THE ASSOCIATION BETWEEN DIETARY IODINE CONSUMPTION AND BODY COMPOSITION IN CAUCASIAN FEMALES BETWEEN THE AGES OF 18 TO 60

A THESIS

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BY

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To the Dean of the Graduate School:

I am submitting herewith a thesis written by Alexis Neal entitled "The Association Between Dietary Iodine Consumption and Body Composition in Caucasian Females Between the Ages of 18 to 60." I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Exercise and Sports Nutrition.

Nancy DiMarco, Ph. D., Major Professor

We have read this thesis and recommend its acceptance:

Department Chair/Dean

Accepted:

Interim Dean of the Graduate School

ABSTRACT

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THE ASSOCIATION BETWEEN DIETARY IODINE CONSUMPTION AND BODY COMPOSITION IN CAUCASIAN FEMALES BETWEEN THE AGES OF 18 TO 60

DECEMBER 2012

The purpose of this study was to determine if there was an association between dietary iodine consumption and body composition in Caucasian females between the ages of 18 to 60. Spearman rank order correlation assessed the association between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, total body bone mineral density (TBBMD), and circulating concentrations of T3, T4, and thyrotropin stimulating hormone (TSH). No significant association was found between iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, TSH, T3, or T4. Analysis of variance (ANOVA) evaluated any significant differences between tertiles of iodine intake. ANOVA revealed no significant differences between iodine intake tertiles on percent lean body mass, percent body fat, and waist-to-hip ratio.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Iodine is a micronutrient that is essential for the health and well-being of every individual (Ahad & Ganie, 2010). Iodine is a trace element with 5 g adequate to meet the life-time needs of an individual with a life-span of 70 years (Ahad & Ganie, 2010). Iodine is primarily concentrated in the thyroid gland (70-80%), and a healthy adult body will contain at least 15-20 mg of iodine (Ahad & Ganie, 2010).

The iodine level in plants is a result of the iodine present in the soil in which the plants are growing (Paknahad, 2010). Consequently, those individuals living in countries that still encounter iodine deficiency may be because of the low iodine content of their soils (Mahan & Escott-Stump, 2008). An unpredictable amount of iodine can be found in both drinking water and food (Mahan & Escott-Stump, 2008). The main food sources that provide iodine for the human diet are bread made in commercial bakeries, iodized salt, seaweed, seafood, saltwater fish, molasses, as well as milk and milk products (Brown, 2008; Dunford, 2006). Seafood choices include oysters, lobsters, clams, sardines, and other saltwater fish (Mahan & Escott-Stump, 2008). Iodophors are another way that iodine enters into our food; these include coloring agents, dough conditioners, and disinfectants used in dairy processing (Paknahad, 2010). Iodine content in milk is mainly affected by iodophor sanitizing solutions used by the dairy industry and iodine added to animal feed (Pennington, 1990).

Goitrogens are substances that are naturally present in foods that can block iodine uptake by the thyroid cells from the blood. Goitrogens can reduce iodine organification by the thyroid gland (Konijn, Gershon, & Guggenheim, 1973). Food items that contain these substances are soybeans, cassava, sweet potatoes, peanuts, kelp, cabbage, turnips, and rapeseeds from rapeseed plants (Paknahad, 2010). Goitrogens can be inactivated during cooking or when heated (Paknahad, 2010).

In the body, iodine is a component of thyroid hormones and regulates growth, as well as energy production. Thyroid hormones are important for metabolism and growth, as well as numerous biochemical reactions (Soldin, 2007). Iodine can affect brain development and has increased importance in the maturation of fetal heart and lungs (Soldin, 2007). About 25% of iodine in an individual's diet is taken up by the thyroid gland (McCance & Huether, 2006). Most of the iodine in an individual's body can be found in the thyroid gland with the remainder primarily located in the gastric mucosa, blood, and mammary gland (Mahan & Escott-Stump, 2008). Iodine can be bound to protein or it can exist freely in circulation, with the predominating form being bound iodide (Mahan & Escott-Stump, 2008). Iodide (I^-) is the inorganic form of iodine (I_2) and the form that enters the thyroid gland (Ahad & Ganie, 2010). Thyroidal peroxidase then oxidizes iodide to iodine (Filetti et al., 1999). The enzyme, thyroidal peroxidase, liberates iodine for addition onto tyrosine residues. Therefore, thyroidal peroxidase catalyzes the iodination of tyrosine residues to form both monoiodotyrosine (MIT) and diiodotyrosine (DIT), which assists with the formation of triiodthyronine (T3) and

thyroxine (T4; Ruf & Carayon, 2006). A mineral that is important in iodine metabolism is selenium because it is part of one of the enzymes, iodothyronine-5'-deiodinase, that contributes to the formation of active T3 from thyroglobulin and T4 (Arthur et al., 1992).

Figure 1 that follows shows iodine metabolism in the thyroid follicle. A follicular cell of the thyroid is displayed below facing the follicular lumen (top) and the extracellular space (bottom; Murray, Granner, & Rodwell, 2006). Iodide mainly enters the thyroid gland through a transporter (bottom left; Murray, Granner, & Rodwell, 2006). Thyroid hormone synthesis takes place in the follicular space during a series of reactions; and, many of these reactions are peroxidase-mediated (Murray, Granner, & Rodwell, 2006). Thyroid hormones that are stored in the colloid of the follicular space are released from thyroglobulin through hydrolysis within the thyroid cell (Murray, Granner, & Rodwell, 2006).

The thyroid gland usually produces about 90% T4 and 10% T3, with T4 having the ability to convert to T3 in tissues of the human body (McCance & Huether, 2006). Iodine stored in the thyroid gland is used in the production of both thyroid hormones, T3 and T4 (Ahad & Ganie, 2010). T3 has the predominant metabolic effects in the body (Arthur, Nicol, & Beckett, 1992). The storage form of thyroid hormones is thryoglobulin which is stored in the thyroid gland (Ahad & Ganie, 2010). Iodine excretion is mainly through the urine, but small percentages can be found in feces because of biliary secretion (Mahan & Escott-Stump, 2008).

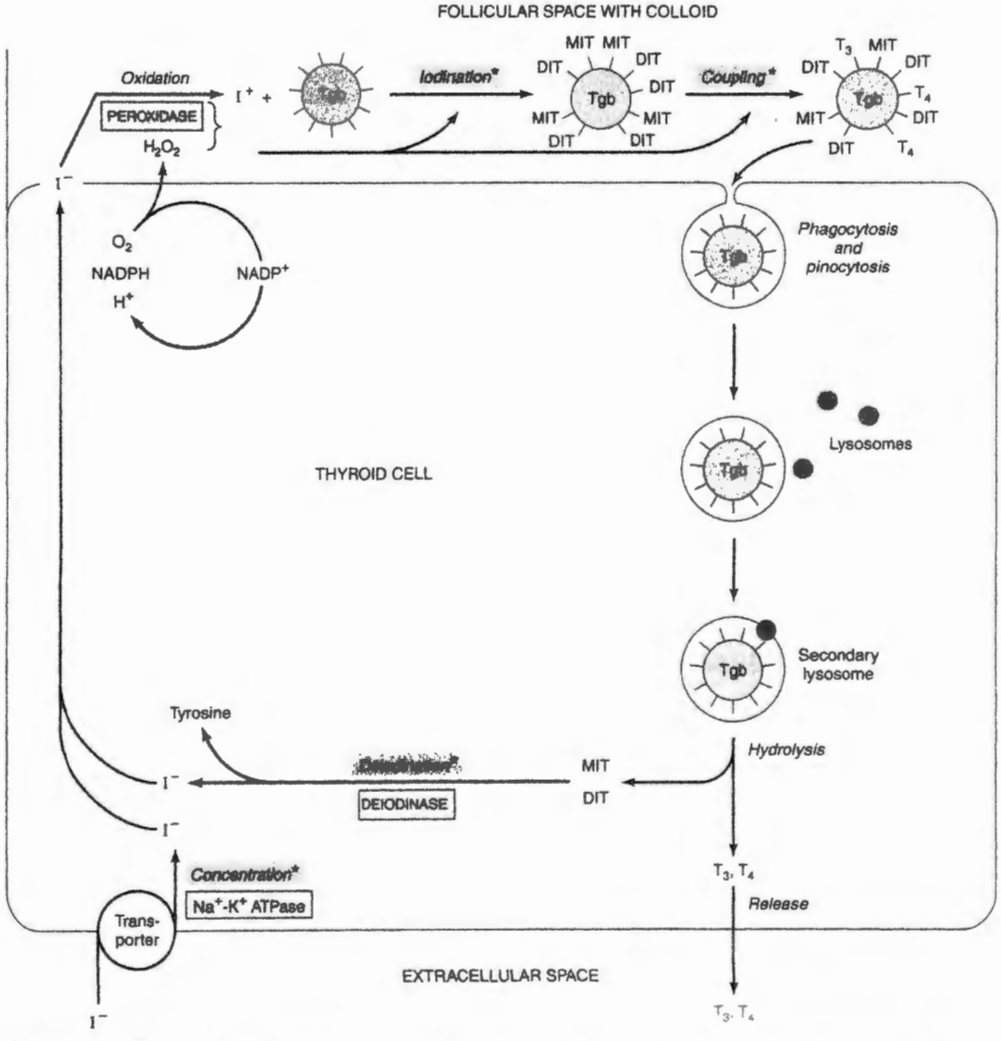

Figure 1: Iodide Metabolism Model in the Thyroid Follicle (Murray, Granner, & Rodwell, 2006)

[Tgb- thyrogolbulin, MIT- monoiodotyrosine, DIT- diiodotyrosine, T_3- triiodothyronine, T_4- tetraiodothyronine]. Asterisks indicate steps or processes that are inherited enzyme deficiencies that cause congenital goiter and often result in hypothyroidism.

Thyroid hormones regulate metabolism in humans (American Thyroid Association, 2005). Metabolism is determined by the measurement of oxygen utilized by the body over a specified amount of time (American Thyroid Association, 2005). If this

measurement is acquired while the individual is at complete rest, then it is called the basal metabolic rate (BMR; American Thyroid Association, 2005). An individual who has an inefficiently working thyroid gland will experience changes in BMR (American Thyroid Association, 2005). Patients with hyperthyroidism, which is excess secretion of thyroid hormone, tend to have an elevated BMR, and concentrations of serum T3 and T4 that can lead to weight loss. Patients with hypothyroidism, which is deficiency of the thyroid hormone, tend to have a decreased BMR and serum T4 concentration that can lead to weight gain. Conversely, T3 concentration can be low or normal in these individuals. Numerous physicians no longer use BMR because it is a complex test, and BMR can be affected by many other influences beside the state of the thyroid (American Thyroid Association, 2005). With the increasing incidence of obesity and potential lack of iodine in the American diet, use of iodine supplements may help to prevent or decrease obesity through the alteration of body composition and BMR. Therefore, this study assessed whether the amount of iodine an individual eats could also affect their body composition which includes body weight, total body bone mineral density (TBBMD), waist-to-hip ratio, percent body fat, and percent lean body mass.

Purpose of this Study

The purpose of this retrospective study was to determine if there is an association between dietary iodine consumption and body composition in Caucasian females between the ages of 18 to 60. The data used for this study came from the Pioneer Project, a longitudinal study performed from 2000-2004 in the Institute for Women's Health at

Texas Woman's University. The study observed women's health throughout the reproductive, perimenopausal, and postmenopausal years of life.

Hypotheses

The null hypotheses are stated below:

1) There is no significant relationship between dietary iodine intake and body weight.
2) There is no significant relationship between dietary iodine consumption and percent lean body mass and percent body fat.
3) There is no significant relationship between dietary iodine intake and waist-to-hip ratio.
4) There is no significant relationship between dietary iodine intake and TBBMD.
5) There is no significant relationship between dietary iodine consumption and the circulating concentrations of T3, T4, and thyrotropin stimulating hormone (TSH).
6) There is no significant relationship between dietary iodine consumption and the circulating concentrations of T3, T4, and TSH when controlling for all other variables (such as age, percent body fat, percent lean body mass, and total bone mineral density by DXA).
7) There is no significant relationship between age and circulating concentrations of T3, T4, and TSH when controlling for all other variables (such as age, percent body fat, percent lean body mass, and total bone mineral density by DXA).

Assumptions

1) All participants were healthy individuals.
2) The Harvard Food Frequency Questionnaire (HFFQ) is a reliable and a valid measure of the participants' dietary iodine consumptions.
3) The limitations imposed in this study will not destroy the external validity of the results.
4) All participants provided accurate information for this study.
5) All testing that was performed for this study was reliable and accurate.

Limitations

1) The Harvard Food Frequency Questionnaire (HFFQ) consists of what participants say they do or what they say they like or dislike.
2) The Harvard Food Frequency Questionnaire is a food history rather than an actual food record of intake.
3) Not all participants in this study had their T3 and T4 levels documented.
4) All participants in this study were Caucasian females.

Significance of this Study

Iodine is equally important for both growth and metabolism. It also helps in the synthesis of thyroid hormones involved in these processes. By measuring the dietary iodine that an individual consumes, the role of dietary iodine in the synthesis of TSH, T3, and T4 can be evaluated. Increased incidence of overweight or obesity in these

individuals may be the result of a deficiency in iodine, resulting from decreased consumption of foods containing iodine. If T3 and T4 are decreased in an individual's body, lower metabolism which ultimately causes weight gain and excess adiposity may be the result. This study may explain some of the causes of the current obesity epidemic.

CHAPTER II

LITERATURE REVIEW

Iodine is an important constituent for the synthesis of thyroid hormones and is involved in regulation of several metabolic processes and enzymes (Institute of Medicine of the National Academies, 2006). Thyroid hormones play an essential role in the early growth process and development of a majority of the organs, specifically the brain (Delange & Lecomte, 2000). Thyroid hormones are also important for the metabolism of most human cells (Delange & Lecomte, 2000). Thyroid iodine accretion and turnover decide the iodine requirement for each individual (Institute of Medicine of the National Academies, 2006). Iodine is an essential trace element that has a daily requirement of 150 μg/day and tolerable upper intake level (UL) of 1100 μg/day (Baker, 2004; Paknahad, 2010). The greatest amount of iodine that can be consumed each day and likely not cause a risk for unfavorable health effects in most individuals is known as the UL (Baker, 2004). Around 120 μg of iodide are typically collected daily by the thyroid gland to assist with the synthesis of thyroid hormones, such as T3 and T4 (Ahad & Ganie, 2010).

History of Iodine

While France was at war in 1811, Bernard Courtois manufactured saltpeter to make gunpowder for Napoleon's army (Zimmermann, 2008). He first burned seaweed to

separate sodium bicarbonate and then added sulfuric acid to the remaining ash (Zimmermann, 2008). This created a violet vapor that would crystallize on cold surfaces (Zimmermann, 2008). Courtois sent some of the crystals to Gay-Lussac who identified the crystals as a new element and coined its new name, iodine, after a Greek word that meant violet (Zimmermann, 2008). Iodine has an atomic weight of 126.9 g/mole and plays an important role in the production of hormones from the thyroid gland (Zimmermann, 2008). Iodine is a nonmetallic element and its name is derived from the Greek "iodes." "Iodes" means violet or purple which is the color of iodine in the gaseous phase.

Role of Iodine

Iodine has an essential role in thyroid physiology because it is a major component of thyroid hormones, and it regulates thyroid gland function (Cavalieri, 1997). The biosynthesis of thyroid hormones is based on the presence of iodine (Mansourian, 2011). The thyroid gland is also the primary site for iodine absorption and storage (Mansourian, 2011). An adult human body can contain 15-20 mg of iodine, with about 80% in the thyroid gland (Baker, 2004).

Iodine is oxidized in the thyroid gland, and then is transferred on the tyrosine residues of thyroglobulin (Mansourian, 2011). The tyrosine residues are then converted into monoiodotyrosine (MIT) and diiodotyrosine (DIT; Mansourian, 2011). During the coupling process, MIT and DIT form T3 whereas DIT and DIT form T4. Hence, iodine is an important constituent of the thyroid hormones, T3 and T4 (Institute of Medicine of

the National Academies, 2006). T4's weight is composed of 65% iodine while T3's weight is composed of 59% iodine (Zimmermann, Jooste, & Pandav, 2008). These hormones are involved in numerous biochemical reactions, such as enzymatic activity and protein synthesis (Institute of Medicine of the National Academies, 2006). Most of the iodine in the thyroid gland is stored in the form of the glycoprotein, thyroglobulin, which is the main storage form for thyroid hormones (Baker, 2004).

Sources of Iodine

The primary repositories for iodine are in the oceans with only a small amount of iodine actually being found in soil (Ahad & Ganie, 2010). Volatilization is the process where deposition of iodine in the soil from ocean water takes place (Ahad & Ganie, 2010). This process is further assisted by ultraviolet radiation (Ahad & Ganie, 2010). The soils that are further inland do not contain as much iodine as those of the coastal regions and this problem is further compounded by continuous leeching of iodine from the soil (Ahad & Ganie, 2010). Thus, crops grown in this soil remain iodine deficient (Ahad & Ganie, 2010). In nature, iodine can be found as inorganic sodium and potassium salts (iodides and iodates), organic monoatomic iodine, and inorganic diatomic iodine (molecular iodine or I_2). Table 1 below displays these sources in further detail.

Table 1

Sources of Iodine (Ahad & Ganie, 2010).

Soil	
$NaIO_3$	Sodium Iodate
$NaIO_4$	Sodium Periodate
Seaweed/Algal Phytoplankton	
KI	Potassium Iodide
NaI	Sodium Iodide
I_2	Iodine
I^-	Iodide
Seawater	
I^-	Iodide

Dietary sources of iodine are eggs, potatoes, navy beans, seaweed (wakame, nori or mekabu), cow's milk, seafood, and iodized salt. Most of the iodine that is found in food is iodide, but iodate is the form for iodized salt or it can be used in bread making as a bread conditioner (Baker, 2004). In the body, iodate is readily reduced to iodide when eaten or injected intravenously (Baker, 2004). The amount of iodine found in a majority of food sources is low and the irrigation, fertilizers, and soil content can affect the iodine level in each food item (Institute of Medicine of the National Academies, 2006). Seafood usually has an increased amount of iodine because marine animals are able to concentrate iodine from seawater (Institute of Medicine of the National Academies, 2006). Processed food items might have increased levels of iodine because of any iodized salt that is added or possibly any additives; such as cuprous iodide, potassium iodate, calcium iodate, or potassium iodide (Institute of Medicine of the National Academies, 2006). Radiocontrast media, water purification tablets, certain medications such as Amiodarone (or

Cordarone), food coloring, dental and skin disinfectants have large amounts of iodine that can obstruct accurate functioning of the thyroid (Baker, 2004; Institute of Medicine of the National Academies, 2006).

Iodine is still used as a bread conditioner and can be added into dairy products and chicken through supplementation in feed, as well as any sanitizing agents that may contain iodine (Soldin, 2007). The amount of iodine in both eggs and milk can vary depending on the iodine level in the diet of the hens and cows (Baker, 2004). Cattle and chicken diets are often supplemented with kelp to provide a considerable amount of iodine through eggs (yolks are iodine-rich), meat, and milk products (Lee et al., 1999). Table 2 shows the amount of iodine in some common food items.

Table 2

Iodine Level in Selected Foods (Office of Dietary Supplements, 2011).

Food Item	Approximate Micrograms (mcg) per serving	Percent Daily Value
Seaweed, whole or sheet, 1 g	16 to 2,984	11% to 1,989%
Cod, baked, 3 ounces	99	66%
Yogurt, plain, low-fat, 1 cup	75	50%
Iodized salt, 1.5 g (about ¼ tsp)	71	47%
Milk, reduced fat, 1 cup	56	37%
Fish sticks, 3 ounces	54	36%
Bread, white, enriched, 2 slices	45	30%
Fruit cocktail in heavy syrup, canned, ½ cup	42	28%
Shrimp, 3 ounces	35	23%
Ice cream, chocolate, ½ cup	30	20%
Macaroni, enriched, boiled, 1 cup	27	18%
Egg, 1 large	24	16%
Tuna, canned in oil, drained, 3 ounces	17	11%
Corn, cream style, canned, ½ cup	14	9%
Prunes, dried, 5 prunes	13	9%
Cheese, cheddar, 1 ounce	12	8%
Raisin bran cereal, 1 cup	11	7%
Lima beans, mature, boiled, ½ cup	8	5%
Apple juice, 1 cup	7	5%
Green peas, frozen, boiled, ½ cup	3	2%
Banana, 1 medium	3	2%

Compared to the United States, Japan has some of the highest intakes of iodine because of their consumption of iodine-rich seaweed. Seaweed consumption can add as much as 200 mg of daily iodine to an individual's diet and it might have up to 4.5 g I/kg (Baker, 2004). For those Japanese individuals who favor seaweed, 15-30 g of seaweed Kombu, contains about 35-70 mg of iodine, and would usually be consumed during one meal (Miyai, Tokushige, Kondo, & Iodine Research Group, 2008). In the study by Miyai et al. (2008), eight male and five female healthy volunteers consumed either 15 or 30 g of seaweed for both a short-term experiment of 7-10 days and a long-term experiment of 55-

87 days. Participants had increased levels of TSH, which can cause the thyroid gland to secrete more T3 and T4. Through the measurement of urinary excretion, 20-50 mg of absorbed iodine considerably surpassed the recommended upper intake level of 3 mg in Japan (Miyai et al., 2008). The Japanese population may consume up to 25 times the median amount of iodine in the United States (Patrick, 2008). The recommended dietary intake (RDA) of iodine is 150 μg/day during adolescence and adulthood, with an increase to 200-300 μg/day during pregnancy and lactation (Delange & Lecomte, 2000).

In the United States iodine is added to salt. By weight, iodized salt is composed of one part salt to 10,000 parts sodium chloride; which means that 1 g of iodized salt contains about 75 μg of iodine (Lee, Bradley, Dwyer, & Lee, 1999; McCance & Huether, 2006). Iodine deficiency was almost eliminated with the iodization of salt in the United States and several Western countries (Delange, de Benoist, Pretell, & Dunn, 2001). In one study that assessed the effect of salt iodization on thyroid enlargement, 17.6% of the total cross-section of the population had thyroid enlargement before salt iodization, whereas only 10.9% had thyroid enlargement after salt iodization (Vejbjerg et al., 2007).

Goitrogens

There are a few food items that contain goitrogens that impede thyroid hormone synthesis and utilization (Baker, 2004; Institute of Medicine of the National Academies, 2006). Foods that contain these substances are millet, cassava, and cruciferous vegetables like cabbage and broccoli (Baker, 2004; Institute of Medicine of the National Academies, 2006). These do not normally have clinical significance unless an individual

has a coexisting iodine deficiency (Institute of Medicine of the National Academies, 2006). Any water that is consumed from polluted or shallow streams and wells might also possibly contain goitrogens (Institute of Medicine of the National Academies, 2006). Iodine deficiency can be worsened if an individual already has a deficiency of selenium, iron, or vitamin A (Institute of Medicine of the National Academies, 2006).

Metabolism of Iodine

The thyroid gland plays a crucial role in the metabolism of iodine (Ahad & Ganie, 2010). See Figure 2 below. The first step in iodine metabolism is known as iodine trapping (Ahad & Ganie, 2010). This process is initiated with iodide uptake from the capillary into the follicular cell of the gland through an active transport system (Ahad & Ganie, 2010). This process takes place against both electrical and chemical gradients by a sodium/iodine symporter protein located in the basolateral membrane of the follicular cell (Ahad & Ganie, 2010). The energy required for this process is related to the ATPase dependent Na-K pump (Ahad & Ganie, 2010). The second step in iodine metabolism is synthesis and secretion of thyroglobulin (Ahad & Ganie, 2010). The synthesis of thyroglobulin is initiated in the rough endoplasmic reticulum, and once the thyroglobulin molecule is completed, it contains about 140 tyrosine residues (Ahad & Ganie, 2010). Thyroglobulin serves as the substrate for thyroid hormone synthesis (Ahad & Ganie, 2010). The third step is iodide oxidation with iodide transported by the sodium independent iodide/chloride transporter known as pendrin (Ahad & Ganie, 2010). The iodide (I^-) is immediately oxidized to iodine (I_2) with nitrite or iron (Ahad & Ganie,

2010). Next, organification of the thyroglobulin occurs (Ahad & Ganie, 2010). Iodination of the tyrosine residues found within the thyroglobulin molecule first forms MIT and then DIT (Ahad & Ganie, 2010). Iodination is followed by a coupling reaction where two DIT molecules couple to form the T4 hormone and one MIT molecule couples with one DIT molecule to form T3 hormone (Ahad & Ganie, 2010). This reaction is catalyzed by thyroid peroxidase (Ahad & Ganie, 2010). The thyroid hormones are stored within the thyroid follicles for several months as a colloid, which is the glycoprotein known as thyroglobulin (Ahad & Ganie, 2010). The body's requirements can be met for about 3-months with these stored hormones (Ahad & Ganie, 2010). The epithelial cells of the follicular lumen retrieve the colloid containing iodinated thyroglobulin after it undergoes endocytosis (Ahad & Ganie, 2010). This is facilitated by the thyroglobulin receptor known as megalin which is located on the apical membrane (Ahad & Ganie, 2010). Then the colloid enters the cytoplasm as colloid droplets which move towards the basal membrane (Ahad & Ganie, 2010). Lysosome vesicles combine with the colloid droplets that enter, and the lysosome vesicles have proteolytic enzymes (Ahad & Ganie, 2010). The protease assists with digesting the thyroglobulin which releases T3, T4, MIT and DIT into the cytoplasm (Ahad & Ganie, 2010). T3 and T4 circulate through the basal surface into the blood stream (Ahad & Ganie, 2010). Conversely, MIT and DIT are quickly deiodinated by the enzyme deiodinase (Ahad & Ganie, 2010). This mechanism is what assists in retrieval of iodide and tyrosine for recycling (Ahad & Ganie, 2010). In

the figure below, a depiction of the synthesis and release of the thyroid hormones in an individual's body is shown.

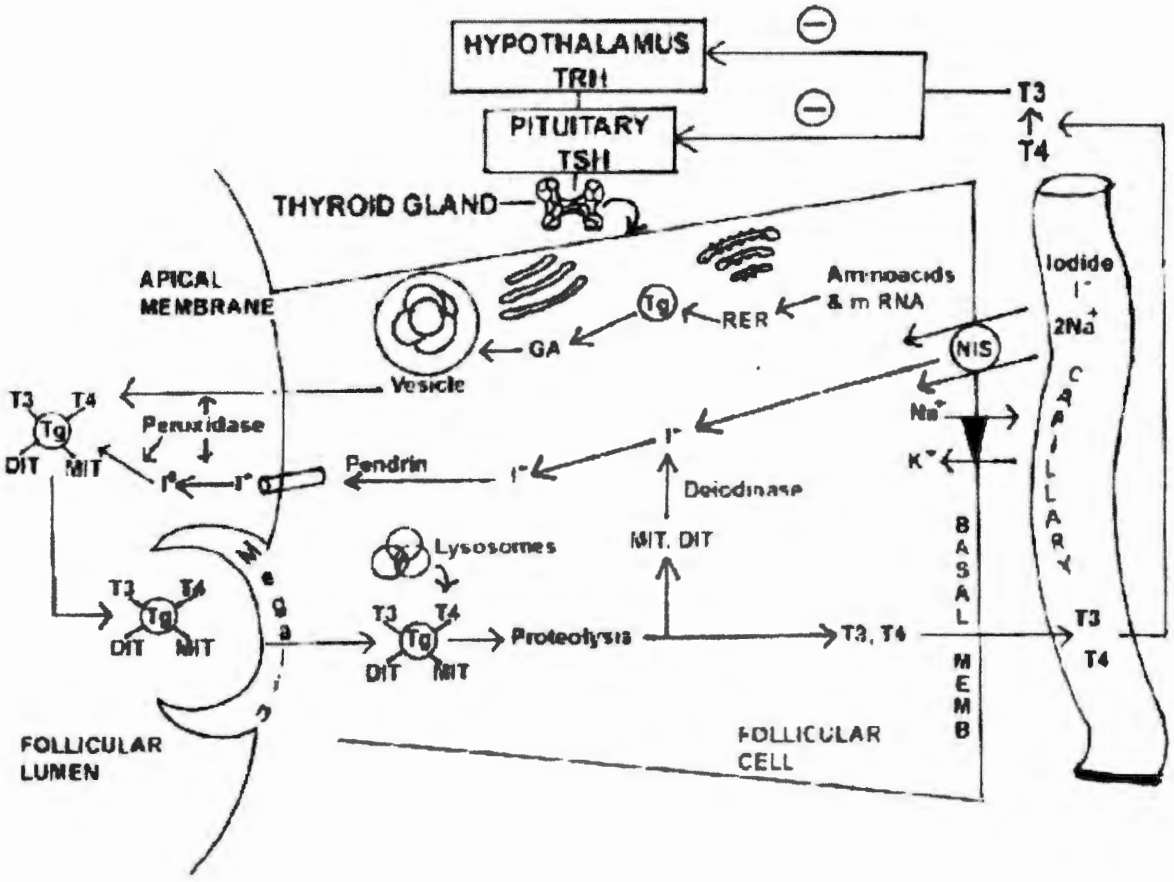

Figure 2: Iodine Metabolism (Ahad & Ganie, 2010)

NIS- sodium/iodine symported protein, DIT- diiodotyrosine, MIT- monoiodotyrosine, Tg- thyroglobulin, GA- golgi apparatus, RER- rough endoplasmic reticulum, TSH- thyroid stimulating hormone, T3- triiodothyronine, T4- thyroxine.

A majority of the ingested iodine is reduced in the gut to iodide and then absorption of iodine primarily occurs as iodide, the main form of dietary iodine, and it is absorbed quickly into circulation (Institute of Medicine of the National Academies, 2006; Lee et al., 1999). On the other hand, some of the iodine-containing compounds are

absorbed intact, such as thyroid hormones (Institute of Medicine of the National Academies, 2006). The iodine will then travel into the bloodstream and it will be allocated throughout the body's extracellular compartments, either as free or protein-bound iodine (Lee et al., 1999). Iodine is mainly removed by the kidneys and thyroid gland (Institute of Medicine of the National Academies, 2006). A sodium-iodide symporter complexes with sodium and iodide to move iodide actively from the bloodstream into the cells of the thyroid gland (Institute of Medicine of the National Academies, 2006; Lee et al., 1999). Any remaining iodine is excreted in urine after the thyroid gland has concentrated a sufficient amount of iodide to complete thyroid hormone synthesis (Institute of Medicine of the National Academies, 2006). If there is still some iodine remaining after it is excreted through the urine, it can also be expelled in the feces or sweat (Baker, 2004; Institute of Medicine of the National Academies, 2006).

The thyroid gland stores about 8 mg of the body's iodine (Lee et al., 1999). Conversely, the mammary, gastric, and salivary glands store a total of 0.25 mg of iodine in the three glands (Lee et al., 1999). If an individual does not consume enough iodine, the body will recycle iodine by deiodinating thyroid hormones (T4) in the liver; which will then be released back into the bloodstream as T3 (Lee et al., 1999). The thyroid will then reabsorb this iodine to be used again (Lee et al., 1999). Iodine excretion is primarily done through the kidneys and therefore, can serve as a consistent assessment for both the status of iodine intake and the amount of iodine in the blood (Lee et al., 1999).

Iodine Deficiency, Hypothyroidism and Goiter

In less developed countries, there are approximately two billion people at risk for iodine deficiency (Paknahad, 2010). Iodine deficiency is found in areas of the world where the topsoil has been depleted of iodine through erosion that results from rain, flooding, wind, or glacier movement (Lee et al., 1999). Cognitive development can be impaired in children with severe iodine deficiency, while adults can experience goiter (Institute of Medicine of the National Academies, 2006). Women who have iodine deficiency are particularly susceptible to an enhanced goiter formation (Lee et al., 1999). The clinical outcomes of iodine deficiency can affect human subjects of all ages, and range from mild hypothyroidism to severe endemic cretinism (Arthur & Beckett, 1999).

Iodine deficiency will interfere with the synthesis of T3 and T4 hormones (Ahad & Ganie, 2010). The thyroid gland is able to release these hormones for a short time through the stored components in thyroglobulin molecules (Ahad & Ganie, 2010). When these stores are depleted, the serum concentrations of T4 starts to decrease and the pituitary gland intervenes by increasing TSH release (Ahad & Ganie, 2010). This causes the thyroid gland to enhance its uptake of iodide to guarantee that there is an adequate release of thyroid hormones (Ahad & Ganie, 2010). Hyperplasia of follicular cells occurs when an individual is in a state of deficiency and TSH is unable to promote T4 release (Ahad & Ganie, 2010). In the case of severe iodine deficiency, T4 levels remain reduced and the TSH levels remain increased (Ahad & Ganie, 2010). With continuous TSH stimulation, the thyroid glands experiences hypertrophy and hyperplasia of the follicular

cells (Ahad & Ganie, 2010). During this time, the thyroid gland enlarges and appears as a goiter (Ahad & Ganie, 2010). Iodine deficiency can be improved through the addition of iodine to dietary sources such as salt, water, sauces, oil, consumption of iodine-rich foods and so forth (Ahad & Ganie, 2010). Iodized salt and iodized oil are methods that have proven to be effective for numerous individuals (Ahad & Ganie, 2010).

When a limited amount of iodine is available, the thyroid gland will first use any reserve iodine and become enlarged in an attempt to extract more from what is available, resulting in the development of goiter (Soldin, 2007). Iodine absorption can be inhibited by consuming soy flour, and some infants who consumed this in their infant formula were faced with hypothyroidism and goiter (Institute of Medicine of the National Academies, 2006). Alternatively, when iodine was added to the formula, there was no appearance of goiter (Institute of Medicine of the National Academies, 2006). Goiter affects approximately 200 to 300 million individuals worldwide and in a few countries, goiter has become a normal physical characteristic (Mahan & Escott-Stump, 2008). The prevalence of goiter in the United States is 1.9/1000 persons, with the rate higher in women and older individuals (Mahan & Escott-Stump, 2008). Depending on several factors, goiter will respond slowly to intervention (Assey et al., 2009). Goiter can occur anywhere from 6-months to several years behind the increased iodine intake level (Assey et al., 2009). Figure 3 shows the difference between a normal thyroid gland and an enlarged thyroid gland, or goiter.

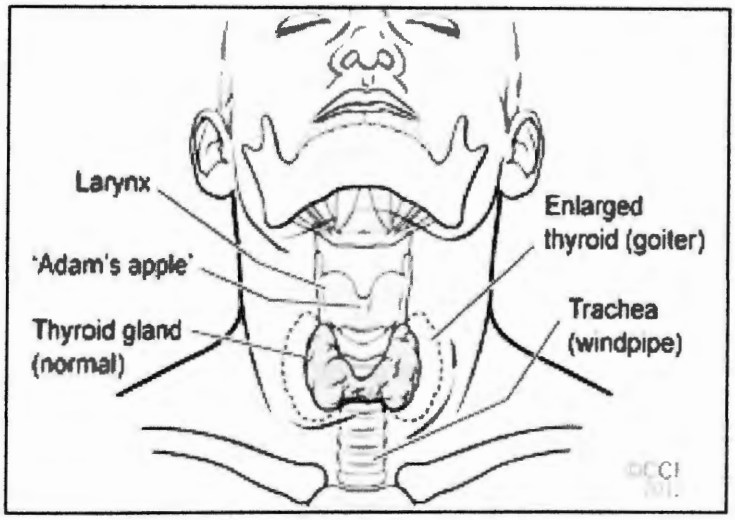

Figure 3: Normal Thyroid Gland Compared to Enlarged Thyroid Gland (Cleveland Clinic, 2012)

The current belief is that if too much iodine is consumed over a long period of time, then there will be a decreased organic binding between iodine and the thyroid gland (Baker, 2004). This event may result in goiter and hypothyroidism (Baker, 2004). Too much iodine can cause hyperthyroidism, hypothyroidism, or goiter formation based on the original thyroid pathology (Lee et al., 1999). Excessive iodine in an individual's diet can also affect the diagnosis and treatment of those with thyroid diseases who are about to receive radioactive iodine (Lee et al., 1999). High iodine intake will affect each individual differently depending on the health of their thyroid gland (Lee et al., 1999).

Alternatively, when the physiological requirements of iodine are not met, there are a variety of functional or developmental abnormalities that can occur (Delange & Lecomte, 2000). These abnormalities can include defects in thyroid function (Delange & Lecomte, 2000). When iodine deficiency is severe, there may be endemic goiter and

cretinism, reduced fertility rate, endemic mental retardation, and a rise in perinatal death and infant mortality (Delange & Lecomte, 2000).

In 2004, a national survey in mainland Tanzania was performed to investigate the effect of universal salt iodination that began in the early 1990's. In this country, rural areas had greater incidence of goiter than did urban areas. Rural areas had a goiter prevalence of 8.0% compared to 5.5% for urban areas (Assey et al., 2009). In the 1980's, 5.0-19.9% of the population had mild iodine deficiency, 20-29.9% had moderate iodine deficiency, and greater than or equal to 30% had severe iodine deficiency (Assey et al., 2009). Twelve years after the initiation of the universal salt iodination, 84% of the population consumed iodized salt and 94.5% of children between the ages of 6-12 had normal sized thyroid glands (Assey et al., 2009).

Wolff-Chaikoff Effect

The Wolff-Chaikoff Effect is the theoretical, inhibitory result of peripheral inorganic iodide levels, which are greater than or equal to 0.2 mg/L (10^{-6} M), on the organification of iodide (Abraham, 2005). This effect supposedly results in hypothyroidism and goiter (Abraham, 2005). When there is an increase in intracellular iodide, the organic-binding and coupling reactions that occur in the thyroid gland are blocked. In the study by Wolff and Chaikoff (1948), following the injection of increased doses of iodide; there was almost a complete block of the thyroid gland's ability to bind organically throughout the initial 6-12 hrs. During this time period, the gland does not lose its capability to concentrate iodine (Wolff & Chaikoff, 1948). The inorganic iodine

concentrations located within the blocked gland were approximately 100-300 times those found in the plasma (Wolff & Chaikoff, 1948). Therefore, the results found in this study establish that the normal thyroid gland does not only depend on the conversion to organic forms, but there is an alternative mechanism to continue to concentrate iodine (Wolff & Chaikoff, 1948).

The sodium-iodide symporter system is a main contributor to the maintenance of normal thyroid hormone secretion (Bürgi, 2009). An unexpected iodine overload obstructs the second step of hormone synthesis which is iodide organification (Bürgi, 2009). The Wolff-Chaikoff Effect needs a high intracellular iodide (greater than or equal to 10^{-3} molar [M]) concentration (Bürgi, 2009). The obstruction does not remain long because once the sodium-iodide symporter is turned off, the intracellular iodide falls below the 10^{-3} M which then allows for a near-normal secretion to recommence (Bürgi, 2009).

Clinical Uses of Iodine

Lugol's solution was first made in 1829, and it is named after the French physician, Jean Guillaume Auguste Lugol. This solution is a mixture of elemental iodine and potassium iodide. Lugol's solution is used as a disinfectant or antiseptic. Lugol's solution is a 5% solution of 5% iodine and 10% potassium iodide mixed in distilled water. This solution has a total iodine content of 130 mg/mL. A tincture of iodine is composed of an iodine solution in ethyl alcohol. Tincture of iodine is an antiseptic that can be applied topically to wounds. The tincture of iodine can also be utilized to purify

water for drinking. Another type of iodine that can be used as an antiseptic in medicine is silver iodide. Radiocontrast agents are a type of contrast medium used in medicine to enhance visibility for a variety of X-ray techniques. Iodine compounds can be used in these agents. Amiodarone is an iodine-rich drug that is commonly used in the treatment of tachyarrythmias (Martino et al., 1987). This drug is one of the most common reasons for iodine-induced thyrotoxicosis (Martino et al., 1987).

Current Methods to Detect an Iodine Deficiency

Iodine is primarily excreted from an individual's body through urine. The best way to assess if a large population is iodine deficient is through the measurement of the amount of iodine in urine samples. Iodine deficiency is diagnosed if the median urinary iodine concentration is less than 50 µg/L in a population (American Thyroid Association, 2008). Table 3 displays the median urinary iodine concentration, the related iodine intake, and what the values indicate related to nutrition.

Table 3

Median Population Urinary Iodine Values and Iodine Nutrition (American Thyroid Association, 2008).

Median Urinary Iodine Concentration (µg/L)	Corresponding Iodine Intake (µg/day)	Iodine Nutrition
<20	<30	Severe deficiency
20-49	30-74	Moderate deficiency
50-99	75-149	Mild deficiency
100-199	150-299	Optimal
200-299	300-449	More than adequate
>299	>449	Possible excess

When comparing different geographical areas, urinary iodine excretion and thyroid size are the two most widely utilized measures of an individual's iodine status (Rasmussen et al., 2002). Alternatively, this relationship is rarely seen within one geographical area (Rasmussen et al., 2002). In a study by Rasmussen et al. (2002), the cohort study was comprised of 4629 randomly selected subjects who had mild-to-moderate deficiency. The subjects in this study lived in two cities in Denmark, Aalborg and Copenhagen. The serum thyroglobulin concentration ($P \leq 0.002$) was significantly associated with all measures related to iodine intake (Rasmussen et al., 2002). Increased serum thyrogolobulin was shown to be a characteristic of chronic iodine deficiency and in patients who had goiter (Rasmussen et al., 2002). Otherwise, no association between serum thyroglobulin concentrations and thyroid volume has been displayed in an area with sufficient iodine consumption (Rasmussen et al., 2002). The findings in the study by Rasmussen et al. (2002) indicated that serum thyroglobulin is a good marker of iodine status in an iodine-deficient population.

Current Research

In the United States, overweight and obesity levels continue to rise with more than two-thirds of the population being characterized in one of these two groups (Carlton, 2010). One-third of this population is on some type of diet that may not provide adequate amounts of micronutrients (Carlton, 2010). Micronutrient deficiencies have been shown to be correlated with an increased risk of either becoming overweight or obese or possibly other diseases (Carlton, 2010). Carlton (2010) examined the Atkins for Life

Diet, the South Beach Diet, the DASH (Dietary Approaches to Stop Hypertension) Diet, and the Best Life Diet. Twenty-seven micronutrients were analyzed, including iodine, and none of the four diet plans provided a sufficient amount of any of the twenty-seven micronutrients. Iodine was one of the six micronutrients that were classified as being consistently low or absent.

Data from the National Health and Nutrition Examination Survey, 2009-2010, displayed several key points about the trend being seen related to obesity. More than one-third of adults in the United States (35.7%) are obese, and the obesity prevalence does not differ between genders (Centers for Disease Control, 2012). Of the youth population, about 17% were obese during that same time period (Centers for Disease Control, 2012). The prevalence of obesity amongst children or adults from 2007-2008 to 2009-2010 indicated no change (Centers for Disease Control, 2012). Obesity has also shown to influence some ethnicities more than others. The highest age-adjusted rates of obesity were shown in non-Hispanic blacks (49.5%) compared to Mexican Americans (40.4%), all Hispanics (39.1%) and non-Hispanic whites (34.3%; Centers for Disease Control, 2012). In 2011, the obesity prevalence varied across regions; with the South having the highest prevalence of obesity (29.5%), followed by the Midwest (29.0%), the Northeast (25.3%) and the West (24.3%; Centers for Disease Control, 2012).

Iodine Intake, Body Weight and Thyroid Volume

Two primary factors controlling the growth of the thyroid gland are TSH and iodine intake (Wesche et al., 1998). TSH is released in response to reduced serum

concentrations of T4. TSH stimulates the thyroid gland to generate more thyroid hormones and to also grow in size in an attempt to concentrate as much iodine as possible (Cleveland Clinic, 2012). When iodine availability is reduced, the thyroid gland will begin by utilizing any reserve iodine. Then, the thyroid gland will become enlarged while trying to remove more iodine from what is available which will lead to goiter development (Soldin 2007). The thyroid volume in pregnant women increases in those who live in iodine-deficient areas, but this is not shown in iodine-replete areas (Wesche et al., 1998). A significant association was shown between iodine intake and thyroid volume in a cohort study of 4649 participants from two cities in Denmark (Rasmussen et al., 2002). In a cross-sectional study, a reduction in thyroid volume was seen in all age groups of an adult population (18-65 years old) after salt iodization of 13 ppm iodine (Vejbjerg et al., 2007). The mean volume was reduced 12% [95% confidence interval (CI), 9-15%] following salt iodization in the area with moderate iodine deficiency and 6% [95% CI, 2-9%] decrease in the area with mild iodine deficiency (Vejbjerg et al., 2007).

Furthermore, an association ($r = 0.3$ or greater) between thyroid volume and body composition has been shown in a number of studies. Whether an individual is obese or not can have an effect on that individual's thyroid gland. There are several studies that have found significant correlations between body weight, height, and thyroid volume (Boyanov et al., 2004). Though body weight is positively correlated with thyroid volume, lean body mass (LBM) was strongly associated with thyroid volume in one study

(Boyanov et al., 2004). In a study of 126 girls and 86 boys between the ages of 11-15 years, thyroid volume had a significant relationship with body weight ($r = 0.35$ in girls and 0.43 in boys), height ($r = 0.33$ and 0.50, respectively), body surface area (BSA; $r = 0.38$ and 0.50, respectively), and fat-free mass ($r = 0.39$ and 0.49, respectively; Boyanov et al., 2004). Conversely, there was less of a correlation with an individual's body mass index (BMI; $r = 0.26$ in girls and 0.16 in boys; Boyanov et al., 2004). In another study that compared obese to non obese participants, thyroid volume in obese participants was not associated with body weight ($r = 0.23$, NS), but positively correlated to LBM ($r = 0.54$, $p = 0.01$; Wesche et al., 1998). Conversely, in non obese participants, the correlation between thyroid volume and LBM ($r = 0.55$, $p = 0.0001$) was stronger than the correlation between thyroid volume and body weight ($r = 0.42$, $p < 0.005$; Wesche et al., 1998). In another study that observed differences between obese and non obese participants, along with changes associated to weight loss, an increased TSH concentration and thyroid volume was shown in obese women compared to the women who were not obese (Sari et al., 2003). There was also a positive correlation between thyroid volume and body weight (Sari et al., 2003). There was a significant reduction in TSH and thyroid volume in participants who had greater than 10% weight loss in six months with the obesity treatment, but there was no effect on participants with less than 10% weight loss (Sari et al., 2003).

Basal Metabolic Rate and Thyroid Function

Basal metabolic rate (BMR) contributes about 60-75% to an individual's daily energy expenditure (Meunier et al., 2005). The three factors that affect energy expenditure include BMR, adaptive thermogenesis, and exercise-induced thermogenesis (Goglia, Silvestri, & Lanni, 2002). BMR is also essential in the regulation of body weight (Meunier et al., 2005). The reduction in BMR with age has been explained in several studies, and it was estimated that the decrease in basal metabolism was less than 1-2% per decade during the second to seventh decade of life (Meunier et al., 2005). Numerous studies have supported the conclusion above as well as the fact that the decrease in BMR is related to changes in body composition, especially a reduction of fat-free mass (Meunier et al., 2005). Studies have also suggested that physiological, hormonal and lifestyle factors could also lead to a decrease in BMR of older individuals (Meunier et al., 2005). Therefore, thyroid hormones may be a potential modulator of the changes seen in BMR (Meunier et al., 2005).

One of the primary roles of thyroid hormones in adult humans is the regulation of thermogenesis (Kim, 2008). A variety of studies have observed effects of thyroid hormones on cellular processes important to energy expenditure (Kim, 2008). Even though there is this wealth of data, it still is unclear whether 3-3'-triiodothyronine-responsive energetic processes are the most significant in determining BMR (Kim, 2008).

CHAPTER III

METHODS

This retrospective study used data collected during the Pioneer Project, a longitudinal, observational study of women's health throughout the reproductive, perimenopausal, and postmenopausal years. The Pioneer Project was performed by the Texas Woman's University (TWU) Institute for Women's Health (IWH) from 2000-2004, with funds provided from the State of Texas. The Pioneer Project recorded comprehensive medical, psychological, physiological, socioeconomical, and nutritional information from 351 women between 18 to 60 years of age. The anthropometric and nutritional information that was obtained through the Pioneer Project was used for this retrospective study.

Participants

The participants included in this study were 351 Caucasian females between 18 and 60 years of age. Most of the participants lived in the Denton area, but some were from Dallas and Houston. Participants who met the inclusion criteria and had all data collected were included in this study. Recruitment was completed by distributing flyers around the TWU Campus, through radio announcements, and in local newspapers throughout the surrounding areas of Denton, Dallas, and Houston, Texas.

All participants were first screened in a phone interview and if they met the inclusion criteria, they were sent a medical history questionnaire that was completed before their first visit to the IWH.

Inclusion criteria consisted of the following:

1) Participants were in generally good health and able to give informed consent

2) Females aged between 18 and 60 years

3) Willingness to undergo the necessary testing at yearly intervals

4) No anticipated change in geographic location for at least 2-years

Exclusion criteria consisted of the following:

1) A resting systolic blood pressure > 200 mm Hg, a diastolic value at 115 mm Hg, a weight > 275 lbs, an individual who was pregnant or was currently attempting to become pregnant, if the individual was within 6-months post-partum, or unable to stand freely

2) Any indication of cardiovascular disease, all of which include frequent or complex ventricular ectopy, acute congestive heart failure, suspected myocarditis or pericarditis, aortic stenosis, valvular heart disease, uncontrolled atrial arrhythmia, uncontrolled ventricular arrhythmia, any history of a myocardial infarction, unstable angina, third degree atrioventricular block, and recent significant changes in a resting electrocardiogram (ECG) suggesting infarction or other acute, cardiac event

3) Cardiovascular accident (CVA); renal disease including (but not limited to) polycystic kidney disease, glomerulonephritis, chronic polynephritis, pylonephritis, recurrent kidney

stones; transient ischemic attacks (TIA); positive HIV/AIDS status; seizure disorder; and cancer, except for basal cell skin cancer that is completely treated

4) Any history of pulmonary embolus, ventricular aneurysm, acute infection, thrombophlebitis (active), pacemaker, electrolyte abnormalities, hypertension, implantable defibrillator, diagnosed with diabetes, hypercholesterolemia, diagnosed with thyroid disorder, taking oral contraceptives or hormone replacement therapy, participating in clinical drug study, or involving investigator's judgment

5) Autoimmune disorders such as scleroderma, rheumatoid arthritis, or systemic lupus erythematous; and respiratory disorders like emphysema, asthma (currently), or chronic bronchitis

6) Surgeries such as valve replacement, cardiac bypass, gastric stapling, or intestinal bypass; medication like antipsychotics, thyroid replacement, anticoagulants, corticosteroids, or cardiac medication

7) Hepatic disease such as that which includes Hepatitis B or C, cirrhosis, a transplant of any kind, current or past history of alcohol or drug abuse, illegal drug use, or eating disorder

8) Any pre-existing condition that would prohibit their ability to complete the study procedures (this could include such things as foot problems, hip replacement, or orthopedic injury/surgery)

Participants were required to complete a Consent Form to Participate in Research and the Physiological Assessment Addendum Consent prior to their initial visit. During the

screening, participants were provided an opportunity to ask any questions about the Pioneer Project. Participants were asked to sign the consent form when a Pioneer Project staff member acquiring the consent was present. This study was approved by the Institutional Review Board of Texas Woman's University (See Appendix A).

The initial visit included a review of the participant's medical history. If the participant was eligible to complete the entire study, then the individual's height, body weight, pulse, blood pressure, and hip and waist circumference measurements were collected. Fasting blood and urine samples were also collected at the initial visit. Participants were provided with the Harvard Food Frequency Questionnaire and a physical activity questionnaire and were instructed to complete both of the questionnaires before their next scheduled visit.

Study Design

This retrospective study used data collected during the Pioneer Project to determine if there was an association between dietary iodine intake and body composition. Data used in the study included body weight, height, dietary iodine consumption, total body bone mineral density (TBBMD), percent body fat, percent lean body mass, and serum concentrations of T3, T4, and TSH. Dietary iodine consumption levels were estimated using the Harvard Food Frequency Questionnaire (HFFQ). Serum concentrations of T3, T4, and TSH were measured from participant blood samples. The data for these hormones were collected at the beginning of the Pioneer Project and as a follow-up 1-year later. The blood samples were analyzed by Covance, a clinical research laboratory. TBBMD was

measured with the Dual-energy X-ray Absorptiometer (DXA, Lunar Prodigy, Madison, WI) at Texas Woman's University, Institute for Woman's Health, Exercise and Sports Nutrition Clinic. The DXA also provided measurements of the ratio of fat-to-lean-tissue, and the amount of both muscle and bone mass and density.

Harvard Food Frequency Questionnaire

The Harvard Food Frequency Questionnaire (HFFQ) was developed by Walter Willett from Harvard University's School of Public Health (Rimm et al., 1992). The HFFQ is a self-administered assessment tool that was completed by the participants. The HFFQ was given to the participants at their initial visit to be filled out, and returned at their next visit. The HFFQ is a 115-item questionnaire used for dietary data related to the participants' dietary intake for the past year. This questionnaire had the participants recall and document the amount of times per day, week, or month they consumed certain foods. These food items are categorized by specific food groups including eggs and meat, breads and cereals, dairy, vegetables, and fruits. The HFFQ also had questions concerning how their food was prepared, types of food used, condiment use, vitamin and mineral supplement use and the amount of beverages and sweets or baked goods throughout the past year. Once the questionnaires were completed, they were sent to the Harvard University's School of Public Health for the analyses of total energy consumption and nutrient content. The results were sent back to Texas Woman's University in an Excel spreadsheet format. Estimated daily iodine intake was obtained from the HFFQ for the present study.

Height and Weight

Height was measured with the use of a wall-mounted stadiometer (Perspectives Enterprises, Portage, MI) that displayed both inches and centimeters. The participants removed their shoes and any heavy outer garments or accessories for the measurement of height and weight. The participants stood underneath the sliding platform facing away from the stadiometer with their weight evenly distributed between both feet. The participant's heels were pressed against the wall of the stadiometer with their arms hanging at the side, palms facing their thighs. The participant looked forward with their chin parallel to the floor. Two measurements were obtained within 0.1 cm of each other, and measurements were averaged and recorded. If the two measurements were not within 0.1 cm, a third measurement was obtained and the median value was recorded.

There were two different standard methods utilized to measure weight. One of the methods had the participant stand still on a balance scale (Continental Scale Corporation, Bridgeview, IL), facing the wall, with both feet flat, and arms by their side. The second method had the participant standing still on a digital scale (Tanita Corporation, Japan) with arms by their side. Two weight measurements were obtained for each participant, and the two measurements had to be within 0.1 kg of each other. Then the two measurement values were averaged and recorded. If the weight was not within 0.1 kg, a third measurement was obtained with the median value being recorded.

Waist-to-Hip Ratio

The waist-to-hip ratio is a method that helps to estimate body composition. This ratio also helps to describe an individual's body proportions, and it reflects the degree of abdominal obesity that an individual displays. A measuring tape (Graham Field, Atlanta, GA) was used to determine the circumference of each participant's hips (widest part of the buttocks) and the circumference of each participant's waist (just above the belly button). Once both of these measurements were obtained, the waist-to-hip ratio was calculated by dividing the participant's hip circumference by the participant's waist circumference in centimeters.

Dual-Energy X-ray Absorptiometry

The bone densitometer that was utilized in this study is a Dual-energy X-ray Absorptiometer (DXA, Lunar Prodigy, Madison, WI). DXA utilizes two different photon energies (X-ray beams) to measure an individual's soft tissue and bone. Therefore, DXA can provide measurements of fat mass, lean body mass, bone mass, and bone density. The test results are two scores known as the T-score and the Z-score. The T-score displays the amount of bone an individual has compared to a young adult (age 20) of the same sex with peak bone mass. A T-score that is above -1 is considered normal, but a score between -1 and -2.5 is classified as osteopenia or low bone mass. A score below -2.5 is considered osteoporosis. The T-score is used to provide an estimate of an individual's risk for developing a fracture. Alternatively, the Z-score reflects the amount of bone that an individual has compared with other people in the same age group, sex and

race. If the Z-score is unusually low or high, it may indicate a need for the individual to undergo additional medical tests. DXA is currently the most widely used method for the measurement of bone mineral density. This assessment tool helps to determine if an individual has osteoporosis or if the individual is at risk for osteoporosis.

Age

Age was determined according to the individual's date of birth and represents the individual's age at the time of data collection.

Hypotheses

These hypotheses were evaluated to determine if dietary iodine consumption was associated with body composition. The independent variable is dietary iodine intake. The dependent variables in this study include body weight, TBBMD, percent lean body mass, percent body fat, waist-to-hip ratio, and serum concentrations of T3, T4, and TSH. The null hypothesis of the study were:

1) There is no significant relationship between dietary iodine intake and body weight.
2) There is no significant relationship between dietary iodine consumption and percent lean body mass and percent body fat.
3) There is no significant relationship between dietary iodine intake and waist-to-hip ratio.
4) There is no significant relationship between dietary iodine intake and TBBMD.

5) There is no significant relationship between dietary iodine consumption and the circulating concentrations of T3, T4, and TSH.
6) There is no significant relationship between dietary iodine consumption and the circulating concentrations of T3, T4, and TSH when controlling for all other variables (such as age, percent body fat, percent lean body mass, and total bone mineral density by DXA).
7) There is no significant relationship between age and circulating concentrations of T3, T4, and TSH when controlling for all other variables (such as age, percent body fat, percent lean body mass, and total bone mineral density by DXA).

Statistical Analyses

The software used for the analysis in this study is the IBM Statistical Packages for the Social Sciences (SPSS) version 19.0 (SPSS Inc., Chicago, IL). The tests given below were used:

1) Spearman's rank order correlation was performed to determine if there was an association between:
    a. dietary iodine intake and body weight.
    b. dietary iodine consumption and percent lean body mass and percent body fat.
    c. dietary iodine intake and waist-to-hip ratio.
    d. dietary iodine intake and TBBMD.

e. dietary iodine consumption and the circulating concentrations of T3, T4 and TSH.

2) Partial correlation was performed to determine if there was an association between the following variables while controlling for all other variables that could affect the dependent variables:

   a. dietary iodine consumption and the circulating concentrations of T3, T4 and TSH.

   b. age and the circulating concentrations of T3, T4 and TSH.

3) One-way analysis of variance (ANOVA) was performed with tertiles of iodine intake at three levels (the level of significance was set at $p < .05$). The three levels included Group 1, $\leq 33^{rd}$ percentile of the sample that had the lowest iodine intake; Group 2, $> 33^{rd}$ percentile and $\leq 66^{th}$ percentile of the sample with an iodine intake in the middle; and Group 3, $> 66^{th}$ percentile of the sample with the highest iodine intake.

   a. dietary iodine consumption and percent lean body mass and percent body fat.

   b. dietary iodine intake and waist-to-hip ratio.

CHAPTER IV

RESULTS

The purpose of this study was to determine if there was an association between dietary iodine consumption and body composition in Caucasian females between the ages of 18 and 60 years. Correlation was used to assess the association between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and circulating concentrations of T3, T4, and TSH. Before the correlation tests were performed, the data were tested for normality. The data were found to not be normally distributed and therefore, the Spearman rank order correlation was chosen to test the association between the variables. Partial correlations were also performed to determine if there was an association while controlling for certain variables. The partial correlations included the assessment between 1) dietary iodine intake with the circulating concentrations of T3, T4, and TSH while controlling for all other variables that could affect the outcome, and 2) age with the circulating concentrations of T3, T4, and TSH while controlling for all other variables that could affect the outcome. ANOVA was performed to evaluate if there were any significant differences between the means of three groups of iodine intake (Group 1, $\leq 33^{rd}$ percentile; Group 2, $> 33^{rd}$ percentile and $\leq 66^{th}$ percentile; and Group 3, $> 66^{th}$ percentile) on percent lean body mass, percent body fat, and waist-to-hip ratio. Group 1 includes all participants of the sample that had the lowest

iodine intake, Group 2 includes all participants of the sample with an iodine intake in the middle, and Group 3 includes all participants of the sample with the highest iodine intake.

Description of the Participants

There were 351 participants from the Pioneer Project who were measured for height and body weight. Out of these participants, there were only 211 who completed the HFFQ. The sample sizes also varied based on what variables were measured. There were 188 participants who had their body weight, percent lean body mass, percent body fat, and TBBMD measured. There were 180 participants who had waist-to-hip ratio measured and 57 participants who had TSH, T3, and T4 measured. The sample sizes described above vary for each test because not every participant provided all the data which were analyzed in this study. All participants in this study were Caucasian, even though this was not part of the inclusion criteria.

The participants' body weights ranged from 46.5 to 115.8 kg. The participants' iodine intakes ranged from 0 to 340.1 μg per day. The percent of lean body mass ranged from 4.6 to 81%. The percent of body fat ranged from 5.4 to 59%. The participants' waist-to-hip ratios ranged from 0.6776 to 0.9143. TBBMD for the participants ranged from 1.01 to 1.39 g/cm^2. The circulating level of TSH ranged from 0.008 to 7.783 μIU/ml while T3 ranged from 0.446 pg/ml to 17.819 pg/ml, and T4 ranged from 0.462 ng/dl to 1.721 ng/dl. Tables 4 and 5 show the mean and standard deviation values for each of the variables.

Table 4

Mean Iodine Intake, Weight, Percent Body Fat, Percent Lean Body Mass, and TBBMD Data for Pioneer Project Participants.

Variable	Sample Size (n)	Mean	SD
Iodine Intake (µg)	188	55.8	82.9
Weight (kg)	188	66.5	13.0
LBM%	188	.62	.09
BF%	188	.38	.08
TBBMD (g/cm^2)	188	1.18	.07
Waist-to-hip Ratio	180	0.8	.05

Percent Body Fat – BF%, Percent Lean Body Mass – LBM%, and Total Body Bone Mineral Density – TBBMD

Table 5

Mean Iodine Intake, TSH, T3, and T4 Data for Pioneer Project Participants.

Variable	Sample Size (n)	Mean	SD
Iodine Intake (µg)	57	44.8	82.4
TSH (µIU/ml)	57	1.21	1.17
T3 (pg/ml)	57	2.81	2.28
T4 (ng/dl)	57	1.16	.35

Thyrotropin Stimulating Hormone – TSH, Triiodothyronine – T3, and Thyroxine – T4

Table 6

Mean Percent Body Fat Among Tertiles for Iodine Intake.

Group	Sample Size (n)	Mean	SD
1	113	37.6%	8.9%
2	12	39.4%	8.9%
3	63	37.4%	7.3%

Group 1, $\leq 33^{rd}$ percentile of the lowest iodine intake; Group 2, $> 33^{rd}$ percentile and $\leq 66^{th}$ percentile of iodine intake in the middle; Group 3, $> 66^{th}$ percentile of the highest iodine intake

Table 7

Mean Percent Lean Body Mass Among Tertiles for Iodine Intake.

Group	Sample Size (n)	Mean	SD
1	113	61.6%	10%
2	12	60.6%	8.9%
3	63	62.6%	7.3%

Group 1, $\leq 33^{rd}$ percentile of the lowest iodine intake; Group 2, $> 33^{rd}$ percentile and $\leq 66^{th}$ percentile of iodine intake in the middle; Group 3, $> 66^{th}$ percentile of the highest iodine intake

Testing the Hypothesis

Spearman's rank order correlation assessed the association between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and circulating concentrations of T3, T4, and TSH. No significant association was found between iodine intake and body weight ($r_s = .085$, $p = .247$), percent lean body mass ($p = .808$, $r_s = .018$), percent body fat ($r_s = -.003$, $p = .962$), waist-to-hip ratio ($r_s = .021$, $p = .775$), TBBMD ($r_s = .087$, $p = .235$), TSH ($r_s = -.156$, $p = .250$), T3 ($r_s = -.038$, $p = .778$), or T4 ($r_s = -.216$, $p = .109$). After analyzing the data, the hypothesis was accepted (all p values were $> .05$) which indicated that there were no significant associations between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and circulating concentrations of T3, T4, and TSH.

Table 8

Spearman's Rank Order Correlation Results.

Iodine Intake (μg) vs. Variable Below	r_s	P
Weight (kg)	.085	.247
LBM%	.018	.808
BF%	-.003	.962
Waist-to-Hip Ratio	.021	.775
TBBMD (g/cm^2)	.087	.235
TSH (μIU/ml)	-.156	.250
T3 (pg/ml)	-.038	.778
T4 (ng/dl)	-.216	.109

Percent Body Fat – BF%, Percent Lean Body Mass – LBM%, Total Body Bone Mineral Density – TBBMD, Thyrotropin Stimulating Hormone – TSH, Triiodothyronine – T3, and Thyroxine – T4

Partial correlations were also performed to determine if there was an association while controlling for specific variables. The partial correlations included the evaluation of 1) dietary iodine intake with the circulating concentrations of T3, T4, and TSH while controlling for all other variables that could affect the outcome, and 2) age with the circulating concentrations of T3, T4, and TSH while controlling for all other variables that could affect the outcome. When controlling for body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and age, there was a lack of correlation between iodine intake and T4. Concentrations of TSH and T3, and their correlation with iodine intake had a slight increase in their "r" value, but the values indicated no significant correlation. The control variables (body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and age) did not significantly affect the outcome of iodine intake on TSH (r_s = -.069, p = .673), T3 (r_s = -.056, p = .731), and T4 (r_s = -.152, p = .348). Alternatively, when controlling for body weight, percent lean body mass, percent body fat,

waist-to-hip ratio, TBBMD, and iodine intake; there was an increase in the correlation between age and TSH, T3, and T4 than when compared to iodine intake with the levels of circulating hormones. When analyzing the data for age with TSH (r_s = -.040, p = .806), T3 (r_s = .214, p = .185) and T4 (r_s = .154, p = .342), there was no significant association with the circulating hormone levels.

Table 9

Partial Correlation Results.

Variable	r_s	P
Iodine Intake vs. TSH (μIU/ml)	-.069	.673
Iodine Intake vs. T3 (pg/ml)	-.056	.731
Iodine Intake vs. T4 (ng/dl)	-.152	.348
Age vs. TSH (μIU/ml)	-.040	.806
Age vs. T3 (pg/ml)	.214	.185
Age vs. T4 (ng/dl)	.154	.342

Thyrotropin Stimulating Hormone – TSH, Triiodothyronine – T3, and Thyroxine – T4

ANOVA was used to assess if there were any significant differences between the means of three tertiles of iodine intake on percent lean body mass, percent body fat, and waist-to-hip ratio. As a whole, the ANOVA results displayed that there were no significant differences between the iodine intake groups on percent lean body mass (p = .696), percent body fat (p = .747), and waist-to-hip ratio (p = .973). Therefore, the hypothesis was retained.

Table 10

ANOVA Results Table for the Relationship Between Iodine Intake and Percent Body Fat.

Source	Df	SS	Mean Square	F	P
Iodine Intake	2	.004	.002	.293	.747
Error	185	1.301	.007		

Table 11

ANOVA Results Table for the Relationship Between Iodine Intake and Percent Lean Body Mass.

Source	Df	SS	Mean Square	F	P
Iodine Intake	2	.006	.003	.364	.696
Error	185	1.525	.008		

Table 12

ANOVA Results Table for the Relationship Between Iodine Intake and Waist-to-Hip Ratio.

Source	Df	SS	Mean Square	F	P
Iodine Intake	2	.000	.000	.028	.973
Error	177	.392	.002		

CHAPTER V

SUMMARY, DISCUSSION, CONCLUSION, AND RECOMMENDATIONS FOR FURTHER STUDIES

The purpose of this study was to determine if there was an association between dietary iodine consumption and body composition in Caucasian females between the ages of 18 and 60. The data utilized in this study came from the Pioneer Project, which was a longitudinal study of women's health that was performed by the Texas Woman's University (TWU) Institute for Women's Health (IWH).

Summary

The participants included in this study were Caucasian females between the ages of 18 and 60 years. Most of the participants who were involved in the Pioneer Project were from the Denton area. There were a total of 351 participants from the Pioneer Project that provided anthropometric data. Of the 351 initial participants, only 188 participants completed the HFFQ to be analyzed for the amount of dietary iodine consumed in their diet. A total of 237 participants had their weight measured, but only 188 of those participants were used in this study because not all 237 of the participants provided a HFFQ to be analyzed. There were 225 participants who had grams of total mass, grams of total lean mass measured, and grams of total fat mass; but only 188 of those participants were used in this study because not all 225 of the participants provided a HFFQ to be

analyzed. These measurements allowed for the percent of lean body mass and percent of body fat to be calculated. There were 220 participants who had their waist-to-hip ratio measured, but only 180 of those participants were used in this study because not all 220 of the participants had their waist-to-hip ratio recorded nor did all the participants provide a HFFQ to be analyzed. There were 237 participants who had their TBBMD measured with the DXA, but only 188 of those participants were utilized in this study because not all 237 of the participants provided a HFFQ to be analyzed. Out of the 237 participants, only 57 participants were analyzed for circulating levels of TSH, T3, and T4 because not all the participants provided a blood sample to be analyzed nor did all the participants provide a HFFQ to be analyzed. There were 237 participants who had their age provided for the Pioneer Project data, but only 46 participants were evaluated for this study due to missing data for the other variables included in the analysis. Data for the mean and standard deviation of all the variables were provided.

Iodine intake was classified into tertiles based on percentiles of iodine intake. The tertiles were classified as follow: Group 1, $\leq 33^{rd}$ percentile; Group 2, $> 33^{rd}$ percentile and $\leq 66^{th}$ percentile; and Group 3, $> 66^{th}$ percentile. Group 1 includes all participants of the sample that had the lowest iodine intake, Group 2 includes all participants of the sample with an iodine intake in the middle, and Group 3 includes all participants of the sample with the highest iodine intake. Most of the participants were classified in Group 1, with the least amount of participants classified in Group 2.

Spearman's rank order correlation was performed to assess the association between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and circulating concentrations of T3, T4, and TSH. After analyzing the data obtained, the hypothesis was rejected that there was a significant association between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and circulating concentrations of T3, T4, and TSH.

A partial correlation was also performed to determine if there was an association between dietary iodine intake and age with the circulating concentrations of T3, T4, and TSH while controlling for all other variables that could affect the outcome that is displayed by the dependent variables. The hypothesis was rejected that there was a significant association between dietary iodine intake and the circulating concentrations of T3, T4, and TSH when controlling for all other variables. After analyzing the data obtained, the null hypothesis was accepted that there was no significant association between age and the circulating concentrations of T3, T4, and TSH when controlling for all other variables.

ANOVA was completed to assess if there were any significant differences between the means of the iodine intake tertiles on percent lean body mass, percent body fat, and waist-to-hip ratio. Even after analyzing the effect of iodine intake separated into tertiles, the hypotheses were still accepted that there was no significant association between dietary iodine intake and percent body fat, percent lean body mass, and waist-to-hip ratio.

Discussion

In summary, this study did not demonstrate any significant relationships between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, and circulating concentrations of T3, T4, and TSH in Caucasian females between the ages of 18 and 60 years. Even when controlling for body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, iodine intake, and age, there was no significant association found between iodine intake or age with circulating concentrations of TSH, T3, and T4. When iodine intake was separated into tertiles, there was no significant association between dietary iodine intake and percent body fat, percent lean body mass, and waist-to-hip ratio. One finding that is important to note is that the participants who had the highest iodine intake (Group 3, > 66^{th} percentile of the RDA) had the highest mean percent lean body mass and lowest mean percent of body fat. In Group 3, the highest mean percent lean body mass was 62.6% and the lowest mean percent body fat was 37.4%.

Iodine is an important nutrient involved in the production of thyroid hormones. Iodine is essential for normal thyroid function, and the thyroid hormones are responsible for regulating basal metabolic rate (BMR). The thyroid is required for cellular respiration and energy production of ATP. This further enhances an individual's oxygen consumption and metabolism. Both T3 and T4 are needed for normal growth as well as development, energy metabolism, and protein synthesis. T4 is synthesized solely in the thyroid gland (Arthur, Nicol, & Beckett, 1992). Once T4 is circulating in the bloodstream, this thyroid

hormone enters all tissues of the body where it can be converted to the more metabolically active T3 (Arthur, Nicol, & Beckett, 1992). The thyroid stimulates energy production through the cellular mitochondria which has an effect on an individual's BMR. With an advanced age, there is a tendency for serum TSH levels to be increased whereas T3 levels have been shown to decrease (Hegedües et al., 1983).

A selenium deficiency has also been shown to decrease conversion of T4 to T3 in the tissues that contain type I and II iodothyronine deiodinases (Arthur, Nicol, & Beckett, 1992). Future studies should consider assessing selenium with iodine to determine what effect a selenium deficiency plays on the production of thyroid hormones. Both selenium and iodine are important for the proper performance of the thyroid gland as well as thyroid hormone biosynthesis and metabolism (Schomburg & Köhrle, 2008). Selenium is necessary for the biosynthesis and function of a minimal amount of selenocysteine-containing selenoproteins involved in thyroid hormone metabolism and the function of the thyroid gland (Schomburg & Köhrle, 2008). By also analyzing selenium, the researcher can determine what effects this element has on human metabolism in regards to body mass index (BMI), BMR, weight, and body composition.

One variable that was not measured in this study was thyroid volume. Thyroid volume can be affected by daily iodine intake, geographical region and food intake habit (Moghadam, Shajari, & Afkhami-Ardekani, 2011). In several other studies, the researchers compared the effect of thyroid volume on body weight, body fat percentage, body fat weight, waist circumference, TSH, T4, and T3. Thyroid volume was typically

measured using thyroid ultrasonography. These studies have suggested that an individual's thyroid volume is significantly associated with body weight (Gomez et al., 2000; Hegedües et al., 1983; Ivarsson et al., 1989; Sari et al., 2003; Semiz et al., 2001). Whereas, one study indicated that only lean body mass was related to thyroid volume (Wesche et al., 1998). Thyroid volume has a relationship with BMI, waist-to-hip ratio, and fat mass in areas with an adequate iodine intake as well as mild or moderate iodine-deficient areas (Gomez et al., 2000; Hegedües et al., 1983; Ivarsson et al., 1989; Semiz et al., 2001). The results from the study by Sari et al. (2003) indicated a significant association between thyroid volume and body weight, body fat percentage, body fat weight, waist circumference, and BMI. A study by Wesche and Wiersinga (2001) looked at the effects of a 6-month intensive physical training program on thyroid volume. The 6-month intensive physical training program caused changes in thyroid volume related to body composition changes (Wesche & Wiersinga, 2001). The group of freshman participants had reductions in thyroid volume ($p = .08$), body weight ($p < .01$), body mass index ($p < .01$), fat weight ($p < .05$), and lean body mass ($p < .05$; Wesche & Wiersinga, 2001). The control group included senior rowers who had participated in a training program for more than two years. The control group had no alterations in thyroid volume or body composition throughout the 6-month surveillance period (Wesche & Wiersinga, 2001).

The Harvard Food Frequency Questionnaire (HFFQ) utilized in this study can be a practical method for performing a dietary assessment, but it is not without its limitations.

The HFFQ requires that the participants recall the frequency of food items they consumed during the week, the month, or year before. Participants also estimate what they consumed in their diet instead of providing exact measurements through a food record. In addition, there are some questions included on the food frequency questionnaire that are not specific. For example, one question asked about salt added at the table, but did not specify what kind of salt was used. If an individual does not consume the same foods all the time, then they may forget about certain food items such as seasonal foods like fruits and vegetables. Validation studies have shown that the correlations are limited by error in both diet records and food frequency questionnaires (Longnecker et al., 1993). Diet records may have a degree of error similar to food frequency questionnaires (Longnecker et al., 1993). This is the case because when keeping diet records, the portion sizes of some foods may be estimated by dimensions or through household measurements instead of by weight (Longnecker et al., 1993). As a result, the nutrient content may be off by 20% on average (Longnecker et al., 1993). The reproducibility of food frequency questionnaires have displayed correlations ranging from 0.39-0.88 (Longnecker et al., 1993). In the present study, the HFFQ was not an adequate indicator of iodine intake. The results showed that 60% of the participants consumed 0 μg of iodine per day while 70% of the participants consumed below the 150 μg of iodine per day for the RDA. It is hard to believe that such a large majority of the participants consumed no iodine in their diet since iodized salt has been distributed nationally since 1924.

Daily urinary iodine excretion can be a reflection of iodine intake because only a small amount of iodine is excreted through the feces with the remainder excreted in the urine (Thomson et al., 1996). Therefore, analyzing an individual's urine output may provide a better estimate of the amount of iodine that an individual consumes each day. The 24-hour urinary iodide is the most widely utilized measure of iodine status, but can be inconvenient for the subject and may be hard to collect accurately (Thomson et al., 1996). Sometimes casual or fasting urine samples with iodine expressed per unit of creatinine are utilized, but it is not well supported whether these casual or fasting samples are sufficient to evaluate iodine status (Thomson et al., 1996). The single spot urinary samples are preferred in population studies (Vejbjerg et al., 2009). Since there is considerable variability in daily iodine consumption, spot urine samples are unreliable for assessing iodine deficiency (Vejbjerg et al., 2009). Both the intake of iodine and fluid can affect the iodine concentration in urine (Vejbjerg et al., 2009). When the urinary iodide concentration is expressed as a function of urinary creatinine, this can help to correct the influence of fluid intake (Vejbjerg et al., 2009).

Strengths of this study include the availability of the data from the Pioneer Project. The duration of the Pioneer Project with data collected over a period of 4-years allowed for ample data collection. The Pioneer Project provided comprehensive medical, psychological, physiological, socioeconomical, and nutritional information from 351 women between 18 to 60 years of age. The wide range of ages for the participants and the large sample size provided more data for analysis.

Limitations of this study include that only Caucasian females were analyzed. It is unsure if the male sex or other ethnicities would have different outcomes from what was shown in this study as neither population was assessed. For all variables measured throughout the study, not all the participants had data collected for every variable. The HFFQ was used to analyze the participant's iodine intake as opposed to assessing the participant's urinary iodine excretion which may be more accurate. The HFFQ revealed that a large group of participants from the Pioneer Project had an intake of 0 μg of iodine per day. Thus, the variability was decreased in the population. The majority of participants consumed less than the RDA of 150 μg of iodine per day. Based on data from this study, the HFFQ was not an adequate indicator of iodine intake because a majority of Americans consume some amount of iodine as a result of the initiation of iodized salt.

Conclusion

In conclusion, there was not a significant association between dietary iodine intake and body weight, percent lean body mass, percent body fat, waist-to-hip ratio, TBBMD, or circulating concentrations of T3, T4, and TSH using the data from the Pioneer Project. The HFFQ did not provide accurate measurements of iodine intake for analysis in the Pioneer Project. Therefore, a more accurate indicator of iodine status needs to be utilized in future studies to analyze the effect of iodine consumption on an individual's body weight, BMR, and body composition including percent lean body mass and percent body fat. Analyzing the effect of selenium on iodine is another aspect to consider when assessing iodine's effect on the human body.

Recommendations for Further Studies

Below are some recommendations for additional research on the relationship between iodine intake and body weight:

1. Utilization of a more accurate indicator of iodine status such as measuring urinary iodine excretion, food diaries, or an iodine controlled diet.
2. Assessing the effect of different amounts of selenium on iodine metabolism in the human body.
3. Studies should be done to determine if there are any differences between variable iodine intake and ethnicity or sex.
4. Studies should include samples with more variability of iodine intake.
5. Studies should assess the effect of iodine intake on thyroid volume.

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Appendix A

Institutional Review Board (IRB) Approval

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940-898-4416
e-mail: IRB@twu.edu

June 29, 2011

Ms. Alexis Neal

[redacted]

Dear Ms. Neal:

Re: The Association Between Dietary Iodine Consumption and Body Composition in Caucasian Females Between the Ages of 18 to 60 (Protocol #: 16741)

The above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and was determined to be exempt from further review.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. Because a signed consent form is not required for exempt studies, the filing of signatures of participants with the TWU IRB is not necessary.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

Sincerely,

Kathy DeOrnellas, PhD.

Dr. Kathy DeOrnellas, Chair
Institutional Review Board - Denton

cc. Dr. Chandan Prasad, Department of Nutrition & Food Sciences
Dr. Nancy DiMarco, Department of Nutrition & Food Sciences
Graduate School