for children and adolescents 1 to 18 years of age ranges from 500 to 1300 mg/d (Table 4).

Tolerable Upper Intake Level (UL)

The UL is defined as “the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects” to almost all individuals in the general population (22, p.26). As intake increases above the UL, the risk for adverse effects increases. The UL is based solely on intake from supplements and fortified foods and applies to chronic daily use only. The UL for children and adolescents 1 to 18 years of age is set at 2,500 mg/d (22).

Table 4. Dietary Reference Intakes for calcium for children and adolescents 1 to 18 years.

Age	AI (mg)	UL (mg)
1-3 years	500	2,500
4-8 years	800	2,500
9-18 years	1,300	2,500

Source: (22)

Sources

Calcium is widely available in the U.S. food supply. Sources of calcium include milk, cheese, ice cream, yogurt, calcium-set tofu, soy milk, salmon, sardines (with bones), clams, oysters, turnip and mustard greens, broccoli, kale,

rhubarb, Chinese cabbage, legumes, dried fruits, and calcium-fortified foods such as orange juice and some cereals (22,24,25). Calcium bioavailability is fairly similar in dairy products such as milk and cheddar cheese, as well as fortified juices, soy milk, and yogurt (25). Calcium is poorly absorbed from spinach, rhubarb, and legumes, which are sources of oxalic acid, and from legumes, grains, and soy isolates, which are sources of phytic acid (22).

Milk, cheese, and yogurt are the most calcium-dense foods consumed by Americans, providing approximately 300 mg per serving (22). According to data for 1999, 73% of calcium in the U.S. food supply is from milk products, 9% is from fruits and vegetables, 5% is from grain products, and the remaining 13% is from all other sources (34).

Calcium Intake in the U.S.

Overall, calcium intake in the U.S. has declined because grains have become staples in the diets of Americans (25). The calcium content of grains and fruits are typically quite low, except in fortified cereals and grains (25). Calcium intake of Americans, especially adolescent girls, are below current recommendations (25). According to data from the 1994-1996 and 1998 CSFII, higher intake of total dairy and milk were associated with statistically significant increases in calcium intake (35). Additionally, the authors found that individuals with low dairy or milk intake did not compensate for their lower intake of these calcium-rich foods by consuming other foods that are good sources of calcium. Other factors that may affect dietary calcium intake in the U.S. are lactose intolerance, which occurs in 25% of adults, and consumption of vegetarian diets (22).

Vitamin D

Structure and Function

Vitamin D is a fat-soluble vitamin that plays a key role in normal growth, development, and maintenance of bone and other calcified tissues through its effect on calcium (22). Vitamin D also is active in cardiac tissue, muscle, brain, skin, hematopoietic cells, and immune system tissues (24). Blood is the primary storage sight for 25-OH D₃.

The primary biologic function of vitamin D is to maintain adequate serum concentrations of calcium and phosphorus through its actions on the intestinal, kidney, and bone cells (22,24). In the intestine, vitamin D primarily functions by increasing the absorption of calcium and phosphorus by upregulating the production of calbindin. In the kidney, PTH activates vitamin D (calcitriol) to stimulate calcium and phosphorus reabsorption. Vitamin D also functions with PTH in the bone to mobilize calcium and phosphorus by inducing differentiation of cells to osteoclasts and/or increasing osteoclast activity (24). Vitamin D also is involved in bone formation and remodeling through its role in promoting the synthesis of osteocalcin.

Digestion, Absorption, and Transport

Dietary vitamin D is absorbed primarily in the distal small intestine in association with fat through passive diffusion (24). Approximately 50% of vitamin D is absorbed. Once absorbed into the enterocytes of the small intestine, dietary vitamin D, in the form of D₃, is incorporated into chylomicrons that enter the lymphatic system. Vitamin D-binding protein (DBP) transports vitamin D to the liver through the blood. In the liver, vitamin D (cholecalciferol) undergoes a

hydroxylation at carbon 25 to form 25(OH) D₃. It is released back into the blood and transported to the kidney via DBP (24,36,37). In the kidney, 25(OH) D₃ undergoes another hydroxylation to form 1,25(OH)₂ D₃ (calcitriol), the active form of vitamin D. Calcitriol is released from the kidney, transported to target tissues on DBP, released by DBP, and bound to receptors in the target tissues.

In addition, vitamin D can be synthesized in the skin through exposure to sunlight. A sterol found in the skin, 7-dehydrocholesterol, absorbs ultraviolet (UV) light from the sun and is converted to vitamin D₃ (cholecalciferol) (24,36). Cholecalciferol enters the blood to be activated by the same mechanism as dietary vitamin D.

Deficiency

A potential cause of abnormal calcium and bone metabolism is vitamin D deficiency (22,38), which can lead to rickets in infants and children and osteomalacia in adults. Both rickets and osteomalacia are a result of failure of the organic matrix of bone to calcify or mineralize (24,36). In children less than 6 months of age, vitamin D deficiency is associated with convulsions or tetany (36). Vitamin D deficiency in children 6 months of age and older is associated with tetany, bone pain, and bone deformity. Adults with osteomalacia are likely to experience bone pain and osteopenia, which increase the risk for skeletal fractures (24,36,39).

Risk for vitamin D deficiency is associated with advancing age; fat malabsorption; disorders affecting the parathyroid gland, liver, or kidney; insufficient sun exposure; dark skin pigmentation; anticonvulsant therapy; unsupplemented breastfeeding infants; and renal disease (24,36). The

prevalence of vitamin D insufficiency in adults living in the U.S. and Canada ranges anywhere from 1 to 76% depending on the latitude and the season (40).

Status Assessment

Serum 25(OH) D₃ is the most accurate and reliable measure of vitamin D status (41,42). The ranges of serum 25(OH) D₃ concentrations used to determine vitamin D status are listed in Table 5.

Table 5. Vitamin D status assessment according to serum 25(OH) D₃ concentrations.

Vitamin D Status	Serum 25(OH) D₃ (nmol/L)
Normal/Adequate	100-200
Hypovitaminosis	50-100
Insufficiency	<40-50
At risk for deficiency	13-25
Deficient	<13

Sources: (36,37)

Dietary Reference Intakes (DRIs)

Adequate Intake (AI)

Similar to calcium, an AI rather than an RDA was established for vitamin D due to lack of sufficient data for setting an EAR. The AI for vitamin D for children and adolescents 1 to 18 years of age is 5.0 mcg/d (200 IU/d) (22).

Tolerable Upper Intake Level (UL)

The UL for vitamin D for children and adolescent 1 to 18 years of age is 50 mcg (2,000 IU)/d (22).

Sources

Vitamin D is not as widely available in the food supply as calcium. It is found primarily in saltwater fish such as herring, salmon, tuna, and sardines and

fish liver oils (24,36). Small quantities of vitamin D also are found in eggs, veal, beef, butter, cheese, and vegetable oils. Fortification of foods with vitamin D is an inexpensive approach for promoting adequate vitamin D intake for all children and adults.

The U.S. fortifies milk, some butter, margarine, cereals, and chocolate mixes with vitamin D₃ (calciferol) (24,36). Recently some types of fruit juice, such as orange juice, and some brands of yogurt also have been fortified with vitamin D (43). Vitamin-D fortified juice provides approximately 100 IU (50% AI) of highly bioavailable vitamin D per serving for children and adults (43,44).

Vitamin D Intake in the U.S.

Most humans obtain their vitamin D requirement from exposure to sunlight, which accounts for 80 to 100% of the body's requirement (42). It has been estimated that 53% to 63% of all children meet the AI for vitamin D, with adolescent and adult females being half as likely to obtain the AI as males (44). The majority of dietary intake of vitamin D in the U.S. comes from fortified dairy products (45 to 47%) (44).

Factors Influencing Bone Health during Childhood and Adolescence

Several studies have identified factors that may influence bone health in children and adolescents. These factors include age, Tanner stage (i.e., stage of puberty), height, weight, body mass index (BMI), and dietary intake of calcium, vitamin D, and milk and dairy products.

Numerous studies, including cross-sectional, intervention, and longitudinal studies, have reported a positive correlation between bone density or BM development in children and calcium, vitamin D, and milk and dairy products

intake (22,45). In a 3-month study of healthy, Caucasian children and adolescents, researchers found that dietary calcium intake, age, weight, and height were positively correlated with BMD (46). These researchers also observed that children whose average daily intake of calcium was at least 1000 mg had higher bone mineral content (BMC) than those ingesting less than this amount. Serum calcium, vitamin D, phosphorous, magnesium, or alkaline phosphatase concentrations were not correlated with bone mineral status in this study. Similarly, Ruiz and colleagues determined that body weight, physical activity, and dietary calcium intake (expressed as Z scores) were significant determinants of femoral and vertebral bone density in healthy, Caucasian, physically active children and adolescents with normal growth velocity (47). Height and Tanner stage also were significant determinants of vertebral BMD, and age influenced femoral BMD in this population. Sentipal and colleagues also found dietary calcium intake to have a positive effect on bone density (48). These researchers conducted a cross-sectional study of healthy, Caucasian female children and adolescents that examined the contribution of calcium intake on vertebral BMD and observed that current calcium intake was a significant contributor to vertebral BMD after adjusting for weight, height, age, and total energy expenditure. Sexual maturity rating, age, and calcium intake accounted for 81% of the variance in vertebral BMD.

Calcium supplementation also has been shown to positively affect BMD in children and adolescents. A 3-year, double-blind, placebo controlled, co-twin trial conducted with healthy, 6 to 14 year old identical twins sought to determine

whether calcium alone was effective in increasing the rate of change in BMD (49). These researchers found that calcium supplementation had a positive effect on the rate of increase in BMD at several skeletal sites.

Consumption of milk and dairy products, which are good sources of calcium and vitamin D, also has been shown to positively affect BMD. A large, cross-sectional study of randomly selected Chinese adolescent girls found that milk consumption, total calcium intake from milk, and vitamin D intake were positively associated with BMD (50). Body weight and Tanner stage also were predictors of BMD. Another study conducted in Yugoslavia reported that despite almost identical lifestyles, BM by 30 years of age was greater in individuals living in a region of Yugoslavia where consumption of dairy products was twice that of another region of the country (51). These studies suggest that elimination of dairy products from a growing child's diet may have a negative impact on BMD.

Achievement of PBM also has been studied. A cross-sectional study of premenopausal, Caucasian, children and adults conducted by Matkovic and colleagues sought to determine the timing of PBM, the maximum attainable BM within an individual's genetic potential, and BMD (52). Researchers did not detect a significant difference in BM or BMD for most skeletal sites except for the skull after 18 years of age, indicating early attainment of PBM for the hip and spine. Similarly, Henry and colleagues found that the majority of the body's bone mass (i.e., BMC and BMD) was achieved by late adolescence, with peak BMC being achieved between 21 and 22 years of age in men and 23 and 28 years in women, and peak BMD being achieved between 12 and 22 years in men and 12

to 29 years in women (53). This suggests that PBM is achieved sometime between the end of adolescence and early adulthood. Overall, the research studies summarized in this section support the importance of adequate intake of calcium, vitamin D, and dairy products during childhood and adolescence to promote bone health and achievement of PBM.

A limited number of studies have not observed a positive correlation between bone density in children and calcium intake or physical activity level as reviewed by the IOM (22). This could be due to other factors that affect BMD, such as maturational and chronological age and genetics. A study of physically active children and adolescents did not detect a significant positive correlation between calcium intake and bone density when stage of puberty and body weight were controlled (54). Researchers concluded that in healthy, physically active children with adequate calcium intake there is no appreciable effect of calcium on bone density. Bone density may be a function of the relationships between calcium intake, body weight, and stage of puberty. Similarly, in a prospective, longitudinal, 1 year-long study of healthy Finnish children and adolescents, physical activity and daily calcium intake were not correlated with BMD (55). It is important to note that calcium intake in the majority of study subjects was relatively high (≥ 800 mg/d). It is important to note that these 2 studies did not compare the relationship between the type of exercise in which study subjects participated (i.e., weight-bearing or non-weight-bearing exercise) and BMD.

Although a few studies suggest that calcium, vitamin D, and dairy products intake do not influence bone health, most of the studies conducted support the

role of dietary intake of calcium, vitamin D, and dairy products in promoting bone health during childhood and adolescence.

Factors Influencing Bone Health during Adulthood

Several factors that may influence bone health during adulthood have been identified from research studies. These factors include dietary intake of calcium, vitamin D, milk and dairy products, and level of physical activity during childhood and adolescence. Numerous retrospective studies have reported an association between higher calcium intake during childhood and adolescence with achievement of maximal PBM and greater BM in adulthood (22,45,56). As discussed earlier, calcium is important for healthy skeletal growth and development throughout life and because PBM is achieved by early adulthood, early calcium intake can significantly influence the degree to which PBM is achieved (53). Insufficient PBM has been shown to contribute significantly to the risk of osteoporosis later in life (57).

Halioua and Anderson assessed the independent and combined effects of lifetime calcium intake and physical activity on BMD, as well as body weight, in healthy, ambulatory, premenopausal Caucasian women (58). This cross-sectional study found that both lifetime calcium intake and physical activity were significant positive predictors of BMD and BMC. Individuals with low lifetime calcium intake and sedentary lifestyles were found to have the lowest bone BMD and BMC. A similar study was conducted by Sandler and colleagues (59). These researchers conducted a retrospective study of white, middle to upper-middle class women in which information about milk consumption and calcium intake during childhood and adolescence were collected. These researchers

observed that women who reported drinking milk with every meal during childhood and adolescence had significantly higher bone density measurements than women who reported drinking milk less frequently. As a result, the researchers concluded that milk consumption during childhood and adolescence appears to be necessary for optimal PBM. Results from a large, cross-sectional survey of women also suggest the importance of milk and dietary calcium consumption during childhood and adolescence on bone density of adults.

Kalkwarf et al. examined data collected on non-Hispanic, white women 20 years of age and older from the third National Health and Nutrition Examination Survey (NHANES III) conducted from 1988 to 1994 (60). Milk and dietary calcium intake was determined through household surveys on milk consumption during specific periods of life, including childhood, adolescence, and adulthood. Milk intake during childhood, adjusted for confounders, was positively associated with total hip BMC and bone area in women between 20 and 49 years of age. In addition, milk intake during adolescence was positively associated with hip BMD in women between 20 and 49 years of age. In women over the age of 50 years, milk intake during childhood and adolescence positively influenced total hip BMD, and low BMD was associated with a significantly greater incidence of lifetime fracture. Also, low calcium intake during childhood was significantly associated with an increased risk for osteoporotic fractures in women over 50 years of age, thereby supporting the importance of milk consumption and adequate calcium intake during childhood and adolescence. Collectively, these studies strongly suggest

that dietary intake of calcium, vitamin D, and dairy products are important during childhood and adolescence because of the impact on bone health later in life.

Factors Influencing Bone Health in Children and Adolescents with Asthma

Calcium and vitamin D intake is important for promoting bone health in all children and adolescents, including those with asthma; however, health beliefs and practices among this population may interfere with achieving optimal intake of these nutrients. Furthermore, other factors may put children and adolescents with asthma at higher risk for poor bone health including altered metabolism related to the disease, the medications used to treat asthma, and the restriction of physical activity to avoid exercise-induced asthma (EIA) symptoms.

Health Beliefs about the Impact of Milk and Dairy Products on Asthma

One of the health beliefs adopted by some parents of children with asthma is that cow's milk and cow's milk products affect asthma symptoms. For this reason, some parents may eliminate or restrict the intake of milk and dairy products in their children's diets, which could severely limit their intake of calcium and vitamin D and have a negative impact on bone health over time. Research has shown that parents of children with asthma commonly (47%) avoid or eliminate foods from their children's diets, with milk and dairy products being the primary (79%) category of foods eliminated or avoided (6). As reported by Dawson et al., parents reported family, friends, and the media as the most common (77%) sources of advice that influenced their decision to make a change in their child's diet (6). Only 14% of parents reported receiving this advice from a medical source (i.e., family doctor, dietitian, specialist, etc.). A similar study conducted by Woods and colleagues on pediatric and adult asthma

patients showed that 45% of subjects had been advised by a doctor, specialist, or a dietitian to avoid or eliminate specific foods, such as milk and dairy products, at some time in their lives to improve asthma symptoms, and approximately 61% were currently eliminating or avoiding these foods or had in the past (7). Dairy products were one of the most commonly (36%) reported food categories to induce asthma symptoms, the most commonly advised dietary restriction, and the most commonly avoided food category.

Another factor that may influence milk and dairy intake by children with asthma are the attitudes and beliefs held by them and their parents or caregivers. For example, a survey was completed by 330 parents waiting in a pediatric pulmonology office (61). Parents were asked if they avoided serving milk to their child when they were ill, whether they thought their child was allergic to milk, if their child had allergies, asthma, or cystic fibrosis (CF), and other questions related to health beliefs and practices. Over half of the parents surveyed had a child with asthma. Approximately 62% of parents of children with asthma believed that drinking milk increased mucus. Family members were the most common source of this information followed by pediatricians, physicians, and others. Additionally, 8.2% of parents believed that their child was allergic to milk and of these, approximately 70% believed that milk increased mucus production. Overall, the studies summarized in this section suggest that intake of milk and dairy products may be restricted or avoided in the diets of children and adolescents with asthma due to health beliefs about the role of these foods in producing asthma symptoms and allergies.

Calcium and vitamin D intake and bone health in cow's milk-free and cow's milk-limited diets

Several studies suggest that the calcium intake of children on cow's milk-free or cow's milk-limited diets is inadequate. A prospective, 2-year study of male and female prepubertal children who were milk-avoiders (i.e., individuals with a history of avoiding the consumption of cow's milk for more than 4 months at some stage in their lives) found that milk-avoiders not only had lower calcium intake, but also smaller bones, significantly lower bone area and BMC, and lower volumetric BMD (62). The researchers concluded that children with a history of long-term avoidance of cow's milk have low dietary calcium intake and poor bone health in comparison to children who drink milk. In a two-year follow-up of this same population milk-avoiding children had a significantly higher prevalence of bone fractures compared to milk drinkers (controls). Furthermore, milk-avoiding children did not make appropriate dietary substitutions to compensate for their low calcium intake (63). In a younger population of children, calcium intake also was found to be inadequate in cow's milk-free and cow's milk-limited diets. Henriksen et al. conducted a prospective, cohort-based study to evaluate the nutrient intake of children (mean age = 33 months) whose parents perceived that their child had reactions to milk or egg when they were 2 years of age (64). Each subject was categorized into one of four groups (i.e., milk-free, formula, low milk, and milk consumers) based on their current diet. The milk-free group included subjects on a diet completely free of cow's milk protein; the formula group included subjects who consumed various amounts of hypoallergenic formula (i.e., soy-based or hydrolyzed); the low milk group consumed some dairy products, but

did not drink cow's milk; and the milk consumers group included children who were milk-drinkers. Subjects in the milk-free, formula, and low-milk groups had significantly lower calcium intake than the milk-consuming group. In fact, children in the milk-free group had an average daily calcium intake of less than 300 mg and children in the low milk and formula groups each had an average daily calcium intake of less than 500 mg. These studies suggest that children's calcium needs most likely will not be met on a cow's milk-free or cow's milk-limited diet.

Cow's milk and pulmonary function

Despite the popular belief that ingestion of cow's milk and other dairy products increases mucus and negatively affects pulmonary function in individuals with asthma, studies have shown that cow's milk ingestion does not decrease pulmonary function, as evidenced by FEV₁, FVC and/or PEF, nor does it induce bronchoconstriction (20,21). A statistically significant difference was not detected in pulmonary function (i.e., FEV₁ and PEF) between a cow's milk challenge and a placebo challenge (i.e., rice milk) in a randomized, double-blind, placebo-controlled, cross-over study conducted in adults with asthma (21). Additionally, a statistically significant difference was not detected in pulmonary function from baseline after cow's milk challenge even in those subjects who perceived that their asthma worsened after ingestion of dairy products. No subjects reported an increase in cough or sputum production after any of the challenges. A study using water instead of rice milk as the control reported similar results (19). This 3-day pilot study designed to assess the effects of milk ingestion on pulmonary function, recruited adults with and without asthma who

did not have a history of milk protein allergy or lactose intolerance, and randomly assigned them to consume 10 ounces of water, whole milk, or skim milk after which lung function was evaluated using FVC, FEV₁, and V₅₀ (i.e., airflow at 50% of vital capacity) (19). Neither group (i.e., subjects with asthma or subjects without asthma) showed a significant change in any lung function parameters from baseline over three hours following ingestion of any of the test beverages (i.e., water, skim milk, or whole milk) and there were no significant differences in lung function parameters between the subjects with asthma and the subjects without asthma for any of the test beverages. The authors concluded that because they did not detect a significant increase in airway resistance (i.e., a decrease in FVC, FEV₁, or V₅₀), there was not a significant increase in mucus production in the airways. A prospective, randomized, double-blind, placebo-controlled study of adult patients with mild asthma and no history of milk allergy reported similar results with regard to the lack of a clinically significant effect of cow's milk on pulmonary function (i.e., FEV₁ and FEV₁/FVC) (20). No clinically significant effect of cow's milk on pulmonary function was detected at any time point (i.e., 30 minutes, 1 hour, or 7 hours) compared to a placebo solution. There also was no evidence of asthma symptoms, acute or delayed, after either challenge. The authors concluded that pulmonary function does not deteriorate in response to cow's milk ingestion. The studies presented in this section suggest that cow's milk ingestion does not have a negative impact on pulmonary function in people with asthma.

Cow's milk or food allergy, adverse reactions to milk, and asthma

A potential reason that parents of children with asthma may eliminate milk and dairy products from their children's diets is related to the concern that their child may be allergic to milk. This concern may be real or perceived. A double blind placebo-controlled trial showed that incidence of cow's milk allergy was low in children with asthma even in those who perceived that their asthma worsened after ingestion of dairy products (65). Similarly, a double-blind, placebo controlled, cross-over study conducted in children and adults with asthma found that of those subjects who by history, skin prick test, or radioallergosorbent test had a response suggestive of food allergy (8.3%), asthma was induced in only 30% of these subjects following a food challenge (e.g., milk, cheese, etc.), suggesting that food-induced asthma occurs in only 2% of individuals with asthma (66).

A study conducted by Emery et al. also found a low prevalence of food allergy in individuals with asthma (67). This cross-sectional survey study of a well-characterized population of children and adults with asthma found that 45% of the subjects reported adverse reactions to foods, with milk being the leading cause of reactions (9.7% of the total surveyed, 21.5% of those reporting food reactions). Only 32% of those reporting adverse reactions to foods (14% of total surveyed) indicated that they had been diagnosed with a food allergy. Similarly, a study conducted with children who had bronchial asthma found that only 8.5% of the subjects had asthma due to a food allergy (68). All food allergies were confirmed by a positive intracutaneous test and hemagglutination test. Additionally, approximately 34% of those with food allergy were allergic to milk.

These studies indicate that although there is a low prevalence of food allergy and food-induced asthma in children with asthma, a significant proportion of the observed cases are caused by milk.

Physical Activity

Observational and intervention studies have led to generalizations that regular, moderate physical activity throughout childhood and adolescence positively affects BMD, particularly at weight-bearing sites (45,69). The prevalence of EIA, bronchial hyperresponsiveness, or wheezing during exercise, as well as physical fitness and reported exercise limitations in children and adolescents with asthma may have an impact on the type and amount of physical activity in which they participate. This can potentially impact their bone health.

Acute and chronic diseases of the respiratory tract and supporting structures, such as asthma, are potential barriers to participation in various forms of physical activity by children and adolescents (70). The prevalence of EIA has been estimated to be anywhere from 9 to 23% in the general population of children and adolescents (71). In contrast, the prevalence of EIA has been estimated to be 50 to 100% in children and adolescents with asthma (70,72). In a study of children and adolescents with asthma, 76% reported that wheezing increased after exercise (73). Both EIA and increased wheezing during exercise have the potential to cause individuals with asthma to limit the amount and type of physical activity in which they participate. This large range in EIA prevalence among individuals with asthma is affected by type, intensity, and duration of activity, environmental conditions, severity of disease, and variations in preventive therapy (72). Overall, these research studies indicate a relatively high

prevalence of EIA, wheezing, and/or bronchial hyperresponsiveness during exercise among children and adolescents with asthma.

Inadequate management or control of EIA may lead to unnecessary avoidance of physical activity and sports (74). There is general agreement that children with mild to moderate asthma are less fit than children without asthma (74). In fact, Kitsantas and Zimmerman reported that adolescent girls with asthma were less physically fit and participated less often in vigorous activities compared with non-asthmatic girls (8). Decreased aerobic capacity among asthmatic children and adolescents may be due to a sedentary lifestyle that results from a lack of full lung expansion during exercise and/or a negative attitude towards sports and other physical activities (72,74,75).

Many preconceptions regarding the effect of exercise on asthma symptoms in children and adolescents have developed (76). A survey administered to Swedish children with asthma was conducted to identify the types of limitations in activities they experienced (9). Approximately 84% of these children reported three restricted activities during the previous week. The most commonly restricted activity was running, which accounted for 74% of restricted activities. Another study found that 52% of those who did not exercise limited their participation because they experienced shortness of breath or wheezing (73). Sixty-five percent of the adults and children in this study did not regularly participate in physical activity, but 64% indicated that their participation in physical activities would be greater if their asthma was under better control.

In contrast, a large cross-sectional, multi-center survey of randomly selected school-aged children living in three different areas of Norway found that asthmatic children were as physically active as their non-asthmatic peers (77). In addition, no significant differences were detected between exercise frequency and hours of exercise per week for asthmatic compared to non-asthmatic children. However, the authors noted that this finding could be due to parents of children with asthma being aware of the importance of physical activity in the management of asthma, leading to overreporting the overall physical activity of their children. In a sub-group analysis, which included individuals only from one region of the country, researchers also found no difference in physical activity levels between children with or without asthma (78). Even though no significant difference in exercise frequency between those with or without asthma was detected, 12% of those with asthma exercised less than one hour per week and 38% exercised 4 to 6 hours per week (79).

Although inconclusive, there is some evidence to suggest that children and adolescents with asthma are less fit, participate less frequently in physical activity, and have limitations in terms of the type of physical activity in which they can participate. This lack of physical activity has the potential to negatively impact bone health in this population.

Inhaled Corticosteroid Use

Another factor that may influence bone health is the use of inhaled corticosteroids. Many asthmatic children use inhaled corticosteroids daily. The role of inhaled corticosteroids on bone health (i.e., BMD and BM) in children and adolescents with asthma is controversial.

The National Asthma Education and Prevention Program (NAEPP) Expert Panel of the NHLBI conducted a systematic review of available literature on the effect of inhaled corticosteroids on BMD through August 2000 (2). A total of 2 studies (i.e., 1 short-term and 1 long-term study) were identified that met the study criteria. The first study was a prospective study of Chinese patients with bronchial asthma using inhaled steroids (i.e., beclomethasone dipropionate (BDP) or budesonide (BUD)) regularly for at least 3 months. Researchers found that total body BMC was similar, but the BMD of the lumbar spine, femur, trochanter major, and Ward's triangle were all significantly lower than that of matched control subjects (i.e., individuals without asthma who were not using inhaled corticosteroids) (80). In female subjects, there was a significant negative correlation between the average daily dose of inhaled steroid and BMD of the lumbar spine and trochanter of the femur. It is important to note that this study did not evaluate children and adolescents, had a small sample size ($n = 30$), and was short-term. The second study was conducted by the Childhood Asthma Management Program Research Group (81). This study was a 6-year, randomized, clinical trial of a large group of children with mild to moderate asthma. Subjects were randomized to BUD, nedocromil sodium, or a placebo. Prednisone administration was permitted as needed. No significant difference in the change in bone density was detected among the 3 groups.

The NAEPP concluded that based on available research, inhaled corticosteroids taken in recommended doses do not have "frequent, clinically significant, or irreversible effects" on BMD in individuals with asthma (2, p.38).

The report also noted that chronic use of inhaled corticosteroids could potentially have cumulative effects on bone health (i.e., increased relative risk for osteoporosis) when initiated during childhood and continued through adulthood, but the lack of high-quality studies assessing this outcome make it difficult to formulate a definitive conclusion.

Studies conducted after this extensive review have not shown an association between inhaled corticosteroid use and a decrease in BMD and/or BM in children and adolescents with asthma. A 6-month randomized, pilot study was conducted with infants, children, and adolescents who had symptoms suggestive of asthma and who were naïve to prophylactic therapy (e.g., corticosteroids) (82). Subjects were randomized to receive either a β_2 -agonist, an active control, or a β_2 -agonist combined with an inhaled steroid (i.e., BDP or BUD). Bone density was measured using two different radiation free predictors of bone density, broadband ultrasound attenuation and velocity of sound. No significant difference in bone density adjusted for age was detected between the control and each of the treatment groups. It is important to note that compliance with therapy in this study ranged from 25 to 100% (median 50%). A long-term study on children with asthma also found similar results. This 2-year randomized, open, multi-center, parallel-group, study was conducted with children with asthma who had only been treated in the past with a β_2 -agonist (83). Subjects were randomized by balanced block randomization to fluticasone propionate, an inhaled steroid, or nedocromil sodium, an active control. Bone mineral density measurements were performed by individuals who were blind to

subject treatment. No significant difference in BMD was detected between the groups. Overall, the studies presented in this section suggest that inhaled corticosteroids do not have a long-term effect on BMD in children and adolescents with asthma.

Systemic Corticosteroid Use

In contrast to research on inhaled corticosteroid use, research suggests that oral or systemic corticosteroid use may have a negative impact on bone health. Oral or systemic administration of corticosteroids may indirectly affect bone health by reducing absorption of calcium in the gut and increasing renal clearance of calcium, resulting in decreased blood calcium. As a result, PTH is secreted, which inhibits the hypothalamo-pituitary-adrenal/gonadal axis and negatively impacts bone by increasing bone resorption (84). Oral corticosteroids also act directly on bone by inhibiting recruitment, differentiation and life span of osteoblasts; production of type 1 collagen; and synthesis of osteocalcin, insulin-like growth factors, and prostaglandin E.

Bone Density of Children with Asthma and Risk for Osteoporosis

Research strongly suggests that children and adolescents with asthma have significantly lower-than-expected BMD. For example, a cross-sectional study in which bone density, bone metabolism, and adrenal function were measured in children who were either exposed or unexposed to oral bursts (i.e., 5-day courses) of oral corticosteroids during the preceding year was conducted (85). Researchers found that even though bursts of oral corticosteroids did not have a prolonged or cumulative impact on bone metabolism, both groups had lower-than-expected bone density (i.e., negative mean Z score) for age, gender,

and race. The researchers concluded that this finding may be due to inadequate protein, calcium, or vitamin D intake, or physical inactivity, factors that increase the risk for developing osteoporosis later in life. It is important to call attention to the fact that researchers did not address dietary calcium and vitamin D intake in this population.

Research Significance

Asthma affects 6.1 million children and adolescents in the United States (U.S.), and its prevalence is on the rise (1). The elimination of dairy products, potentially resulting in low calcium and vitamin D intake, low physical activity, 5-day courses of oral corticosteroids, and long-term use of inhaled corticosteroids seen among children and adolescents with asthma may have negative implications on bone health later in life. The only study identified following an extensive library search that examined the dietary intake of individuals with asthma, was conducted by Woods and colleagues (86). These researchers conducted a survey by mail on a large sample of adults to determine if there were differences in dietary intake between subjects with or without asthma. They found that intake of some foods, such as dairy products, were different between subjects with asthma compared to those without asthma, but intake of nutrients including calcium, were not. Specifically, asthma was negatively associated with whole milk and butter consumption and positively associated with ricotta and low-fat cheese consumption, but overall intake of dairy products was not significantly different between those with and without asthma. To date, no studies have specifically looked at the dietary intake of calcium and vitamin D in children and adolescents with asthma. Therefore, the purpose of this study was to examine

calcium and vitamin D intake of children and adolescents with asthma to determine if they are meeting the recommended intake levels for these nutrients and to compare their intake of these nutrients with national intake data.

Inadequate intake of these nutrients may suggest the need for supplementation as a way to promote bone health in children and adolescents, with the goal of decreasing the risk for osteoporosis in adulthood. It was hypothesized that children and adolescents with asthma would not meet the AI for calcium and vitamin D, and that they would consume less calcium than what has been reported in national survey data from children and adolescents of the same age.

CHAPTER 3 MATERIALS AND METHODS

Subject Description

Subjects recruited for this study were patients with asthma between 1 and 18 years of age. Subjects were recruited from the University of Florida (UF) Pediatric Pulmonary Division during a normal clinic visit and from individuals screened by the UF Asthma Research Lab for participation in other studies. Subjects were excluded if they were less than 1 year of age or greater than 18 years of age; discontinued being followed by the Pediatric Pulmonary Division prior to completing their 3-day food and supplement diary; clinically diagnosed with CF, developmental delay, any GI disorders or diseases that affect absorption of nutrients, milk or dairy allergy, or bone disorders; were unable to speak and/or write in English; or were on tube feeding or intravenous feeding at the time of recruitment.

Study Design

The study design and protocol were approved by the UF Health Science Center Institutional Review Board. The primary objective of this study was to estimate calcium and vitamin D intake from foods, beverages, and supplements of children and adolescents with asthma and to compare their intake without supplement intake with the AI set by the IOM. A second objective of this study was to compare calcium and vitamin D intake without supplement intake of these subjects to those of an age-matched population using survey data from the 1994

to 1996 and 1998 CSFII. To obtain this information, each participant or caregiver completed a 3-day food and supplement diary (Appendix B) that included intake for at least one weekend day. Subjects were recruited through advertisements, letters, as part of outpatient clinical care and/or referral by their primary caregiver, and through review of medical records and databases maintained by the UF Asthma Research Lab. Patients followed by the UF Pediatric Pulmonary Division and children that were screened for studies performed at the UF Asthma Research Lab that met study criteria were sent a letter to determine their interest in participating in this study. Subjects who met study criteria and attended the UF Pediatric Pulmonary Division clinic were contacted during their clinic visit to ascertain their interest in participating in this study. A complete explanation of the study was given and informed consent was obtained. Subjects were given verbal instructions for completing the food diary. Written instructions (Appendix A) were also provided, as well as a sample 1-day food diary (Appendix A), a portion size estimation aid with written information and pictures (Appendix A), a 3-day food diary record form (Appendix B), and a postage-paid envelope. The 3-day food and supplement diary was returned to the study investigators in the postage paid envelope. Subjects received follow-up phone calls, as necessary.

Individuals interested in participating who did not reside in Gainesville or did not have an appointment scheduled in the following month were met at a location convenient for them within the UF Health Science Center or Shands Healthcare System (Gainesville, FL), or they were mailed two copies of the Informed Consent Form signed by the Principal Investigator and all of the materials as

described above. A complete explanation of the study and how to complete the food diary was given by the Principal Investigator over the phone. These subjects received follow-up phone calls, as necessary. The subject signed one copy of the Informed Consent Form and returned it in the postage paid envelope with the completed 3-day food and supplement diary.

The 3-day food and supplement diary needed to be postmarked by May 31, 2004 to be included in the study, and consented subjects who had not completed and returned the 3-day food and supplement diary were notified of this deadline by phone at least one month in advance of the close of the study. The completed 3-day food and supplement diary for each study participant was manually entered and analyzed using the ESHA (version 8.1) Food Processor software for Windows to determine the 3-day average intake for calcium, vitamin D, calories, protein, and fat (87). The medical records of study subjects also were reviewed to obtain information such as address, phone number, insurance, gender, ethnicity, age, prescribed medications, BMI, and growth percentiles for height, weight and weight-for-height, although these data were not available for all subjects. In cases where this information was not available in the medical record, subjects were contacted by phone to collect the information.

After the 3-day food and supplement intake diaries were returned and the other information was collected, a \$10 gift card to Target, Wal-mart, or another national chain discount store was mailed to each participant. The results of the 3-day calcium and vitamin D intake analysis were summarized and mailed to

each subject. Average calcium and vitamin D intake was compared to the AI and the CSFII. Other nutrient analysis information may be evaluated at a later date.

In order to protect patient confidentiality, all subject information was coded. The code key was kept in a locked filing cabinet to minimize risk for breach of confidentiality. The study code key will be destroyed upon completion of the final study report.

Dietary Intake Tool and Analysis

The dietary intake tool used to enter and analyze dietary intake in this study was ESHA Food Processor (version 8.1) for Windows (87). Food Processor 8.1 is an accurate, complete, versatile, quick, and easy-to-use diet analysis program (88). It can be used to analyze dietary intake and compare them to recommended standards. The data source is primarily derived from the latest U.S. Department of Agriculture (USDA) Standard Reference database, as well as the CSFII survey database, and data available from manufacturers, fast food companies, and published research.

To determine the 3-day average intake of calcium and vitamin D, each 3-day food and supplement diary was manually entered by the Principal Investigator into Food Processor 8.1 (87). This automated program was used to calculate the 3-day average intake of calories, protein, fat, calcium, and vitamin D for each study subject. The average intake values for calcium and vitamin D without supplement intake were compared with age-appropriate calcium and vitamin D intake reported in the CSFII database and the AI.

Overview of Three-day Food Diary Method Used to Assess Dietary Intake

The dietary assessment method selected for use in this study was a 3-day food diary. This method requires that subjects or caregivers record detailed information about all foods and beverages consumed during a specified time period, usually 3 to 7 days (89,90). Foods and beverages ingested are ideally recorded at the time of consumption (91) and portion sizes are recorded based on actual weights or measures or visual estimation (90,91). Multiple days are usually recorded due to variation in dietary intake from day to day (91). Food diaries are appropriate to use when the research question focuses on a select group of nutrients or when nutrient intake is compared to a nutrient-specific standard, such as the AI (92). Data obtained from food diaries can be used to rank and quantify nutrient intake (91). A food diary is considered the most accurate and precise method for dietary assessment (93) and is often used as the “gold standard” (93-95). Ideally, this method reflects usual current intake (93,94). Several studies have used food diaries to validate other types of dietary assessments, such as food recalls and food frequency questionnaires (FFQs) (91). This method is accurate and quantitative (93,94) and can be more economical than some dietary intake methodologies because it eliminates the need for interviewing (93). Compared to retrospective methods, estimation of portion size is likely to be better since there is decreased reliance on memory. Another advantage is that this method requires little adaptation for different populations or age groups (91). In addition, incorrect statements about food habits are less likely to occur when food diaries are used compared to interview methods (96).

Potential drawbacks of the food diary method are that it has the potential to be tedious and time-consuming (93), and it requires the child, adult, or caregiver to be literate and motivated (94,95), write legibly (92), recognize and describe quantities accurately (92,95), decipher food label information (92), and immediately record foods and portions consumed (91,94). Much of this can be resolved or improved with proper instruction. Disadvantages may include poor compliance (93) and alteration of diet by subject caregiver to ease recording of foods (93,96). An appropriate computerized database is needed for analysis of the data and a nutritionist or appropriately trained staff is needed for instructing subjects, checking records for accuracy, and completing the computerized nutrient analysis (91,93,95).

Comparison of Methodologies to Assess Dietary Intake

In addition to a food diary, there are several other commonly used methods to assess the dietary intake of individuals. These include FFQs, 24 hour recalls, and diet histories. Twenty-four hour recalls involve recollection of all food and beverages consumed during the previous 24 hours (90). A drawback of this method is that it does not represent and reflect an accurate picture of habitual or usual intake in children unless multiple recalls are obtained (91,93-95).

Food frequency questionnaires require subjects to report frequency of consumption and sometimes portion sizes of foods and beverages from a long list (91). This method ranks intake and cannot be used to quantify usual intake of nutrients (91,95), and it generally overestimates intake (91). It also needs to be culture (93,97) and population (91) specific and may lack the unique details of an individual's diet (94,95).

Diet histories are used to “assess usual meal patterns, food intake, and other information in an extensive 1- to 2-hour interview or questionnaire” (91, p.493). This method, which is generally used to establish intake in the distant past, can be costly and time consuming (96).

Several studies of older children, adolescents, and adults have provided evidence that no one method used for dietary assessment is consistently more accurate than the others and that underreporting often occurs (90,97,98).

Serdula et al. reviewed the available literature on validity of food recalls, food diaries, FFQs, and diet histories in preschool children (91). The authors were unable to form any general conclusions because of the varied study designs, small sample sizes, and the limited number of studies examined (91).

Crawford et al. conducted a validation study with 9 to 10 year old girls to compare 3 methods (i.e., 24-hour recall, 3-day food diary, and FFQ) against observed intake (99). They found that the 3-day food diary had the lowest percentage of missing food items and fewest phantom food items (i.e., foods reported, but not observed) compared to the other methods, and it was highly correlated with observed intake. Thus, the food agreement score (i.e., accuracy of reporting observed intake) was the highest for the 3-day food diary. These researchers concluded that the higher agreement score for the food diary methodology was due to the fact it did not rely as heavily on the subjects' memory as the other methods. The 5-day FFQ was found to consistently overestimate intake and correlation with observed intake was low. The 24-hour recall had an intermediate correlation with observed intake. Hill and Davies

reviewed self-reported energy intake obtained from using different dietary assessment methods and compared these data to the results obtained using doubly labeled water (90). They found that in studies of young children where the parent or guardian completed the food diary, there was good agreement between reported intake and measured energy expenditure. Finally, food diaries have been shown to be accurate measures of intake in lean subjects up to 9 years of age, but may not be as accurate in adolescents and younger adults where intake may be underreported by approximately 20% (100).

Overview of the 1994 to 1996, 1998 CSFII

Intake data from the 1994 to 1996, and 1998 CSFII was used as the age-matched reference population to which data from our subjects was compared. The CSFII is a national survey conducted by the Agricultural Research Service, USDA to gather data on the food and nutrient intake of the U.S. population, including the general population, as well as low-income individuals (101). The National Nutrition Monitoring and Related Research Program uses data from this survey and others to provide continuous monitoring of food use and consumption to determine the dietary and nutritional status of the U.S. population. The target population includes noninstitutionalized individuals residing in all U.S. states and Washington, DC. The 1994 to 1996 CSFII included collection of data from individuals of all ages and the 1998 CSFII included children from birth through 9 years of age (102). The dietary assessment method used to determine the food and nutrient intake was a multiple-pass 24-hour recall (101). Two, in-person, detailed twenty-four hour recalls collected 3 to 10 days apart were conducted by well-trained interviewers. They also gathered information on vegetarianism,

supplement use, height and weight, allergies, smoking, exercise frequency, dieting, health status, and consumption of alcoholic beverages. In addition, the 2-day dietary recall included a food list in which subjects identified foods consumed during the past year.

Statistical Analysis

Statistical analyses were conducted using SAS version 8.02 (103) and Microsoft Excel 2002 (104). Average age and average intake of calories, protein, fat, calcium, vitamin D, and dairy products by age category and gender were calculated using Microsoft Excel 2002 (104).

A power analysis was conducted to determine the sample size needed for each age category. An alpha of 0.05, beta of 0.2, power of 0.8, and the SD from the CSFII for each age category were used to calculate these sample sizes. The delta value, also used to calculate these sample sizes, was based on results from BMD studies used in establishing the AI for calcium. The delta value was defined as the difference in milligrams of calcium that is considered to be significantly different when comparing 2 populations. A range of delta values were used due to the highly variable results in the studies examined. The range for delta was determined to be 200 to 300 mg, 220 to 300 mg, and 400 to 443 mg for the 1 to 3, 4 to 8, and 9 to 18 year old age categories, respectively. It was determined that sample sizes of 22 to 48, 19 to 35, and 17 to 20 were needed to yield adequate statistical power for the 1 to 3, 4 to 8, and 9 to 18 year old age categories, respectively.

Comparison of Dietary Intake to AI

A one-tailed small sample t-test was used to compare the 3-day average calcium intake without supplements and the 3-day average vitamin D intake without supplements to the recommendations set by the IOM for each age category (22). The study sample size was small and the true population SD was unknown, so the t-distribution rather than the standard normal z-distribution was used for comparisons of average intake to the AI.

Comparison of Dietary Intake to 1994 to 1996, 1998 CSFII

A one-tailed large sample z-test was used to compare the difference in mean intake of calcium without supplement intake of the study subjects to the age-matched CSFII population. A two-tailed large sample z-test was used to compare the difference in mean dairy intake of the study subjects to the age-matched CSFII population. The sample size in this study was extremely small compared to that of the CSFII, so the CSFII mean more likely reflected the true population mean than the mean of the study sample. The population (i.e., CSFII) SD was known, so the standard normal z-distribution was used for these comparisons.

CHAPTER 4
RESULTS

Subjects

Demographics

Eighty-four subjects (i.e., 56 males, 28 females) enrolled in the study and 36 subjects (i.e., 26 males, 10 females) completed and returned a food and supplement diary. The number of male and female subjects in each category and the number of males and females who completed the food and supplement diary are listed in Table 6. The average age of subjects who completed the study

Table 6. Number of subjects who enrolled and completed the study and percent return rate by age category and gender.

Age category (years)	Gender	Number enrolled	Number completed	% Return rate
1 to 3	All	22	9	40.9%
	Males	19	9	47.4%
	Females	3	0	0.0%
4 to 8	All	27	14	51.9%
	Males	15	9	60.0%
	Females	12	5	41.7%
9 to 18	All	35	13	37.1%
	Males	22	8	36.4%
	Females	13	5	38.5%
Total	All	84	36	42.9%
	Males	56	26	46.4%
	Females	28	10	35.7%

by age category was 2.5 years, 6.4 years, and 13.9 years in the 1 to 3 year old, 4 to 8 year old, and 9 to 18 year old age categories, respectively. Due to new

restrictions on health information, race was not obtained for study subjects. Reasons for not completing the study that were relayed by some of the subjects' caregivers were that they were too busy, it was too difficult to arrange cooperation with the daycare to record food intake, or they didn't wish to complete the 3-day food and supplement diary.

Dietary Intake of Calories, Protein, and Fat

Mean dietary intake of calories, protein, and fat are presented in Table 7. Subjects in the 1 to 3 year old age group consumed a 3-day mean intake of 1,616 calories, 58 g of protein, and 57 g of fat. Subjects in the 4 to 8 year old age group consumed a 3-day mean intake of 1,994 calories, 72 g of protein, and 75 g of fat. Subjects in the 9 to 18 year old age group consumed a 3-day mean intake of 2,285 calories, 87 g of protein, and 91 g of fat.

Table 7. Three-day dietary intake of calories, protein, and fat by study subjects.

Age category (years)	Gender	Calories* (kcal)	Calories (% of AI)	Protein* (g)	Protein (% of AI)	Fat* (g)
1 to 3	Both	1,616 ± 251	118%	58 ± 15	360%	57 ± 18
4 to 8	Males	2,214 ± 625	112%	78 ± 26	322%	85 ± 35
	Females	1,598 ± 458	87%	63 ± 12	279%	58 ± 27
	Both	1,994 ± 631	N/A	72 ± 23	N/A	75 ± 34
9 to 18	Males	2,573 ± 835	94%	92 ± 30	167%	102 ± 43
	Females	1,824 ± 479	78%	78 ± 31	156%	74 ± 26
	Both	2,285 ± 793	N/A	87 ± 30	N/A	91 ± 39

*Values represent mean ± SD.

N/A = not applicable

Dietary Intake of Calcium and Vitamin D

Three subjects consumed a calcium-containing supplement during the 3-day recording period, 1 subject in the 1 to 3 year old group and 2 subjects in the 4 to 8 year old group. The mean dietary intake of calcium by gender and age

categories are presented in Table 9. The mean 3-day dietary intake of calcium in the 1 to 3 year old age group was 891 mg (178% AI) not including supplement intake and 899 mg (180% AI) including supplement intake. The mean 3-day dietary intake of calcium in the 4 to 8 year old age group was 883 mg (110% AI) not including supplement intake and 888 mg (111% AI) including supplement intake. The mean 3-day dietary intake of calcium in the 9 to 18 year old group was 973 mg (75% AI).

Mean dietary intake of vitamin D by age and gender categories are presented in Table 9. Mean 3-day dietary intake of vitamin D in the 1 to 3 year old age group was 209 IU (5.2 mcg; 104% AI) not including supplement intake and 239 IU (5.9 mcg; 119% AI) including supplement intake. Mean 3-day dietary intake of vitamin D in the 4 to 8 year old age group was 180 IU (4.5 mcg; 90% AI) and 227 IU (5.7 mcg; 114% AI) not including supplement intake and including supplement intake. Mean 3-day dietary intake of vitamin D in the 9 to 18 year old group was 198 IU (4.96 mcg; 99% AI).

Comparison of Dietary Calcium and Vitamin D Intake to the AI

The one-tailed small sample t-test was used to compare the calcium and vitamin D intake of study subjects to the AI based on age and gender. The 3-day mean dietary calcium intake without supplements for the 1 to 3 year old group was significantly greater than the AI ($p = 0.001$) (Figure 1). The 3-day mean dietary calcium intake for the 9 to 18 year old age group was significantly lower than the AI ($p = 0.02$). No significant difference was detected between the 3-day mean dietary calcium intake and the AI for the 4 to 8 year old age group. No

significant differences were detected between the 3-day mean dietary vitamin D intake and the AI for all age groups (Figure 2).

Comparison of Dietary Calcium Intake to 1994 to 1996, 1998 CSFII

The one-tailed large sample z-test was used to compare the mean calcium

Table 8. Calcium intake of children and adolescents with asthma compared to the AI by age category.

	Calcium intake* (mg) (% of AI)	AI (mg)	Test of equal mean p-value
Age category (years)	Mean		
1 to 3 (n = 9)	890 ± 244 (178%)	500	0.001
4 to 8 (n = 14)	883 ± 359 (110%)	800	0.200
9 to 18 (n = 13)	973 ± 517 (75%)	1300	0.021

*Values represent mean ± SD.

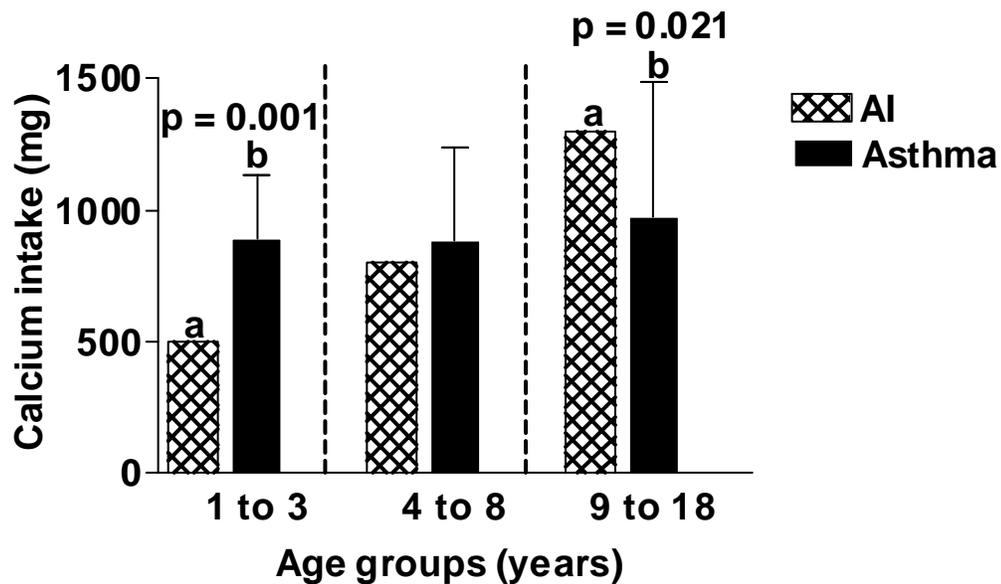


Figure 1. Calcium intake of study subjects (asthma) compared to the AI by age group.

Table 9. Vitamin D intake of children and adolescents with asthma compared to the AI by age category.

	Vitamin D intake* (mcg) (% of AI)	AI (mcg)	Test of equal mean p-value
Age category (years)	Mean		
1 to 3 (n = 9)	5.19 ± 2.43 (104%)	5.0	0.412
4 to 8 (n = 14)	4.49 ± 2.32 (90%)	5.0	0.213
9 to 18 (n = 13)	4.96 ± 3.71 (99%)	5.0	0.484

*Values represent mean ± SD.

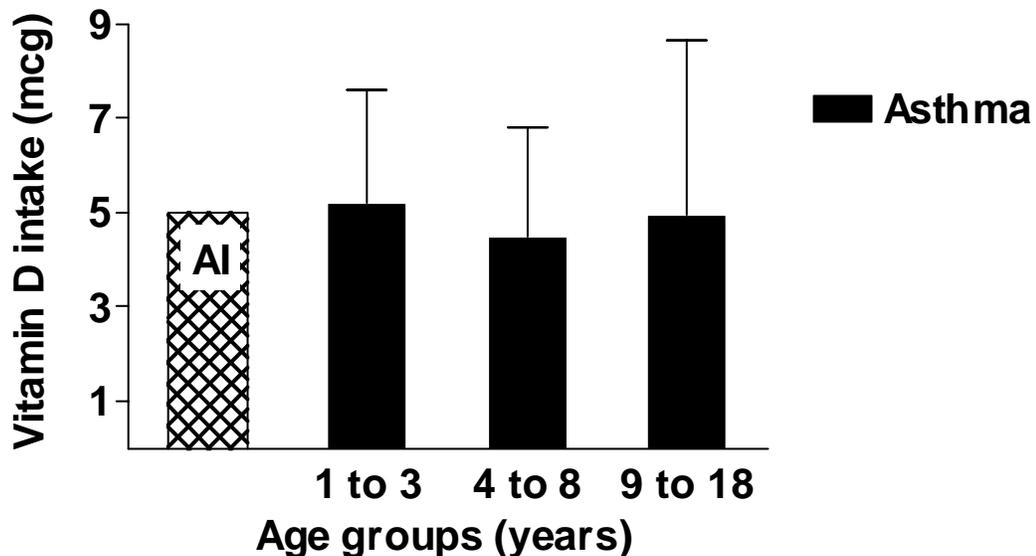


Figure 2. Vitamin D intake of study subjects (asthma) compared to the AI by age group.

intake of study subjects to data from the 1994 to 1996 and 1998 CSFII. The 3-day mean dietary calcium intake of study subjects in the 1 to 3 year old age category was significantly ($p = 0.001$) less than the mean dietary calcium intake of the age-matched reference population (i.e., CSFII) (Table 10 and Figure 3),

although the mean intake for both groups exceeded the AI. No significant ($p > 0.05$) differences in mean dietary calcium intake between the study subjects and the age-matched reference population were detected in any other age category.

The two-tailed chi-square test was used to compare the variance of the mean calcium intake of study subjects to the variance of the age-matched reference population. The variance of the mean calcium intake of study subjects in the 9 to 18 year old age category was significantly different than the variance of the mean calcium intake of the age-matched reference population (Figure 4). No significant differences were detected in the variance of the mean for calcium intake of the subjects compared to the age-matched reference population in the remaining age categories.

Table 10. Calcium intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Calcium intake* (mg)		Test of equal mean	Test of equal variance
	CSFII	Asthma	p-value	p-value
1 to 3	1297 ± 397 (n = 4,027)	891 ± 244 (n = 9)	0.001	0.934
4 to 8	721 ± 99 (n = 3,935)	883 ± 359 (n = 14)	1.000	0.188
9 to 18	392 ± 110 (n = 2130)	973 ± 517 (n = 13)	1.000	<0.001

*Values represent mean ± SD.

Intake of Milk and Milk Products

Intake of dairy products was determined based on the categories used for the CSFII (Appendix C). The percent of total calcium intake from several dairy

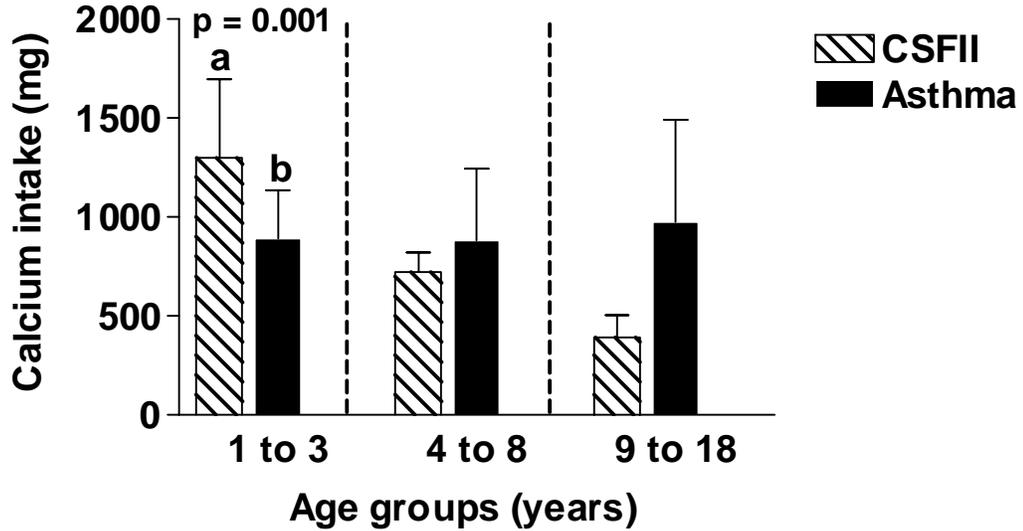


Figure 3. Calcium intake of study subjects (asthma) compared to CSFII by age group.

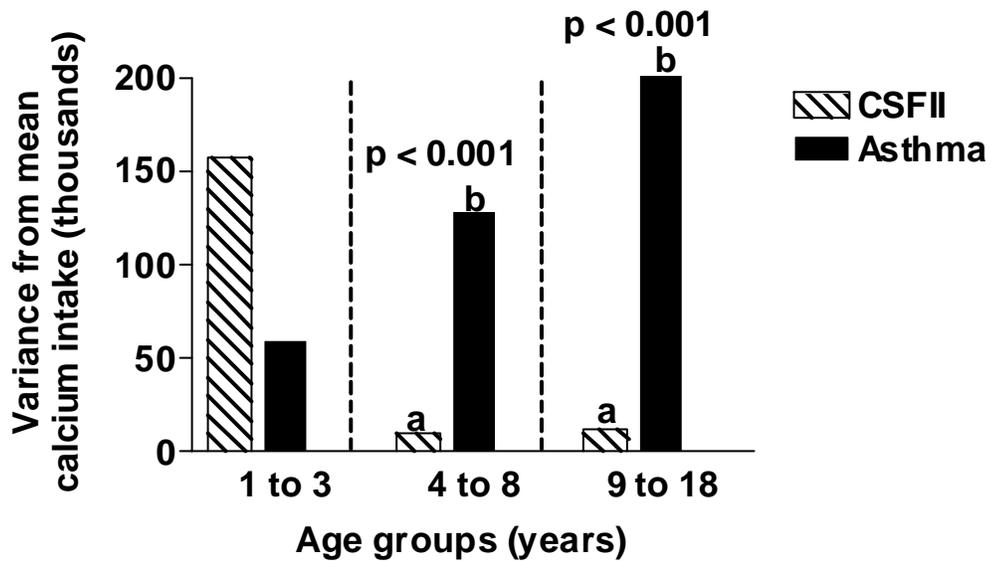


Figure 4. Variance from the mean calcium intake of study subjects (asthma) compared to CSFII by age group.

product categories by age are expressed in Table 11. Mean dietary intake for each dairy product category by age and gender are presented in Tables 12 to 20.

Table 11. Calcium intake and percent of total calcium intake from dairy product categories.

Age category (years)	Total calcium intake (mg)	Calcium intake* (mg) (% of total)			
		Total milk & milk products	Total milk, milk drinks, and yogurt	Milk desserts	Cheese
1 to 3	891	572 ± 238 64.2%	456 ± 247 51.2%	31 ± 47 3.4%	86 ± 85 9.6%
4 to 8	883	543 ± 290 61.4%	386 ± 284 43.7%	71 ± 75 8.0%	84 ± 85 9.5%
9 to 18	973	535 ± 417 55.0%	378 ± 361 38.8%	20 ± 39 2.0%	136 ± 128 14.0%
1 to 18	918	547 ± 323 59.6%	401 ± 299 43.7%	42 ± 60 4.6%	103 ± 120 11.2%

*Values represent mean ± SD.

Comparison of Milk and Milk Products Intake to 1994 to 1996, 1998 CSFII

The two-tailed large sample z-test was used to compare the 3-day mean dietary intake of various categories of dairy products of the study subjects to the age-matched reference population. No significant differences were detected between the intake of study subjects compared to the age-matched reference population for any of the dairy product categories for any of the age categories (Figures 5 to 13).

Table 12. Total milk and milk products intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Total milk and milk products intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	438 ± 324 (n = 11,737)	423 ± 200 (n = 9)	0.444
4 to 8	409 ± 279 (n = 11,473)	391 ± 245 (n = 14)	0.405
9 to 18	362 ± 345 (n = 6,204)	386 ± 336 (n = 13)	0.595

*Values represent mean ± SD.

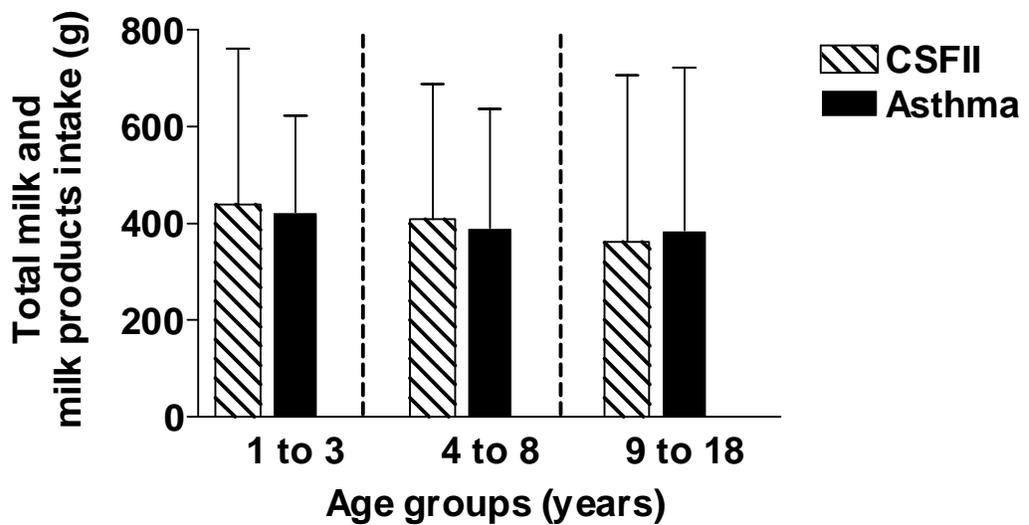


Figure 5. Total milk and milk products intake by study subjects (asthma) compared to CSFII by age group.

Table 13. Total milk, milk drinks, and yogurt intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Total milk, milk drinks, and yogurt intake* (g)		Test of equal mean p-value
	CSFII	Asthma	
1 to 3	411 ± 322 (n = 11,737)	384 ± 208 (n = 9)	0.397
4 to 8	367 ± 271 (n = 11,473)	321 ± 241 (n = 14)	0.261
9 to 18	313 ± 353 (n = 6,204)	334 ± 335 (n = 13)	0.583

*Values represent mean ± SD.

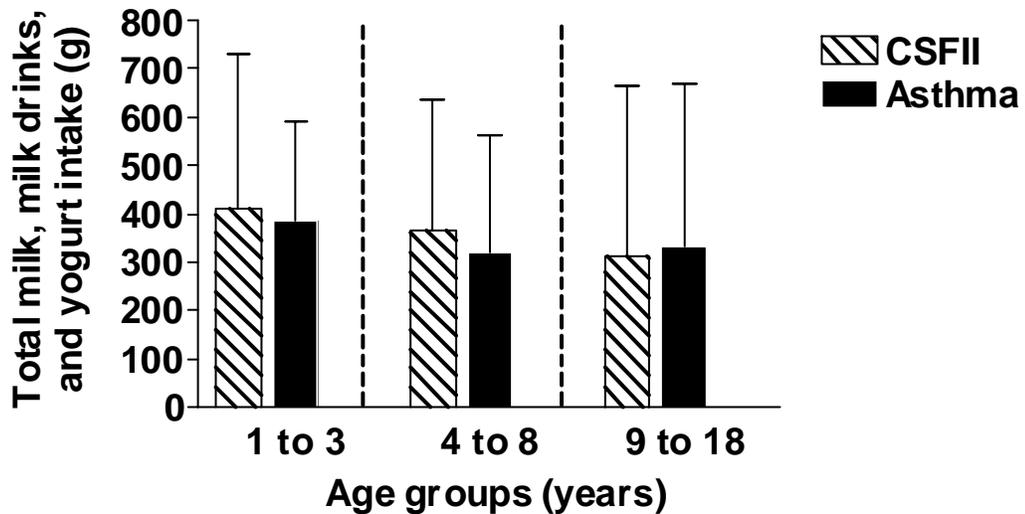


Figure 6. Total milk, milk drinks, and yogurt intake by study subjects (asthma) compared to CSFII by age group.

Table 14. Total fluid milk intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Total fluid milk intake* (g)		Test of equal mean p-value
	CSFII	Asthma	
1 to 3	374 ± 317 (n = 11,737)	289 ± 172 (n = 9)	0.212
4 to 8	315 ± 259 (n = 11,473)	263 ± 247 (n = 14)	0.227
9 to 18	263 ± 308 (n = 6,204)	269 ± 300 (n = 13)	0.528

*Values represent mean ± SD.

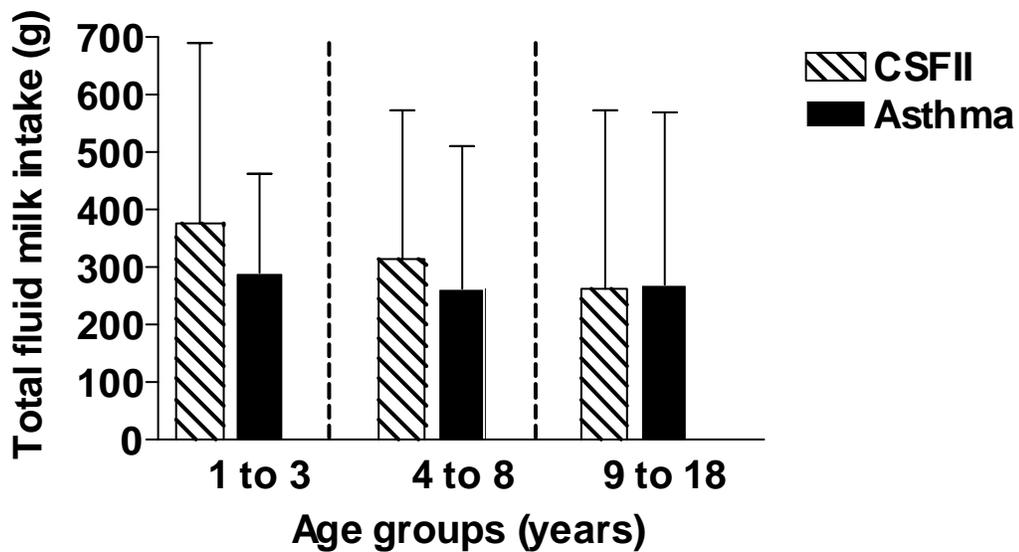


Figure 7. Total fluid milk intake by study subjects (asthma) compared to CSFII by age group.

Table 15. Whole milk intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Whole milk intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	221 ± 313 (n = 11,737)	198 ± 177 (n = 9)	0.417
4 to 8	125 ± 211 (n = 11,473)	139 ± 234 (n = 14)	0.603
9 to 18	89 ± 204 (n = 6,204)	138 ± 233 (n = 13)	0.805

*Values represent mean ± SD.

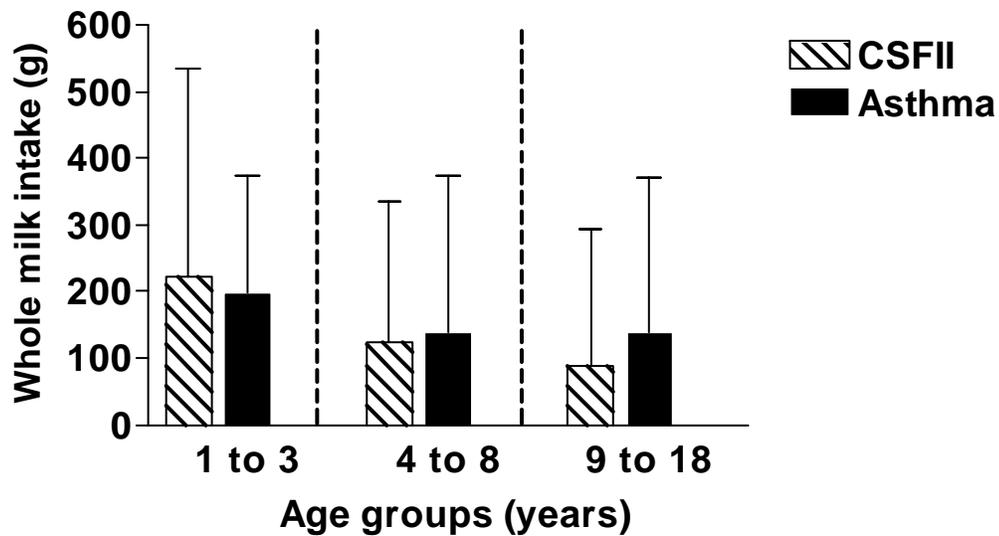


Figure 8. Whole milk intake by study subjects (asthma) compared to CSFII by age group.

Table 16. Lowfat milk intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Lowfat milk intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	132 ± 238 (n = 11,737)	55 ± 125 (n = 9)	0.164
4 to 8	156 ± 232 (n = 11,473)	76 ± 137 (n = 14)	0.099
9 to 18	136 ± 257 (n = 6,204)	75 ± 245 (n = 13)	0.195

*Values represent mean ± SD.

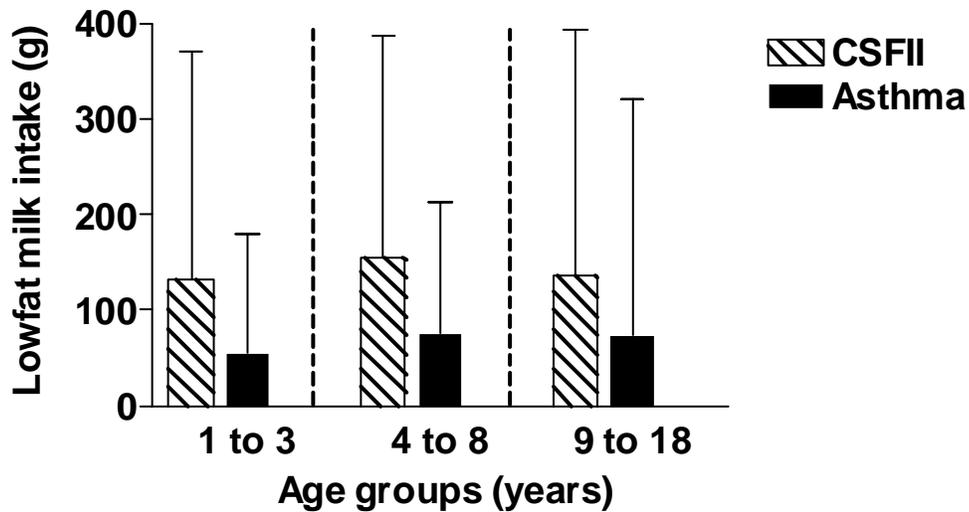


Figure 9. Lowfat milk intake by study subjects (asthma) compared to CSFII by age group.

Table 17. Skim milk intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Skim milk intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	15 ± 88 (n = 11,737)	36 ± 56 (n = 9)	0.764
4 to 8	25 ± 75 (n = 11,473)	45 ± 79 (n = 14)	0.839
9 to 18	35 ± 135 (n = 6,204)	38 ± 136 (n = 13)	0.532

*Values represent mean ± SD.

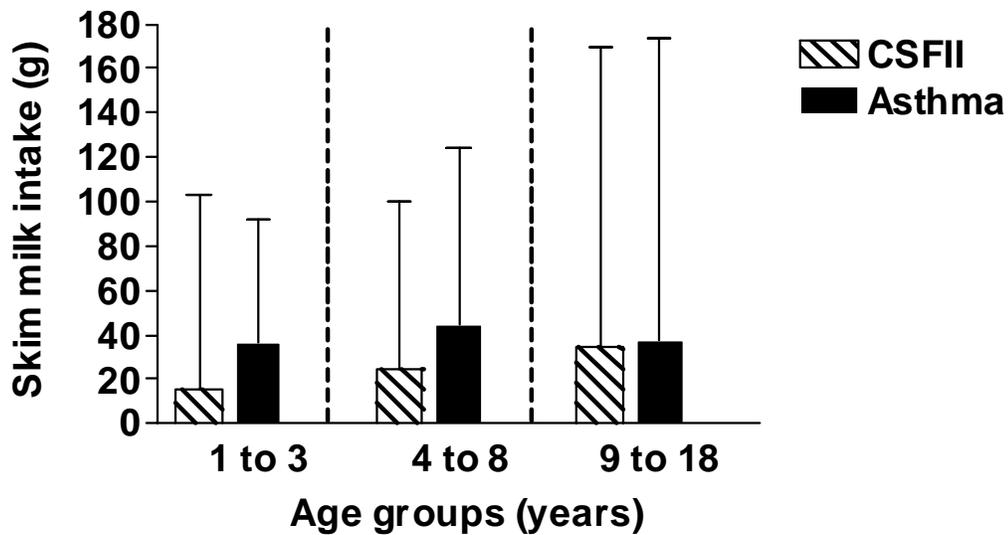


Figure 10. Skim milk intake by study subjects (asthma) compared to CSFII by age group.

Table 18. Yogurt intake by study subjects (asthma) compared to CSFII by age group.

Age category (years)	Yogurt intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	11 ± 41 (n = 11,737)	4 ± 13 (n = 9)	0.312
4 to 8	7 ± 34 (n = 11,473)	12 ± 25 (n = 14)	0.702
9 to 18	4 ± 30 (n = 6,204)	0 ± 0 (n = 13)	0.305

*Values represent mean ± SD.

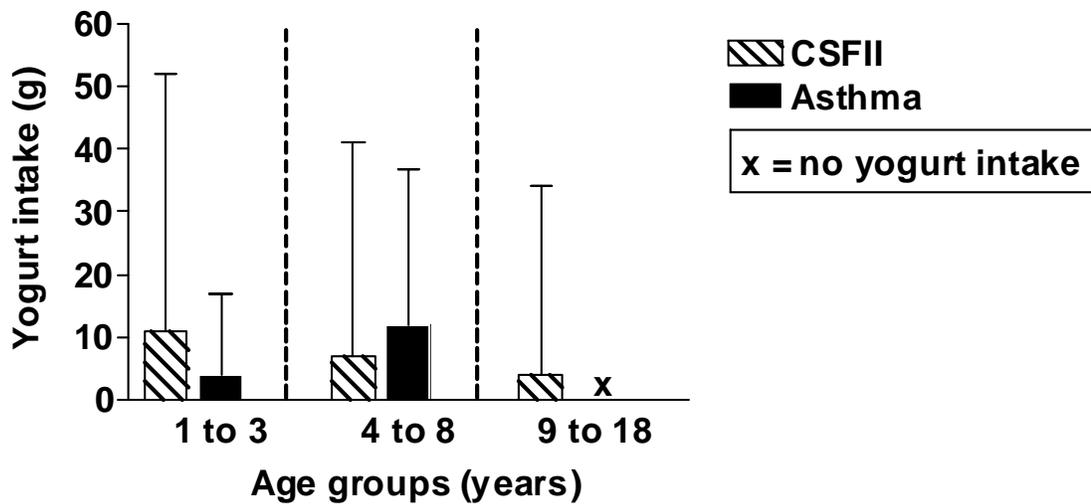


Figure 11. Yogurt intake by study subjects (asthma) compared to CSFII by age group.

Table 19. Milk desserts intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Milk desserts intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	16 ± 41 (n = 11,737)	27 ± 41 (n = 9)	0.794
4 to 8	27 ± 59 (n = 11,473)	55 ± 64 (n = 14)	0.960
9 to 18	30 ± 81 (n = 6,204)	20 ± 37 (n = 13)	0.316

*Values represent mean ± SD.

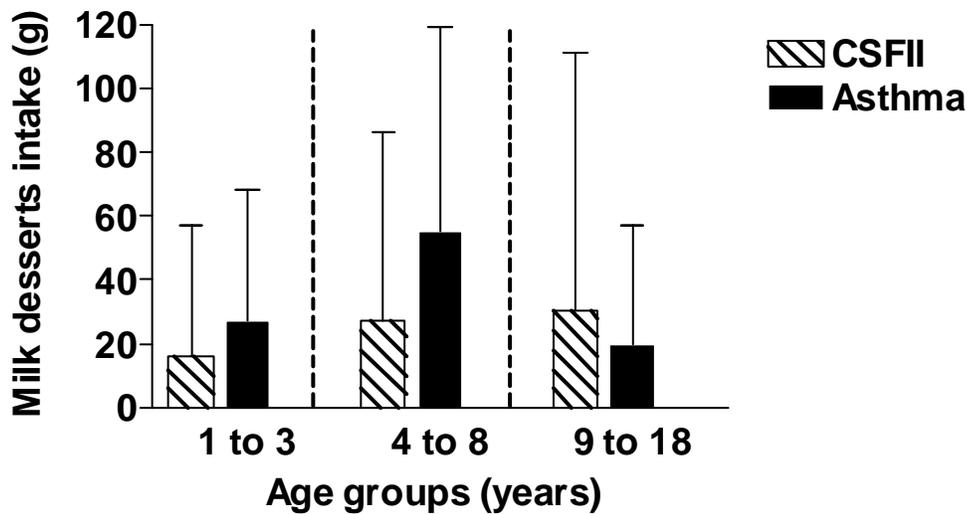


Figure 12. Milk dessert intake by study subjects (asthma) compared to CSFII by age group.

Table 20. Cheese intake of study subjects (asthma) compared to CSFII by age group.

Age category (years)	Cheese intake* (g)		Test of equal mean
	CSFII	Asthma	p-value
1 to 3	11 ± 22 (n = 11,737)	13 ± 12 (n = 9)	0.610
4 to 8	13 ± 27 (n = 11,473)	14 ± 23 (n = 14)	0.587
9 to 18	16 ± 35 (n = 6,204)	24 ± 21 (n = 13)	0.797

*Values represent mean ± SD.

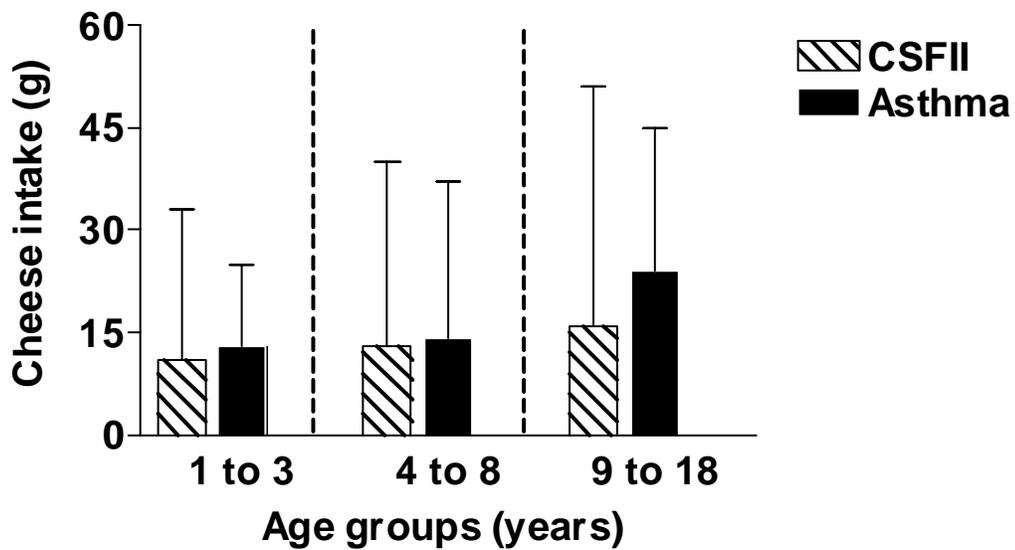


Figure 13. Cheese intake by study subjects (asthma) compared to CSFII by age group.

CHAPTER 5 DISCUSSION AND CONCLUSIONS

Adequate calcium and vitamin D intake is important during childhood and adolescence to promote adequate bone mineralization and achievement of PBM (22,45-48,56). Inadequate intake of these nutrients increases the risk for osteoporosis (22). Milk and dairy products are good dietary sources of calcium and vitamin D. Children and adolescents with asthma may be at risk for osteoporosis for several reasons, one of which may be related to inadequate calcium and vitamin D intake due to the restriction or avoidance of milk and dairy products intake. Parents of children with asthma and adults with asthma have been reported to avoid these foods due to the unfounded belief that they worsen or contribute to asthma symptoms (6,7). This could have a negative impact on bone density, especially in a population that is already at risk due the use of certain medications that may negatively influence bone density, as well as the tendency to restrict the frequency and type of physical activity in an effort to avoid wheezing and other asthma symptoms (2,8,9).

The objectives of this study were to determine the adequacy of calcium and vitamin D intake of children and adolescents with asthma using a 3-day food and supplement diary and to compare their intake of these nutrients to an age-appropriate AI. Another objective was to determine if calcium and milk and dairy products intake of children and adolescents with asthma are less than those of an age-matched reference population.

After reviewing the published research, only one study examining dietary intake of calcium and dairy products in individuals with asthma was identified. This study was conducted in adults. The researchers found that consumption of certain types of dairy products, such as whole milk, butter, ricotta cheese, and low-fat cheese, were different in adult subjects with asthma compared to those without asthma, but there was no difference in the overall intake of dairy products and nutrients, including calcium, between the groups (86).

A total of 84 subjects (i.e., 56 males, 28 females) were enrolled in the study; however only 36 (i.e., 26 males, 10 females) returned the 3-day food and supplement diary for an overall return rate of 42.9%. The return rates by age categories were 40.9%, 51.9%, and 37.1% for the 1 to 3 year old, 4 to 8 year old, and 9 to 18 year old age categories, respectively. Our return rate was relatively consistent with the dietary intake survey conducted by mail with adults diagnosed with asthma, in which the overall response rate was 36% (86). It is possible that the 9 to 18 year old age group had the lowest return rate because of greater independence from parental guidance, related to a higher level of reading and writing skills. In contrast, the younger age groups required parental assistance with this task, which may have increased the return rate.

Currently, there are no published data on calcium and vitamin D intake in children and adolescents with asthma. Data from our study indicated that the 3-day mean dietary calcium intake for the 1 to 3 year old group was significantly greater than the AI for this nutrient ($p = 0.001$), but significantly less than the mean dietary calcium intake of the age-matched reference population (i.e.,

CSFII) ($p = 0.001$). Despite our efforts to recruit as many subjects as possible and to increase return rate, the sample size for the 1 to 3 year old age category did not have adequate statistical power. This also is true for the 4 to 8 year old and the 9 to 18 year old age categories and this is important to keep in mind for those comparisons in which a significant difference was not detected.

No significant differences in the 3-day mean dietary calcium intake for the 4 to 8 year old children with asthma compared to the AI and the age-matched reference population were detected in our study. This suggests that children with asthma in this age group are meeting their needs for calcium and are consuming amounts of calcium similar to non-asthmatic children. In addition, children with asthma between the ages of 4 and 8 years consumed approximately 61% of their calcium from milk and dairy products. These results differ from reports of milk and dairy products avoidance in children with asthma (6,7). In the general population of children, adolescents, and adults, as estimated from data from the 1994 to 1996 and 1998 CSFII and the NHANES III, milk and dairy products are major sources of dietary calcium, accounting for 48% of calcium intake (44). In children and adolescents between the ages of 1 and 18 years, as estimated from the 1994 to 1996 and 1998 CSFII, dairy foods and ingredients contribute to approximately 62% of calcium intake (35). This suggests that children with asthma between the ages of 4 to 8 years are generally consuming a similar amount of calcium from milk dairy products as children without asthma and thus are not avoiding or eliminating milk and dairy products due to their asthma.

In the 9 to 18 year old age group, the 3-day mean dietary calcium intake for our study population was significantly lower than the AI ($p = 0.02$), but not significantly different from the age-matched reference population. This finding suggests that all children and adolescents between the ages of 9 and 18 years, regardless of whether they have asthma, are not consuming adequate amounts of dietary calcium to promote optimal bone health. In addition, children and adolescents with asthma between the ages of 9 and 18 years consumed approximately 55% of their calcium from milk and dairy products. These results differ from reports of milk and dairy products avoidance in children and adolescents with asthma (6,7). It has been estimated that children, adolescents, and adults, consume approximately 48% of their calcium from milk and dairy products and specifically children and adolescents consume 62% of their calcium from dairy foods (35,44). This suggests that children with asthma between the ages of 9 to 18 years are generally consuming a similar amount of calcium from milk dairy products as children without asthma and thus are not avoiding or eliminating milk and dairy products due to their asthma.

The inadequate dietary calcium intake observed in 9 to 18 year old children and adolescents in this study is consistent with reports of milk intake patterns in this age group. Mean intake of milk decreases 38% from 1 to 18 years of age and is due to the dramatic increase in soft drink consumption that begins around 8 years of age (105). Intake of soft drinks exceeds that of milk by 13 years of age. This is important because dietary calcium intake during childhood and adolescence is positively associated with bone density throughout adulthood

(22,45-48). As a result of the inadequate dietary calcium intake observed in this study, children with asthma between the ages of 9 and 18 years may be at risk for low bone density and poor bone health in adulthood.

In addition to calcium, vitamin D intake also was analyzed for each of the 3 age groups. No significant differences were detected between the 3-day mean dietary vitamin D intake and the AI for any of the age categories. The database (Food Processor 8.1 for Windows) (87) used to analyze the 3-day food and supplement diaries does not have complete data for the vitamin D content of foods, so it is possible that the actual vitamin D intake of our study population was higher than reflected by our data. The findings of our study suggest that children and adolescents with asthma between the ages of 1 and 18 years are consuming adequate amounts of vitamin D to promote bone health.

Another aim of our study was to examine dairy intake in our population. Currently, there are no published studies that have reported dairy products intake in children and adolescents with asthma, but there is one study that reported the intake of dairy products in adults with asthma. Woods et al. found that overall intake of dairy products was not significantly different between adults with and without asthma, although the types of dairy products consumed by these 2 groups were significantly different (86). Specifically, asthma was negatively associated with whole milk and butter consumption and positively associated with ricotta and low-fat cheese in adults with asthma. Similarly, no significant difference in total milk and milk products intake of children and adolescents with asthma and the age-matched reference population was detected in our study, but

a significant difference was not detected in the types of dairy products consumed by children and adolescents with asthma compared to the age-matched reference population for each of the age categories.

There are several potential clinical applications extending from our research. Health care professionals, such as dietitians, pediatricians, pulmonologists, and nurses, as well as dietitians in community settings who provide services to children and adolescents with asthma should promote adequate consumption of calcium- and vitamin D-containing foods such as milk and dairy products in this population, especially in children between the ages of 9 and 18 years. If milk or dairy products need to be avoided due to the lack of tolerance, a disease that necessitates restriction of milk or dairy, or for other reasons (e.g., lack of acceptance, religious beliefs, health beliefs, etc.), health professionals should recommend suitable calcium-containing foods and/or a supplement.

Although this study provides preliminary data on the dietary intake of calcium, vitamin D, and dairy products in children with asthma, a larger study is needed to confirm our findings. A large, multi-center study may be needed to accomplish this goal. Researchers also could examine the relationship between dietary calcium, vitamin D, and dairy products intake in relation to BMD in children and adolescents with asthma, while controlling for other factors that may influence BM such as physical activity and medications.

In summary, this study compared dietary calcium and vitamin D intake of children and adolescents with asthma to the age-appropriate AIs and to survey

data from an age-matched reference population. The results of this study, which indicated that 1 to 3 and 4 to 8 year old children with asthma met or exceeded the AI for calcium and vitamin D and 9 to 18 year old children and adolescents with asthma consumed less than the AI for calcium have potential clinical applications. Although 9 to 18 year old children and adolescents with asthma consumed less than the AI for calcium, their intake paralleled that of intake data from a national survey. The level of calcium intake from milk and dairy products that was consumed by children and adolescents in our study was similar to the level of intake estimated for the general population. This suggests that in our small study population, individuals with asthma do not avoid or restrict their intake of dairy products; however there is still a need to focus on encouraging adequate intake of calcium- and vitamin D-containing foods such as milk and dairy products, especially in 9 to 18 year old children and adolescents. The results from this study are novel because this is the first study to examine the dietary intake of calcium and vitamin D in children and adolescents with asthma and will pave the way for future studies.

APPENDIX A
THREE-DAY FOOD AND SUPPLEMENT DIARY DIRECTIONS

***Please record everything your child consumes for 3 days, including foods, beverages, and supplements.**

1. Please select three days, including one weekend day (Friday, Saturday, or Sunday).
2. Please record the foods, beverages, and supplements you consume and the amounts of each that you consume as soon after eating as possible. This prevents you from forgetting foods, or over- or under- estimating what you have consumed.
3. In the column labeled “**Foods, Beverages, and Supplements Consumed**” record what you ate. Please be as specific as possible. For example, if you consumed milk: indicate skim, 1%, 2%, or whole. If you consumed cereal, indicate what kind of cereal. If you consumed bread, indicate what kind of bread (white, wheat, rye, oat bran, etc.). Don’t forget to include condiments, such as catsup, mustard, jelly, salad dressing, sauces, etc.

For example:

Foods, Beverages, Supplements Consumed	Description	Amount Consumed
Milk	1% low fat	1 cup
Cornflakes	Kellogg’s	1 ½ cups
Bread	Publix honey wheat	1 slice
Jelly (on bread)	Smucker’s strawberry jam	1 teaspoon
Sugar (on cereal)	White granulated	2 teaspoons

4. In the column labeled “**Description**” please list the brand name and give a product description or include the product label or recipe whenever possible. Tell how the food was cooked (fried, baked, etc). If you ate away from home, list the name of the restaurant or food shop. Be sure to include information about things that you add to your food before you eat it, like margarine, salt, sugar, milk, etc. Please refer to the example above.

5. In the column labeled “**Amount Consumed**” please list the amount of each food, beverage or supplement you consume. Tell how many cups, ounces (oz), teaspoons (tsp), tablespoons (tbsp) you eat or the weight or number of portions or pieces you eat.
6. A sample food diary is included on the next page to help you.
7. When you have completed the diary, please return in the postage-paid stamped envelope that has been provided.

Sample:

Foods, Beverages, Supplements Consumed List each food, beverage or supplement you consume. List only one item per line.	Description List the brand name and product description or include the product label or recipe for everything you eat. Tell how the food was cooked (fried, baked, etc). If you ate away from home, list the name of the restaurant or food shop. Be sure to include information about things that you add to your food before you eat it, like margarine, salt, sugar, milk, etc	Amount Consumed List the amount of each food, beverage or supplement you consume. Tell how many cups, ounces (oz), teaspoons (tsp), tablespoons (tbsp) you eat or the weight or number of portions or pieces you eat.
Corn Flakes	Kellogg's brand	1 cup
Milk	2%	1/2 cup
Banana	Small	1
Turkey	Baked	2 oz.
Bread	whole wheat, toasted	2 slices
Mayonnaise	Hellmann's brand-Light	1 tsp.
Tomato		2 slices
Apple	With skin	
Pepsi, can		12 oz.
Ice cream	Albertson's brand	1 cup
Chicken Breast	Grilled, no skin	3 oz.
Green beans	Canned, prepared with 1 tbsp. butter and 1 tsp. salt	1/2 cup
Rice	White, Boiled	1 cup
Apple pie	Store bought, bakery	1/5 pie
Children's multivitamin	Flintstone's Brand	1

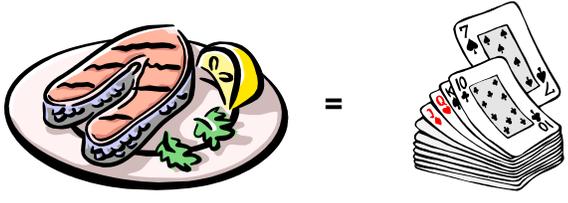
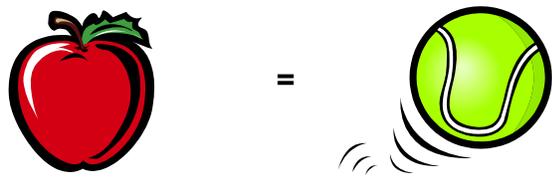
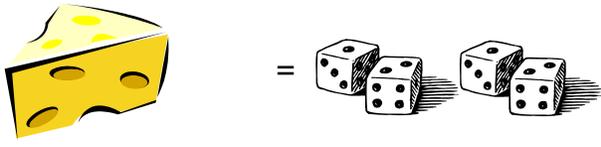
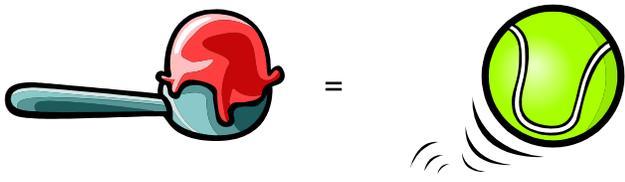
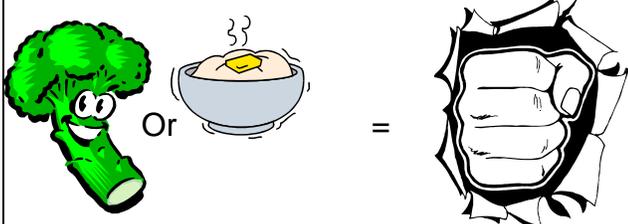
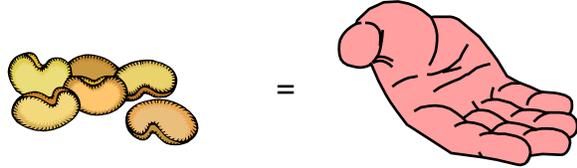
1 cup = 8 fluid ounces (8 fl. oz.) = 237 ml

3 teaspoons = 1 tablespoon

4 tablespoons = 1/4 cup

1 oz. = 28 g (grams)

Estimating Portion Sizes

3 ounces of meat, poultry, or fish is about the size and thickness of a deck of playing cards	
A medium-size piece of fruit (e.g., apple or peach) is about the size of a tennis ball	
1 ounce of cheese is about the size of 4 dice	
½ cup of ice cream, frozen yogurt, yogurt, or cottage cheese is about the size of a tennis ball	
1 cup of mashed potatoes or broccoli is about the size of your fist	
1 teaspoon of butter, margarine, or peanut butter is about the size of the tip of your thumb	
1 ounce of nuts or small candies is about one handful	

Adapted from: Southern Illinois University Carbondale Wellness Center Nutrition Program. 3-day recall. Available at: <http://www.siu.edu/~shp/ Acrobat2002/Recall.pdf>. Accessed February 2002.

APPENDIX B
THREE-DAY FOOD AND SUPPLEMENT DIARY FORM

Name: _____

3-day Food and Supplement Diary

Day 1

Foods, Beverages and Supplements Consumed List each food, beverage or supplement you consume. List only one item per line.	Description List the brand name and product description or include the product label or recipe for everything you eat. Tell how the food was cooked (fried, baked, etc). If you ate away from home, list the name of the restaurant or food shop. Be sure to include information about things that you add to your food before you eat it, like margarine, salt, sugar, milk, etc.	Amount Consumed List the amount of each food, beverage or supplement you consume. Tell how many cups, ounces (oz), teaspoons (tsp), tablespoons (tbsp) you eat or the weight or number of portions or pieces you eat.

Name: _____

3-day Food and Supplement Diary

Day 2

Foods, Beverages and Supplements Consumed List each food, beverage or supplement you consume. List only one item per line.	Description List the brand name and product description or include the product label or recipe for everything you eat. Tell how the food was cooked (fried, baked, etc). If you ate away from home, list the name of the restaurant or food shop. Be sure to include information about things that you add to your food before you eat it, like margarine, salt, sugar, milk, etc.	Amount Consumed List the amount of each food, beverage or supplement you consume. Tell how many cups, ounces (oz), teaspoons (tsp), tablespoons (tbsp) you eat or the weight or number of portions or pieces you eat.

Name: _____

3-day Food and Supplement Diary

Day 3

Foods, Beverages and Supplements Consumed List each food, beverage or supplement you consume. List only one item per line.	Description List the brand name and product description or include the product label or recipe for everything you eat. Tell how the food was cooked (fried, baked, etc). If you ate away from home, list the name of the restaurant or food shop. Be sure to include information about things that you add to your food before you eat it, like margarine, salt, sugar, milk, etc.	Amount Consumed List the amount of each food, beverage or supplement you consume. Tell how many cups, ounces (oz), teaspoons (tsp), tablespoons (tbsp) you eat or the weight or number of portions or pieces you eat.

APPENDIX C DAIRY PRODUCT CATEGORY DEFINITIONS

MILK AND MILK PRODUCTS

Total milk and milk products: Includes milk and milk drinks, yogurt, milk desserts, and cheese. Fluid and whipped cream, half-and-half, sour cream, and milk sauces and gravies are included in this total but not in any of the following subgroups. Excludes butter and nondairy sweet cream and sour cream substitutes, which are tabulated under Fats and Oils. Excludes milk and milk products that were ingredients in food mixtures coded as a single item and tabulated under another food group. For example, cheese on pizza is tabulated under Grain Products.

Total milk, milk drinks, yogurt: Includes fluid milk and yogurt. Flavored milk and milk drinks, meal replacements with milk, milk-based infant formulas, and unreconstituted dry milk and powdered mixtures are included in this total but not in any of the following subgroups.

Total fluid milk: Includes fluid whole, lowfat, skim, and acidophilus milk; buttermilk; reconstituted dry milk; evaporated milk; and sweetened condensed milk.

Whole milk: Includes whole fluid milk, low-sodium whole milk, and reconstituted whole dry milk.

Lowfat milk: Includes lowfat (1 and 2 percent) milk, buttermilk (lowfat and nonfat), acidophilus milk, lowfat lactose-reduced fluid milk, and reconstituted lowfat dry milk.

Skim milk: Includes skim or nonfat fluid milk, lactose-reduced fluid nonfat milk, and reconstituted nonfat dry milk.

Yogurt: Includes plain, flavored, and fruit-variety yogurt. Excludes frozen yogurt, which is tabulated under "milk desserts."

Milk desserts: Includes ice cream, imitation ice cream, ice milk, sherbet, frozen yogurt, and other desserts made with milk, such as pudding, custard, and baby-food pudding.

Cheese: Includes natural hard and soft cheeses, cottage cheese, cream cheese, processed cheese and spreads, imitation cheeses, and mixtures having cheese

as a main ingredient, such as cheese dips and cheese sandwiches coded as a single item.

Source: United States Department of Agriculture (USDA), Agricultural Research Service. Food and Nutrient Intakes by Children 1994-1996, 1998. Table Set 17. 1999. *On Continuing Survey of Food Intakes by Individuals, 1994-1996, 1998*. CD-ROM.

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BIOGRAPHICAL SKETCH

Melissa Metz (Myers) was born in Cincinnati, Ohio, and raised in Mobile, Alabama, and Clearwater, Florida. She attended Countryside High School and graduated with honors in 1998. She attended the University of Florida for her undergraduate studies and graduated with honors in 2002 with a Bachelor of Science in food science and human nutrition, specializing in dietetics. During her undergraduate studies she was actively involved in the Food Science and Human Nutrition Club and held several offices, including President in 2002. She also received several scholarships, including the Dorothy MacRae Hyman Memorial Scholarship, SHARE Scholarship, and the Earl Wilmott Hartt Scholarship.

During her graduate program, she completed a Pediatric Pulmonary Traineeship at the UF College of Medicine Pediatric Pulmonary Center and received the Beechnut Dietetic Internship/Pre-professional Practice Program scholarship from the American Dietetic Association Pediatric Nutrition Practice Group. She is a member of the American Dietetic Association, Florida Dietetic Association, Gainesville District Dietetic Association, and the ADA Pediatric Nutrition Practice Group. She plans to pursue a career in pediatric nutrition. Her long-term goals are to establish a private practice to counsel overweight and obese children and adolescents and actively promote nutrition and oral health.