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## Soft Drink Consumption and Changes in Body Composition in 170 Women: A 4-Year Prospective Study

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SOFT DRINK CONSUMPTION AND CHANGES IN BODY COMPOSITION  
IN 170 WOMEN: A 4-YEAR PROSPECTIVE STUDY

by

Jared M. Tucker

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Exercise Sciences

Brigham Young University

August 2005

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BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Jared M. Tucker

This dissertation/thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the dissertation/thesis of Name in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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## ABSTRACT

### SOFT DRINK CONSUMPTION AND CHANGES IN BODY COMPOSITION IN 170 WOMEN: A 4-YEAR PROSPECTIVE STUDY

Jared M. Tucker

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Master of Science

**Background:** In recent history, there have been significant increases in both soft drink consumption and the prevalence of obesity throughout the developed world. To help curb the obesity epidemic, a better understanding of the behaviors contributing to weight and fat gain is vital.

**Objective:** To examine the extent to which soft drink consumption is predictive of changes in body composition in middle-aged women over a 4-year period, while statistically controlling for age, energy intake, physical activity, and menopause status.

**Design:** A prospective cohort design over 48 months with no intervention. Self-reported soft drink consumption was used to predict changes in body weight and body fat percentage over the study period. Subjects included 170 healthy women (mean: 41.5 yrs at baseline). Soft drink consumption and menopause status were measured by questionnaire. Body weight was assessed using a calibrated, electronic scale, and total

body fat percentage was measured using dual energy x-ray absorptiometry (DEXA).

Energy intake was estimated using 7-day, weighed, food records.

**Results:** Women who primarily consumed sugar-sweetened soft drinks gained significantly more weight than those who consumed diet soft drinks or no soft drinks ( $p = 0.022$ ), even after controlling for confounding variables, except energy intake, which weakened the relationship by 28%. Changes in body fat were unrelated to the type of soft drink consumed. Women who consumed 7+ soft drinks per week gained significantly less body fat ( $p = 0.015$ ) and body weight ( $p = 0.052$ ) over the 4-year study compared to women who consumed fewer soft drinks per week. Further investigation revealed that women who consumed 7+ soft drinks per week did so almost exclusively in the form of diet soft drinks (87%).

**Conclusions:** Drinking sugar-sweetened soft drinks significantly increases risk of weight gain compared to consuming diet soft drinks or no soft drinks over a 4-year period. It appears that this relationship is partly due to differences in energy intake among those who drink different types of soft drinks. Thus, it appears that consuming diet soft drinks or no soft drinks instead of sugar-sweetened soft drinks may be a worthwhile method of preventing weight gain.

**KEY WORDS:** Soft drink, body composition, fat, weight gain, obesity

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Soft Drink Consumption and Changes in Body  
Composition in 170 Women: A 4-Year Prospective Study

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### **ABSTRACT**

**Background:** In recent history, there have been significant increases in both soft drink consumption and the prevalence of obesity throughout the developed world. To help curb the obesity epidemic, a better understanding of the behaviors contributing to weight and fat gain is vital.

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**Design:** A prospective cohort design over 48 months with no intervention. Self-reported soft drink consumption was used to predict changes in body weight and body fat percentage over the study period. Subjects included 170 healthy women (mean: 41.5 yrs at baseline). Soft drink consumption and menopause status were measured by questionnaire. Body weight was assessed using a calibrated, electronic scale, and total body fat percentage was measured using dual energy x-ray absorptiometry (DEXA). Energy intake was estimated using 7-day, weighed, food records.

**Results:** Women who primarily consumed sugar-sweetened soft drinks gained significantly more weight than those who consumed diet soft drinks or no soft drinks ( $p = 0.022$ ), even after controlling for confounding variables, except energy intake, which weakened the relationship by 28%. Changes in body fat were unrelated to the type of soft drink consumed. Women who consumed 7+ soft drinks per week gained significantly less body fat ( $p = 0.015$ ) and body weight ( $p = 0.052$ ) over the 4-year study compared to women who consumed fewer soft drinks per week. Further investigation revealed that

women who consumed 7+ soft drinks per week did so almost exclusively in the form of diet soft drinks (87%).

**Conclusions:** Drinking sugar-sweetened soft drinks significantly increases risk of weight gain compared to consuming diet soft drinks or no soft drinks over a 4-year period. It appears that this relationship is partly due to differences in energy intake among those who drink different types of soft drinks. Thus, it appears that consuming diet soft drinks or no soft drinks instead of sugar-sweetened soft drinks may be a worthwhile method of preventing weight gain.

**KEY WORDS:** Soft drink, body composition, fat, weight gain, obesity

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### INTRODUCTION

The prevalence of obesity has steadily increased throughout the past century.<sup>1</sup> Currently, 65% of Americans are either overweight or obese.<sup>2</sup> In fact, obesity has been labeled an epidemic in the United States because of its continually increasing prevalence and its strong association with several diseases. Every year over 300,000 people die from obesity-related disorders.<sup>3</sup> Experts predict that obesity will replace cigarette smoking as the major killer of Americans in the coming years.<sup>4</sup> Some of the major diseases associated with obesity include coronary heart disease, stroke, hypertension, hyperlipidemia, Type 2 diabetes, osteoarthritis, gallbladder disease, several cancers, and all-cause mortality.<sup>5-8</sup>

These trends are such a major concern to public health officials that a national goal was established in an attempt to curb the expanding epidemic of obesity.<sup>9</sup> The goal stated that the prevalence of obesity would be reduced to no more than 20% by the year 2000. Despite significant efforts to reduce weight gain, the U.S. obesity objective was never achieved.<sup>10</sup> Health authorities have established a new goal to decrease the prevalence of obesity to no more than 15% by the year 2010.<sup>11</sup> However, unless greater efforts are made to reduce this increasing epidemic, the nation will fail again.

There are several factors that contribute to the rising trend of obesity.<sup>12</sup> One of these factors may include a dramatic increase in the frequency and size of soft drinks consumed.<sup>13</sup> According to the National Soft Drink Association, soft drink consumption has increased steadily over the past 60 years.<sup>14</sup> Today the soft drink industry produces 15 billion gallons of soft drinks per year, and Americans spend over \$61 billion on these

beverages. In fact, in 1942 the American Medical Association expressed concern about carbonated beverages and other foods high in sugar stating that “all practical means be taken to limit consumption” of such foods.<sup>15</sup> Since that time, soft drink consumption has increased seven-fold with the average American consuming over 55 gallons of soft drinks in 2001.<sup>16</sup>

Much of the dramatic rise in consumption can be attributed to soft drink serving sizes.<sup>17</sup> In the 1950s, soft drinks were sold in 6.5-ounce bottles, which eventually grew into 12-ounce cans. Today, beverages are sold in 32-, 44-, and even 64-ounce sizes, the latter of which provides about 230 grams of sugar (1/2 lb of sugar) and 900 calories each. In short, if consumed daily over one month, more than 25,000 calories would be consumed from soft drinks alone. Thus, it is easy to see how these extra calories could contribute to excess energy intake.

In addition to high-sugar beverages, the consumption of artificially sweetened soft drinks has also increased over the past several years.<sup>18</sup> Though these beverages do not contain any calories, past research has shown mixed results in regard to the satiating and weight control effects of such diet beverages.<sup>19</sup> The sweetening ingredient in most diet soft drinks is aspartame, which has been shown to increase energy consumption when ingested before a meal.<sup>20</sup> However, other research has shown no effect on dietary intake from aspartame-beverage consumption.<sup>21</sup> Therefore, additional research is needed to better understand the long-term effects of “diet” soft drinks compared to “sugar-sweetened” soft drinks on body fat and body weight.

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To date, research examining the effects of soft drink consumption on changes in body composition has been sparse, especially in the adult population. In addition, the soft drink and weight gain association has not been adequately studied over an extended period of time. Therefore, the present study was conducted to determine the extent to which soft drink consumption, specifically type and frequency, contributes to changes in body weight and body fat percentage in middle-aged women over a 48-month period. An ancillary objective was to ascertain the extent to which age, energy intake, menopause status, and physical activity influence the soft drink and body composition association.

### **SUBJECTS AND METHODS**

#### **Subjects**

The current study used a prospective cohort design. In 2000-2001, baseline data were collected on 228 women. Approximately 48 months following baseline data collection (2004-2005), data were collected on 170 women from the same cohort.

Baseline requirements for subject qualification included nonsmoking females with BMIs below 30. In addition, subjects could not be planning to become pregnant. The vast majority of participants in the present investigation were Caucasian, educated, and married. Before participating in the baseline and follow-up phases of the study, all subjects signed an informed consent document approved by the university IRB.

#### **Measurement Methods**

The current study examined the following 6 variables: soft drink consumption, body composition, specifically changes in body fat percentage and body weight, age, energy intake, menopause status, and physical activity.



**Soft Drink Consumption**

Soft drink intake was assessed using a comprehensive eating behavior questionnaire. Specifically, the frequency and type of soft drinks consumed were measured using a series of questions which focused on use of diet soft drinks, non-diet soft drinks, beverage size, and number of soft drinks consumed per week.

**Body Fat Percentage**

Body fat percentage (BF%) was assessed at baseline and again at follow-up using dual energy x-ray absorptiometry, Model 4500 W (Hologic QDR, Waltham, MA), which has been shown to be an accurate and reliable measure of body fat.<sup>22-23</sup> Reliability of DEXA for the measurement of body fat was evaluated using 100 subjects from the present study. A test-retest was performed with complete repositioning of each subject. The test and retest means ( $\pm$  SD) were statistically equal ( $30.3 \pm 7.2$  and  $30.4 \pm 7.3$ ;  $p < 0.05$ ), and the intraclass correlation between the test and retest was 0.999 ( $p < 0.0001$ ).<sup>24</sup>

**Body Weight**

Body weight was measured at baseline and follow-up using a computerized electronic scale (Tanita Corporation, Tokyo, Japan) that measures to within 10 grams. The scale was calibrated daily to ensure accurate and reliable measures. All subjects wore a lightweight, nylon, one-piece swimsuit provided by the body composition lab to eliminate measurement error associated with differences in clothing. In addition, subjects were asked to use the restroom before being weighed and instructed not to eat anything 4 hours prior to the weight assessment.

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### **Physical Activity**

To reduce measurement error, the current study used MTI (formerly CSA) accelerometers (Fort Walton Beach, FL) to measure physical activity. Subjects wore the MTI accelerometers over the left hip and at the level of the umbilicus. Each participant wore the accelerometer continuously for seven days. Accelerometers were only removed when subjects were bathing or otherwise submerged in water. After seven consecutive days of wearing the accelerometer, activity counts were downloaded and summed to produce one number, which was used to index total physical activity for each participant.

### **Energy Intake**

Energy intake was estimated at baseline using 7-day, weighed food records. Subjects were given written instructions for keeping the food records, and were personally trained to weigh and record everything they put in their mouth. Each participant was issued an Ohaus electronic scale (Florham Park, NJ) which weighed food to the nearest gram, and 7 food logs to use when recording dietary intake. Subjects were instructed to maintain their typical diet throughout the 7-day period, and were contacted by telephone every other day to ensure that the proper protocol was being followed. Food records were then entered into a database by a registered dietitian and analyzed using ESHA software, version 7.2 (Salem, OR).

### **Menopause Status**

To evaluate menopause status, questions focused on the amount of time since the participant's last menstrual cycle, the regularity of menstrual cycles, and the presence of common signs and symptoms associated with menopause. The menopause status of

participants was divided into three categories: premenopausal, perimenopausal, and postmenopausal using the self-reported information.

### **Data Analysis**

The primary objective of the present study was to determine the association between soft drink consumption and changes in body weight and body fat over a 48-month period. Changes in body fat and body weight were calculated by subtracting the baseline measures from the follow-up values. Subjects were divided into categories based on the frequency and type (diet, sugar-sweetened, etc.) of soft drinks consumed. Regression analysis using the general linear model (GLM) procedure was employed to determine the extent to which the groups differed regarding mean changes in body fat and body weight over time. Additionally, contrast coding was employed to compare women who consumed sugar-sweetened soft drinks to the other types of soft drinks, and to compare women who consumed 7+ soft drinks per week to less frequent drinkers. Partial correlation was used to determine the influence of age, energy intake, menopause status, and physical activity on the soft drink and body composition change relationship. The SAS<sup>®</sup> system software (Cary, NC) was used to compute all statistical analysis.

### **RESULTS**

A total of 170 subjects completed all of the assessments at baseline and follow-up and were included in the analyses. Descriptive results of the outcome variables are summarized in Table 1. At baseline, the average subject age was  $41.5 \pm 3.0$  years, mean physical activity level was  $2,581,611 \pm 823,095$  total activity counts, and average caloric

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intake was  $2017.2 \pm 324.2$  kcal/day. Regarding menopause status, 77.0% of subjects were premenopausal, 11.5% were perimenopausal, and 11.5% were menopausal.

Approximately 36% of the subjects reported that they did not consume soft drinks regularly ( $< \frac{1}{2}$  of a 12 oz. soft drink per week). Of those who reported consuming soft drinks regularly, 55.7% consumed  $\frac{1}{2}$ -1 soft drink per week, 25.3% consumed 2-6 soft drinks/week, and 19.0% reported consuming 7+ soft drinks per week (based on 12 oz. soft drink). Of those who consumed soft drinks regularly, 41.8% reported consuming diet soft drinks exclusively ( $> 80\%$  of the time), 40.5% reported consuming sugar-sweetened soft drinks exclusively, and 17.7% reported consuming a mix of both diet and sugar-sweetened soft drinks.

Table 3 summarizes the relationship between the type of soft drink consumed and changes in body composition over time. Specifically, women who consumed sugar-sweetened soft drinks exclusively gained significantly more body weight than women who consumed diet soft drinks exclusively or no soft drinks ( $< \frac{1}{2}$  per week) over the 4-year duration ( $F = 5.37$ ,  $p = 0.022$ ). Further, this relationship remained significant after controlling for age ( $F = 4.92$ ,  $p = 0.028$ ), menopause status ( $F = 4.22$ ,  $p = 0.042$ ), physical activity level ( $F = 4.88$ ,  $p = 0.029$ ), and differences in baseline body weight ( $F = 4.32$ ,  $p = 0.039$ ). After controlling for energy intake, the relationship between type of soft drink consumed and changes in body weight was weakened by 28% and reduced to borderline significance ( $F = 3.87$ ,  $p = 0.051$ ). Furthermore, adjusting for differences in the frequency of soft drink consumption weakened the relationship between soft drink type and changes in body weight by 34% ( $F = 3.52$ ,  $p = 0.062$ ).

Results showed that the type of soft drinks subjects consumed was not predictive of changes in body fat percentage. Moreover, the potentially confounding variables had little effect on the body fat percentage and type of soft drink relationship (Table 2).

The relationship between frequency of soft drink consumption and changes in body weight was moderate ( $F = 3.82$ ,  $p = 0.052$ ). Adjusting for differences in age, energy intake, menopause status and differences in baseline body weight had little effect on the association between frequency of soft drink consumption and changes in body weight over the 4-year study. However, after adjusting for differences in objectively measured physical activity, the association between soft drink frequency and changes in body weight was strengthened ( $F = 4.17$ ,  $p = 0.043$ ). Conversely, after controlling for differences in type of soft drink consumed, the association between soft drink frequency and changes in body weight was weakened by 69% ( $F = 1.20$ ,  $p = 0.276$ ).

When comparing the frequency of soft drink consumption to changes in body fat percentage, women who consumed 7+ soft drinks per week lost body fat, whereas women who consumed fewer soft drinks per week gained body fat over the study period. Specifically, subjects who consumed 0-6 soft drinks per week gained significantly more body fat than participants who consumed 7+ soft drinks per week ( $F = 6.00$ ,  $p = 0.015$ ). Moreover, this relationship remained significant and was only marginally affected after adjusting for the potential confounding variables (Table 4).

## **DISCUSSION**

The current study was prospective in design with 48 months between the baseline and follow-up assessments. The primary purpose of the investigation was to examine the

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extent to which soft drink type and frequency predict changes in body weight and body fat percentage in women over an extended duration. A secondary objective was to ascertain the extent to which age, energy intake, menopause status, and physical activity influence the soft drink and body composition association. No intervention or treatment was introduced between assessments, which allowed time and subjects' choices to induce changes in the outcome variables.

### **Soft Drink Type and Changes in Body Composition**

From baseline to follow-up, subjects who consumed sugar-sweetened soft drinks gained an average of 2.7 kg, while those who consumed diet soft drinks tended to lose weight. Subjects who did not consume soft drinks on a regular basis also tended to gain weight. The difference in weight change between those consuming sugar-sweetened soft drinks and those consuming diet soft drinks or no soft drinks was significant, even after adjusting for each of the potential confounders, except energy intake. Hence, it appears that risk of weight gain over a 4-year duration is increased significantly when middle-aged women drink sugar-sweetened soft drinks compared to diet soft drinks or no soft drinks.

After controlling for energy intake, the association between soft drink type and changes in body weight was weakened by 28%. Thus, it appears that one of the primary ways that sugar-sweetened soft drinks increase body weight in middle-aged women is through failure to compensate for the additional soft drink calories, resulting in weight gain over time. Conversely, it appears that consuming diet soft drinks promotes weight

maintenance or even weight loss over a 48-month period, due in part, to differences in energy intake.

### **Soft Drink Frequency and Changes in Body Composition**

When examining the relationship between frequency of soft drink consumption and changes in body composition, a dose-response increase in both body weight and body fat percentage was apparent, with the exception of subjects consuming 7+ soft drinks per week. Subjects who consumed  $< \frac{1}{2}$  soft drink per week, 1-2 soft drinks per week, and 3-6 soft drinks per week gained an average of 0.5 kg, 1.5 kg, and 3.5 kg, and an average of 1.6% body fat, 1.5% body fat, and 2.7% body fat, respectively. However, subjects consuming 7+ soft drinks per week experienced decreases in both body weight (-0.8 kg) and body fat percentage (-0.5%).

Post hoc analysis helped to explain this unusual finding. In short, 87% of subjects who consumed 7+ soft drinks per week reported drinking diet soft drinks exclusively, whereas, 13% of daily drinkers consumed sugar-sweetened soft drinks. In contrast, 75% of subjects who consumed  $\frac{1}{2}$ -2 soft drinks per week, and 65% of subjects who consumed 3-6 soft drinks per week, consumed sugar-sweetened soft drinks. Thus, the apparent discrepancy among subjects who consumed soft drinks at least daily, yet experienced losses in body weight and body fat, was due at least in part, to the fact that the vast majority of daily drinkers consumed diet soft drinks exclusively.

Though the current investigation used a prospective cohort design, which allows for the assessment of risk, it was not a randomized clinical trial. Therefore, cause-and-effect conclusions are not warranted. Despite the fact that several potential confounders

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were controlled statistically, there are a number of other possible explanations regarding why women who consumed sugar-sweetened soft drinks gained more body weight than those who consumed diet or no soft drinks. For example, women who consumed diet soft drinks in the current study may have been more health conscious than their peers, which might have resulted in other lifestyle differences, leading to differences in weight gain. Further, women who consumed diet soft drinks may have had other dietary differences compared to those consuming sugar-sweetened drinks, besides energy intake, resulting in differences in weight gain over time. Additional limitations include the fact that soft drink consumption was self-reported, and that the cohort was primarily Caucasian, married, and educated, thus limiting the extent to which the findings can be generalized.

To date, there has been little prospective research that has focused on the relationship between soft drink consumption and changes in body composition. Further, it appears that few studies have measured changes in outcome variables similar to those of the current investigation for such an extended duration (i.e., 4 years). Thus, the current findings have valuable implications in the ongoing study of weight gain and obesity.

In summary, the current investigation demonstrates that drinking sugar-sweetened soft drinks tends to increase risk of weight gain in adult females over a 48-month period, whereas, consuming diet soft drinks may reduce risk of weight gain. Furthermore, it appears that one of the primary reasons for the weight gain among women consuming sugar-sweetened soft drinks compared to women consuming diet soft drinks or no soft drinks is differences in energy intake over time. In addition to the type of soft drink, the present study shows that frequency of soft drink consumption may help to explain



changes in body composition. However, after controlling for soft drink type, the association between soft drink frequency and changes in body weight was reduced to non-significance, suggesting that the type of soft drinks consumed is more important than the frequency of consumption.

In conclusion, if a causal relationship were assumed, results of the current study suggest that risk of body weight and fat gain can be significantly diminished by adjusting soft drink consumption behavior. In short, it appears that consuming diet soft drinks rather than sugar-sweetened soft drinks may be a worthwhile weight management strategy.

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**Table 1.** Body Composition from Baseline to Follow-up by Soft Drink Type

Variable	Soft Drink Type	Baseline (mean±SD)	Follow-up (mean±SD)	Change (mean±SD)	F	P
BW (kg)	Non-Drinkers	65.8±10.9	66.3±11.1	0.5±5.0	0.07	0.401
	Diet	67.7±9.8	67.7±10.1	0.0±4.4	0.00	0.976
	Mixed	68.2±7.7	69.5±8.7	1.2±5.0	1.12	0.304
	Sugar-Sweetened	63.4±11.0	66.1±12.4	2.7±5.1	11.65	0.001
	All Subjects Combined	65.9±10.4	67.0±11.0	1.1±5.0	7.07	0.009
BF%	Non-Drinkers	32.3±7.4	33.7± 7.2	1.4±3.9	8.32	0.005
	Diet	33.2±5.9	34.3±6.1	1.1±3.8	3.23	0.080
	Mixed	33.5±7.0	35.4±6.4	1.9±3.1	6.79	0.018
	Sugar-Sweetened	31.8±7.0	33.9±7.0	2.1±3.2	17.79	0.0001
	All Subjects Combined	32.5±6.9	34.1±6.8	1.5±3.6	30.52	0.0001

BW = Body weight

BF% = Body fat percentage

**Table 2.** Body Composition from Baseline to Follow-up by Soft Drink Frequency

Variable	Soft Drink Frequency	Baseline (mean±SD)	Follow-up (mean±SD)	Change (mean±SD)	F	P
BW (kg)	<½ per week	65.0±11.0	65.6±11.0	0.6±4.7	1.40	0.240
	½-2 per week	66.1±10.0	67.5±11.6	1.4±5.5	2.99	0.091
	3-6 per week	66.5±8.4	69.9±9.1	3.4±4.8	10.37	0.004
	7+ per week	70.2±10.4	69.3±11.0	-0.8±4.6	0.47	0.503
BF%	<½ per week	31.9±7.4	33.6±7.1	1.6±3.8	16.28	0.001
	½-2 per week	32.9±7.0	34.4±6.9	1.5±3.4	9.51	0.003
	3-6 per week	33.2±5.3	35.9±5.1	2.7±2.8	17.57	0.001
	7+ per week	34.2±5.5	33.7±6.7	-0.5±3.8	0.24	0.633

BW = Body weight

BF% = Body fat percentage

**Table 3.** Changes in Body Composition by Type of Soft Drink Consumed

Variable	Variable Controlled	Type of Soft Drink Consumed				R <sup>2</sup>	F	P
		None n=68 (mean±SD)	Diet n=40 (mean±SD)	Mixed n=19 (mean±SD)	Sugar n=43 (mean±SD)			
Δ BW(kg)	None	0.50 ± 5.05 <sup>a</sup>	-0.05 ± 4.4 <sup>a</sup>	1.22 ± 5.05 <sup>a,b</sup>	2.68 ± 5.14 <sup>b</sup>	0.042	5.37	0.022
	Age	0.45 <sup>a</sup>	0.05 <sup>a</sup>	1.40 <sup>a,b</sup>	2.64 <sup>b</sup>	0.042	4.92	0.028
	Energy Intake	0.64 <sup>a</sup>	-0.05 <sup>a</sup>	1.45 <sup>a,b</sup>	2.50 <sup>b</sup>	0.036	3.87	0.051
	Menopause Status	0.36 <sup>a</sup>	-0.18 <sup>a</sup>	1.23 <sup>a,b</sup>	2.32 <sup>b</sup>	0.037	4.22	0.042
	Physical Activity	0.41 <sup>a</sup>	0.14 <sup>a</sup>	1.00 <sup>a,b</sup>	2.64 <sup>b</sup>	0.036	4.88	0.029
	Baseline BW*	0.50 <sup>a</sup>	0.09 <sup>a</sup>	1.36 <sup>a,b</sup>	2.55 <sup>b</sup>	0.036	4.32	0.039
Δ BF%	None	1.4 ± 3.9	1.1 ± 3.8	1.9 ± 3.1	2.1 ± 3.2	0.011	0.93	0.337
	Age	1.3	1.0	1.9	2.1	0.014	0.95	0.331
	Energy Intake	1.3	0.9	2.2	2.0	0.016	0.58	0.448
	Menopause Status	1.2	0.9	1.8	1.9	0.010	0.61	0.435
	Physical Activity	1.3	1.0	1.8	2.1	0.012	1.08	0.300
	Baseline BF%	1.3	1.2	2.0	2.0	0.009	0.50	0.483

Note: Means on the same row with the same superscript letter are not significantly different.

Δ BW = Change in body weight

Δ BF% = Change in body fat percentage

## 22 Soft Drinks and Body Composition

**Table 4.** Changes in Body Composition by Frequency of Soft Drink Consumption

Variable	Variable Controlled	Frequency of Soft Drink Consumption				R <sup>2</sup>	F	P
		< 1/2 per wk	1/2-2 per wk	3-6 per wk	7+ per wk			
		n=90 (mean±SD)	n=45 (mean±SD)	n=20 (mean±SD)	n=15 (mean±SD)			
Δ BW (kg)	None	0.55±4.64 <sup>a</sup>	1.45±5.55 <sup>a,b</sup>	3.45±4.77 <sup>b</sup>	-0.82±4.64 <sup>a</sup>	0.047	3.82	0.052
	Age	0.59 <sup>a</sup>	1.45 <sup>a,b</sup>	3.32 <sup>b</sup>	-0.77 <sup>a</sup>	0.043	3.64	0.058
	Energy Intake	0.68 <sup>a</sup>	1.45 <sup>a,b</sup>	3.23 <sup>b</sup>	-0.86 <sup>a</sup>	0.039	3.78	0.054
	Menopause Status	0.50 <sup>a</sup>	1.09 <sup>a,b</sup>	3.32 <sup>b</sup>	-0.91 <sup>a</sup>	0.043	3.59	0.060
	Physical Activity	0.50 <sup>a</sup>	1.41 <sup>a,b</sup>	3.32 <sup>b</sup>	-1.09 <sup>a</sup>	0.047	4.17	0.043
	Baseline BW	0.55 <sup>a</sup>	1.45 <sup>a,b</sup>	1.59 <sup>b</sup>	-0.55 <sup>a</sup>	0.045	3.08	0.081
Δ BF%	None	1.6±3.8 <sup>a</sup>	1.5±3.4 <sup>a</sup>	2.7±2.9 <sup>a</sup>	-0.5±3.8 <sup>b</sup>	0.039	6.00	0.015
	Age	1.6 <sup>a</sup>	1.4 <sup>a</sup>	2.6 <sup>a</sup>	-0.5 <sup>b</sup>	0.039	5.69	0.018
	Energy Intake	1.6 <sup>a</sup>	1.5 <sup>a</sup>	2.5 <sup>a</sup>	-0.5 <sup>b</sup>	0.037	5.73	0.018
	Menopause Status	1.6 <sup>a</sup>	1.3 <sup>a</sup>	2.5 <sup>a</sup>	-0.5 <sup>b</sup>	0.038	5.58	0.019
	Physical Activity	1.6 <sup>a</sup>	1.4 <sup>a</sup>	2.6 <sup>a</sup>	-0.6 <sup>b</sup>	0.038	5.51	0.020
	Baseline BF%	1.5 <sup>a</sup>	1.6 <sup>a</sup>	2.8 <sup>a</sup>	-0.2 <sup>b</sup>	0.035	5.34	0.022

Note: Means on the same row with the same superscript letter are not significantly different.

Δ BW = Change in body weight

Δ BF% = Change in body fat percentage



Appendix A

Prospectus



## Chapter 1

### Introduction

The prevalence of obesity has steadily increased throughout the past century.<sup>1</sup> Currently, 65% of Americans are either overweight or obese.<sup>2</sup> In fact, obesity has been labeled as an epidemic in the United States because of its continually increasing prevalence and its strong association with several diseases. Every year over 300,000 people die from obesity-related disorders.<sup>3</sup> Experts predict that obesity will replace cigarette smoking as the major killer of Americans in the coming years.<sup>4</sup> Some of the major diseases associated with obesity include coronary heart disease, stroke, hypertension, hyperlipidemia, Type 2 diabetes, osteoarthritis, gallbladder disease, several cancers, and all-cause mortality.<sup>5-8</sup>

These trends are such a major concern to public health officials that a national goal was established in an attempt to curb the expanding epidemic of obesity.<sup>9</sup> The goal stated that the prevalence of obesity would be reduced to no more than 20% by the year 2000. Despite significant efforts to reduce weight gain, the U.S. obesity objective was never achieved.<sup>10</sup> Health authorities have established a new goal to decrease the prevalence of obesity to no more than 15% by the year 2010.<sup>11</sup> However, unless greater efforts are made to reduce this increasing epidemic, the nation will fail again.

Due to the high prevalence and numerous health issues associated with this disorder, obesity research is continually developing. Despite the recent expansion of research, the study of obesity is relatively new, with many questions remaining unanswered.

There are several factors that contribute to the rising trend of obesity.<sup>12</sup> One of these factors may include a dramatic increase in the frequency and size of soft drinks consumed.<sup>13</sup> According to the National Soft Drink Association, soft drink consumption has increased steadily over the past 60 years.<sup>14</sup> Today the soft drink industry produces 15 billion gallons of soft drinks per year, and Americans spend over \$61 billion on these beverages. In fact, in 1942 the American Medical Association expressed concern about carbonated beverages and other foods high in sugar stating that “all practical means be taken to limit consumption” of such foods.<sup>15</sup> Since that time, soft drink consumption has increased seven-fold with the average American consuming over 55 gallons of soft drinks in 2001.<sup>16</sup>

Much of the dramatic rise in consumption can be attributed to soft drink serving sizes.<sup>17</sup> In the 1950s soft drinks were sold in a 6.5-ounce bottle, which eventually grew into the 12-ounce can. Today, beverages are sold in 32-, 44-, and even 64-ounce sizes, the latter of which provides about 230 grams of sugar (1/2 lb of sugar) and 900 calories each. In short, if consumed daily over one month, more than 25,000 calories would be consumed from soft drinks alone. Therefore, it is easy to see how these extra calories could contribute to excess energy intake.

In addition to high-sugar beverages, the consumption of artificially sweetened soft drinks has also increased over the past several years.<sup>18</sup> Though these beverages do not contain any calories, past research has shown mixed results in regard to the satiating and weight control effects of such “diet” beverages.<sup>19</sup> The sweetening ingredient in most diet soft drinks is aspartame, which has been shown to increase energy consumption when

ingested before a meal.<sup>20</sup> However, other research has shown no effect on dietary intake from aspartame-beverage consumption.<sup>21</sup> Therefore, additional research is needed in this field to better understand the effects of “diet” soft drinks on energy consumption and changes in body weight.

To date, research examining the effects of soft drink consumption on weight gain and obesity has been sparse, especially in the adult population. In addition, these effects have not been adequately studied over an extended period of time. Therefore, a prospective cohort design using accurate and reliable measures of soft drink consumption, body weight, and body composition would provide new and meaningful data concerning the intricacies of obesity and weight regulation. Given the increasing prevalence of obesity and the many risks associated with this disorder, a study such as the one proposed is warranted.

#### *Statement of the Problem*

The primary purpose of the proposed study will be to ascertain the relationship between soft drink consumption and body composition in approximately 150 middle-aged women. An ancillary objective will be to determine the extent to which age, energy intake, menopause status, and physical activity influence the soft drink and body composition association.

#### *Research Questions*

1. To what extent does soft drink consumption predict changes in body composition over a 48-month period in middle-aged women?

2. To what extent is the relationship between soft drink consumption and body composition influenced by potential confounders such as age, energy intake, menopause status, and physical activity?

*Assumptions*

1. Subjects will accurately respond to eating behavior and physical activity questionnaires.
2. Subjects will not eat at least four hours prior to weight and body composition measurements.
3. Subjects will be able to read and fully understand all questions in each of the questionnaires given.

*Limitations*

1. There is a risk of potential bias in both the physical activity and dietary consumption results because they are both being obtained by way of self-reported questionnaires.
2. The proposed prospective cohort study cannot show causality, but can only evaluate risk.

*Delimitations*

Subjects in the proposed investigation were initially recruited from Utah County, Utah, to be involved in the BYU Lifestyle Project. Subject requirements at baseline (Phase I) included the following: subjects had to be between ages 35-45, have a BMI of less than 30, and not use tobacco. Also, because of Utah demographics, a large percentage of the recruited subjects were Caucasian.

Approximately 18 months following baseline data collection, data were collected for Phase II of the Lifestyle Project. About 18 months after Phase II data collection, data were collected for Phase III of the Lifestyle Project. For the proposed prospective cohort study, Phase II data will serve as baseline data and will be compared to data collected for the proposed study, which will be Phase IV of the Lifestyle Study.

Body composition will be assessed using Dual Energy X-ray Absorptiometry (DEXA). Soft drink consumption, physical activity, and menopause status will be estimated using written questionnaires. Energy intake will be indexed using a food frequency questionnaire by Block.

#### *Operational Definitions*

Soft drink – Any non-alcoholic beverage such as carbonated beverages, fruit drinks, and sports drinks.

Diet soft drink – Any non-alcoholic beverage that contains artificial sweeteners

Physical activity – Bodily movement produced by skeletal muscles measured in the current study with a physical activity questionnaire.

Obesity – A condition in which one's Body Mass Index (BMI) exceeds 30 or in which a female's body fat percentage exceeds 32%.

Dietary Intake – Everything consumed in the form of foods, liquids, and supplements as recorded in an eating behavior questionnaire.

## Chapter 2

### Literature Review

Obesity is one of the most significant public health problems of our time.<sup>22, 23</sup> This is primarily due to its expanding prevalence and the many diseases and ailments associated with excess weight. Because of these many health concerns, obesity research has increased significantly over the past 20 years. This research has shown that obesity is a multifaceted problem, and has helped to identify several factors that contribute to it.<sup>13</sup> Two of the main factors include an excess energy intake and a shortage of energy expenditure due to sedentary lifestyle behaviors.<sup>24, 25</sup> Currently, there are several factors that have been shown to promote overconsumption. One of these includes the intake of excess calories in beverage form, such as soft drinks.<sup>26</sup> Therefore, the purpose of the current literature review is to determine the extent to which high- and low-calorie soft drinks, affect satiety, energy intake, and body weight. The present review will be divided into three sections based on the following criteria: high-calorie soft drinks, artificially-sweetened soft drinks, and soft drinks and children.

#### *High Calorie Soft Drink Studies*

Shulze et al. examined the relationship between consumption of sugar-sweetened beverages and weight change in a prospective cohort study including 51,603 women.<sup>27</sup> Subjects were followed for 8 years with soft drink consumption and body weight being assessed at baseline, during the fourth year, and after the eighth year. After adjusting for potential confounders, women with the greatest increase in soft-drink consumption over both four-year periods experienced the greatest increase in weight gain. Conversely,



women who decreased their soft-drink consumption the most had the lowest increase in body weight. Therefore, the authors concluded that a higher consumption of sugar-sweetened beverages is associated with greater increases in body weight.

Tordoff and Alleva studied the effect of 1150 g of soft drink intake per day on 30 male and female subjects over a three-week period.<sup>28</sup> Soft drinks were either sweetened with aspartame or high-fructose corn syrup. Aspartame-sweetened drinks significantly reduced calorie intake of both females and males and significantly reduced body weight in males but not females. Conversely, consumption of high-fructose-sweetened beverages significantly increased caloric intake and body weight in both males and females. Also, the consumption of either type of soft drink was associated with a reduced intake of dietary sugar.

Raben et al. investigated the effects of artificially vs. sucrose sweetened drink and food consumption on ad libitum food intake and body weight in 41 overweight males and females.<sup>29</sup> After 10 weeks of supplementation, body weight and fat mass significantly increased in the sucrose group (by 1.6 kg and 1.3 kg, respectively), and significantly decreased in the artificial-sweetener group (by 1.0 kg and 0.3 kg, respectively). In addition, subjects who consumed relatively large amounts of sucrose in the form of beverages also had significantly higher energy intakes and blood pressures.

Bukowiecki et al. studied the effects of feeding rats Coca-Cola in addition to their ad libitum, Purina chow diet.<sup>30</sup> The Coca-Cola consuming rats significantly increased total energy intake by 50%. Also, rats that were given ad libitum access to soft drinks experienced significant gains in adipose tissue weight.

Bray et al. investigated the relationship between high-fructose corn syrup intake (the primary sweetener in soft drinks) and obesity using US Department of Agriculture food consumption tables.<sup>14</sup> Consumption of high-fructose corn syrup increased more than 10 fold between 1970 and 1990, and now represents over 40% of caloric sweeteners added to foods and beverages. Because of differences in the digestion and absorption of fructose compared to sucrose, fructose-containing soft drinks may be less efficient at triggering satiety signals and therefore contribute to increased energy intake and eventual weight gain.

A study conducted by DiMeglio and Mattes studied the effect of a 450 kcal/day carbohydrate load in either soft drink or solid form on weight regulation in 15 healthy men and women.<sup>31</sup> After four weeks of treatment subjects who consumed the sweetened soft drink load gained significantly more weight than did those who consumed the energy load in solid form (jelly beans). Therefore, when ingesting calorie-containing beverages, energy compensation may be less precise than when consuming the same amount of energy in solid form.

#### *Artificially-Sweetened Soft Drink Studies*

Blackburn et al. used a prospective, randomized design to investigate the effects of aspartame consumption on weight loss and weight maintenance in 163 females.<sup>32</sup> Subjects in the aspartame group were given aspartame-sweetened pudding and milk shakes in place of their regular milk exchanges, and were encouraged to use other products sweetened with aspartame. During the active weight loss component of the program women in the aspartame-treatment group lost significantly more weight overall

and regained significantly less weight during the maintenance period when compared to the no-aspartame group.

Drewnowski et al. compared the effects of breakfasts that were sweetened with sucrose or aspartame on subsequent energy intake throughout the day.<sup>33</sup> Aspartame-sweetened breakfasts contained only 300 kcals, whereas those that used sucrose contained 700 kcals. Total daily energy intakes were significantly higher for subjects who consumed the sucrose-sweetened breakfasts when compared to those who ate the aspartame-sweetened ones. Additionally, substituting aspartame for sugar in sweetened cereal had no effect on the next meal or subsequent hunger ratings.

Kanders et al. investigated the effect of low-calorie sweetener use on compliance to a hypocaloric diet and long-term weight loss.<sup>34</sup> A total of 59 subjects were assigned to either a control or experimental group, both of which were instructed to maintain a 1000 kcal (for women) or 1200 kcal (for men) diet for 12 weeks. However, subjects in the experimental group were also asked to supplement their diets with at least two aspartame-sweetened beverages or foods per day. Females in the experimental group lost 3.7 lb more than the control group on average after 12 weeks. However, this difference was found to be insignificant.

#### *Soft Drinks and Children Studies*

Ludwig et al. enrolled 548 children from ages 10-12 into a 19-month prospective study examining the association between changes in sugar-sweetened drink consumption and changes in BMI.<sup>35</sup> After adjusting for confounding variable such as anthropometric, demographic, and dietary variables, the odds of becoming obese significantly increased

for each additional serving of sugar-sweetened drink per day. In fact, for each serving of sugar-sweetened soft drink consumed, BMI increased by 0.24 kg/m<sup>2</sup>. In addition, baseline consumption of sugar-sweetened drinks was independently associated with an increase in BMI, and diet drinks were negatively associated with becoming obese.

Mrdjenovic and Levitsky collected dietary intakes from 30 children aged 6-13 who were given unlimited access to water, milk, and sugar-sweetened soft drinks for 4-8 weeks.<sup>36</sup> Children failed to reduce dietary intake of solid food to compensate for the calories contained in the soft drinks consumed which led to higher daily energy intakes in those who consumed >12 oz/day of soft drinks. Similarly, as soft drink consumption increased, weight gain also tended to increase when compared with children who consumed few soft drinks (<12 oz/day).

Harnack et al. collected food intake, recall information from children aged 2 to 18. Data were then analyzed to determine nutrient and total energy intake.<sup>37</sup> On average, energy intakes for children who did not consume soft drinks was 1,830 kcal/day. Conversely, those who consumed 9 oz or more of soft drinks per day averaged a 2,018 kcal/day caloric intake.

Giammattei et al. investigated the effects of soft drink consumption on obesity in 385 seventh-grade boys and girls.<sup>38</sup> Height and weight were measured to determine BMI, and body composition was assessed using bioelectrical impedance. Results showed a significant association between daily soft drink consumption and BMI. Additionally, the mean BMI z-score was significantly lower for those consuming less than 3 soft drinks per day when compared to those consuming 3 or more soft drinks per day.

## Chapter 3

### Methods

The focus of the proposed study will be to assess the association between soft drink consumption and changes in body composition over a 48-month period. A secondary objective will be to examine the extent to which the association between soft drink intake and body composition is affected by age, energy intake, menopause status, and physical activity.

#### *Design*

The proposed study will use a prospective cohort design. In 1998 and 1999, baseline data were collected for the BYU Lifestyle Project. Approximately 18 months following the baseline data collection, data were collected for Phase II of the Project. About 18 months after Phase II data collection, data were collected for Phase III of the Lifestyle Project. For the proposed prospective cohort study, Phase II data will serve as baseline data and will be compared to data collected for the proposed study, which will be Phase IV of the Lifestyle Project.

#### *Subjects*

A total of 150 subjects will be recruited from the ongoing BYU Lifestyle Project, and will participate in the current study as the fourth phase of the Project. In 1998-1999, baseline requirements for subject qualification included nonsmoking, premenopausal females, between the ages of 35 and 45, with BMIs below 30. In addition, subjects could not be planning to become pregnant and had to show high levels of commitment to the study from responses to a Likert-type scale. Because of Utah demographics, the vast

majority of participants in the Lifestyle Project are Caucasian. Before participating in the current study, all subjects will be required to complete an informed consent questionnaire approved by the University IRB.

#### *Instrumentation and Measurement Methods*

The current study will examine the following 6 variables: soft drink consumption, body composition (specifically body fat percentage and body weight), age, energy intake, menopause status, and physical activity. Each of these measures was assessed during Phase II of the Lifestyle Project and will be assessed again during Phase IV of the Project. Changes in these variables will be analyzed over a 48-month period by subtracting the Phase II value from the Phase IV value.

#### *Soft Drink Consumption and Energy Intake*

Soft drink and total energy intake will be assessed using the Block food frequency questionnaire as well as a comprehensive eating behavior questionnaire.<sup>39-40</sup> The Block food frequency questionnaire assesses the portion size and frequency with which several different foods are consumed. Soft drink consumption will be measured using a series of questions within the eating behavior questionnaire which focus on several aspects of consumption, such as diet soft drinks, non-diet soft drinks, beverage size, and frequency of consumption.

#### *Body Composition*

Body composition will be assessed using dual energy x-ray absorptiometry, Model 4500 W (Hologic QDR, Waltham, MA), which has been shown to be an accurate and reliable measure of body fat.<sup>41-42</sup> Subjects will be required to wear a one-piece

swimsuit, which was required during previous phases, to reduce measurement error that might occur from differences in clothing.

Reliability of DEXA for the measurement of body fat has been evaluated using 100 subjects from the Lifestyle Project during Phase II. A test-retest was performed with complete repositioning of each subject. The test and retest means ( $\pm$  SD) were statistically equal ( $30.3 \pm 7.2$  and  $30.4 \pm 7.3$ ;  $P > 0.05$ ). The intraclass correlation between the test and retest was 0.999 ( $P < 0.0001$ ).<sup>43</sup>

#### *Body Weight*

As in past assessments, body weight will be measured using a computerized scale that accurately measures to the hundredth of a pound. The scale will be calibrated daily to ensure accurate and reliable measures. All subjects will wear a lightweight, one-piece swimsuit provided by BYU. In addition, subjects will be asked to use the restroom before being weighed and instructed not to eat anything 4 hours prior to weight assessment.

#### *Menopause Status*

The menopause status of participants will be divided into three categories: pre-menopausal, peri-menopausal, and post-menopausal using a series of questions included in the Eating Behavior Questionnaire. Questions focus on the amount of time since the participant's last menstrual cycle, the regularity of menstrual cycles, and the presence of common signs and symptoms associated with menopause.

#### *Data Analysis*

The primary objective of the proposed study will be to determine the association between soft drink consumption and 48-month changes in bodyweight and body fat. Therefore, baseline body fat and body weight measures will be subtracted from those found in the proposed investigation to determine changes over the 48-month period. Multiple regression analysis will be used to determine the extent of the relationship between soft drink consumption and changes in body composition over time. Additionally, to aid in interpretation of the results, subjects will be separated into equal quartiles based on soft drink intake, after which the middle two quartiles will be collapsed to form a total of three groups. Regression analysis using the general linear model (GLM) procedure will be employed to determine the extent to which the groups differ regarding mean changes in body fat and body weight over time. Partial correlation will be used to determine the influence of age, energy intake, menopause status, and physical activity on the soft drink and body composition relationship. The SAS system will be used to compute all statistical analysis.



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