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Diet Beverage Consumption and Waist Circumference

Austin Higginson

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Diet Beverage Consumption and Waist Circumference

Abstract
ABSTRACT

Background
The rampant problem of obesity, with its related comorbidities, continues to grow in the U.S. This puts strain on national resources and drives up healthcare costs worldwide. Researchers continue to search for the leading offenders in the diets of Americans that contribute to the epidemic. The connection between sugar-sweetened beverages and metabolic disorders is now well-established, being associated with cardiovascular disease, diabetes, cancers and overall mortality. These conditions are further exacerbated in individuals with higher amounts of central abdominal or visceral adiposity. In response to these findings, many consumers have turned to artificially-sweetened "diet" beverages in hopes of mitigating the detrimental effects of weight gain and related illness. The effect of diet beverages on central abdominal adipose deposition and associated comorbidities has not been studied adequately. However, early findings suggest diet beverages may also contribute to increased abdominal girth, metabolic syndrome and may be associated with the same comorbidities as their sugary counterparts.

Methods
An extensive search of MEDLINE-PubMed, CINAHL, Science Direct and Google Scholar was performed to identify research investigating diet soda consumption and central abdominal adiposity. The studies were evaluated using GRADE criteria.

Results
A search of currently-available research yielded 62 studies, two of which met eligibility criteria. Fowler et al and Nettleton et al both conducted prospective cohort studies evaluating the impact of diet beverages on central abdominal obesity. Fowler et al demonstrated a 2- to 3-fold increase in waist circumference compared to non-diet beverage drinkers, and Nettleton et al revealed a hazard ratio of 1.5 (1.23-2.07) for waist circumference meeting criteria for metabolic syndrome in participants who consumed ≥1 serving of diet beverages per day.

Conclusion
These studies suggest diet beverages may contribute to the development of central abdominal adiposity and metabolic syndrome. However, additional research is needed to assess the effect diet beverages may have on central obesity. Clinicians may consider refraining from advising their patients to consume diet beverages in place of sugar-sweetened beverages until their effect on central obesity is better established.

Keywords
Diet soda, non-nutritive sweeteners, abdominal obesity, waist, central obesity, metabolic syndrome

Degree Type
Thesis

Degree Name
Master of Science in Physician Assistant Studies
Keywords
"diet soda", "nonnutritive sweeteners", "abdominal obesity", "waist", "central obesity"

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Diet Beverage Consumption and Waist Circumference

Austin Higginson

A Clinical Graduate Project Submitted to the Faculty of the
School of Physician Assistant Studies
Pacific University
Hillsboro, OR
For the Masters of Science Degree, August 2017
Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
BIOGRAPHY

Austin Higginson was born and raised in Utah. He was blessed to marry his best friend, Carol Ann Bills. They enjoy trying to keep up with their two energetic and infinitely curious children. Austin graduated from the University of Utah with a Bachelor of Arts degree in Biology, and served as a teaching assistant for several courses. These opportunities nudged him toward pursuing medicine. His time providing dedicated care to the residents of the William E. Christofferson Salt Lake Veterans Home as a certified nursing assistant and restorative aide for over two years inspired him to continue his education in physician assistant studies at Pacific University, Oregon. He plans to pursue a career in rural family medicine.
ABSTRACT

Background
The rampant problem of obesity, with its related comorbidities, continues to grow in the U.S. This puts strain on national resources and drives up healthcare costs worldwide. Researchers continue to search for the leading offenders in the diets of Americans that contribute to the epidemic. The connection between sugar-sweetened beverages and metabolic disorders is now well-established, being associated with cardiovascular disease, diabetes, cancers and overall mortality. These conditions are further exacerbated in individuals with higher amounts of central abdominal or visceral adiposity. In response to these findings, many consumers have turned to artificially-sweetened “diet” beverages in hopes of mitigating the detrimental effects of weight gain and related illness. The effect of diet beverages on central abdominal adipose deposition and associated comorbidities has not been studied adequately. However, early findings suggest diet beverages may also contribute to increased abdominal girth, metabolic syndrome and may be associated with the same comorbidities as their sugary counterparts.

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First and foremost, I want to thank my wife Carol for all her patience and support. Especially over these last two years. Thank you for keeping me going when I felt I had nothing left in the tank. I could never have gotten this far without your love and encouragement. I appreciate your strength in caring for our kiddos mostly by yourself during these years. I am so grateful you are still willing to be my adventure buddy. I love you!

Thank you to my awesome children, for always bringing so much joy and happiness into our lives.

I would also like to thank my outstanding parents and siblings for their help in getting me through my formative years and beyond. I am incredibly blessed to have such an outstanding group helping me through the tough times.

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A big ‘thank you’ to all the faculty and staff at Pacific University, who helped me take each hesitant baby step toward becoming a compassionate and competent provider. I am especially grateful to Annjanette Sommers PA-C, MS for her help with navigating the intricacies of completing my thesis.
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List of Abbreviations
ATP III Adult Treatment Panel III
BMI Body Mass Index
DB Diet Beverage
DBI Diet Beverage Intake
HDL High-Density Lipoprotein
HR Hazard Ratio
SAHS San Antonio Heart Study
SALSA San Antonio Longitudinal Study of Aging
SSB Sugar-Sweetened Beverage
Diet Beverage Consumption and Waist Circumference

BACKGROUND

Obesity is a medical crisis in the United States and worldwide. In 2015, two-thirds of the U.S. population were either overweight or obese. With this increased weight gain come myriad comorbidities and medical costs. Kim et al estimated that in 2014 alone the cost of obesity in the U.S. was as high as $149 billion. Wang et al prognosticates that costs of obesity-related diseases will continue to rise by $48-66 billion per year in the U.S. if the current trends continue.

The healthcare community is desperately searching for ways to combat this incredible strain on the economy and their own patients. The Adult Treatment Panel III (ATP III) released by the American Heart Association and the American College of Cardiology in 2001 established guidelines for cholesterol management, and outlines the health concerns of metabolic syndrome. This report established guidelines which serve as the standard of treating hyperlipidemia. ATP III emphasizes the connection between being overweight and having insulin resistance and metabolic syndrome. It also clearly defines the criteria of metabolic syndrome. ATP III particularly stresses the detriments of large amounts of abdominal, or visceral fat as more highly correlated with metabolic risk factors than an elevated body mass index (BMI). Of the 5 elements that make up metabolic syndrome, central abdominal or visceral adiposity is associated with increased risk of cardiovascular disease, diabetes, certain cancers and overall mortality. Iribarren et al found a strong association between central obesity and coronary heart disease, even in the absence of increasing BMI. Considering these alarming findings, researchers have sought to identify the greatest culprits in the development of visceral obesity.

The cause of truncal obesity is likely multi-faceted, with genetic factors, increased caloric consumption, physical inactivity, decreased metabolic rate, less access to nutrition and psychosocial issues each influencing weight gain and fat distribution.
However, research over the past decade has identified a leading offender contributing to the central abdominal obesity epidemic. Sugar-sweetened beverages (SSBs) or soft drinks have been studied extensively and likely contribute significantly to the central abdominal obesity problem and associated health risks.6-8 SSBs have been associated with increased metabolic syndrome, elevated fasting glucose levels, hypertension, hypertriglyceridemia, decreased high density lipoprotein (HDL) levels, insulin resistance and incidence of type 2 diabetes mellitus.9-11 Due to the growing field of evidence linking SSBs to obesity, some researchers now suggest that replacing SSBs with milk or water may help decrease the prevalence of central abdominal obesity.12,13

As patients recognize the detriments of regular consumption of SSBs, and strive to reduce their sugar intake, many make the switch to nonnutritive-sweetened beverages or “diet” beverages (DBs). These patients hope to improve their health and waistlines, while still enjoying their favorite sweet drinks. These alternative beverage options lack high amounts of sugar, and instead contain artificial sweeteners such as aspartame, sucralose, saccharine, acesulfame potassium or neotame.14 Patients and healthcare providers alike hope these alternatives can avoid spiking patients’ blood sugar, causing excessive insulin secretion, development of insulin resistance, weight gain and other metabolic derangements. This approach is supported by a small case-control trial by Tate et al,15 which found DBs may be similar to water in their ability to prevent central abdominal obesity. Yet, despite DBs containing fewer calories compared to SSBs, the waistlines of Americans seem to continue expanding.

Increasing concern has arisen that DB consumption may not be a benign substitute for high-sugar drinks. Lutsey et al16 report a strong association with diet soda consumption and development of metabolic syndrome. The full impact of these chemicals on brain chemistry and metabolism are not yet well-established, even though they are readily available on the market. Before practitioners can give their full
endorsement of exchanging sugar-sweetened beverages for non-nutritive sweetened beverages, the effect of artificial sweeteners needs further investigation.

METHODS
A comprehensive search of available medical literature was conducted using MEDLINE-PubMed, CINAHL, Science Direct and Google Scholar. The search included the following search terms: “diet soda” or “nonnutritive sweeteners;” and “abdominal obesity,” “waist,” “central obesity” or “metabolic syndrome.” The bibliographies from relevant studies were also reviewed for applicable articles. Studies were selected which assessed waist circumference in participants who regularly drank diet beverages compared to participants who drank little or no diet beverages. Other inclusion criteria included: human studies, studies published in the English language, studies using cohort sizes of over 100 participants and studies spanning at least five years. All included studies were assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group guidelines.17

RESULTS
The initial search produced 67 articles. After reviewing pertinent studies, eliminating duplicate articles, and applying eligibility criteria, two articles were selected. These articles were both prospective cohort observational studies assessing DB consumption and waist circumference.18,19 See Table 1

Fowler et al SALSA Study
The San Antonio Longitudinal Study of Aging (SALSA) was a prospective observational cohort study18 involving 749 Mexican Americans and European Americans, conducted in San Antonio, Texas. All participants were recruited from the previous San Antonio Heart Study (SAHS) conducted from 1979 to 1996, and were 65 years or older at the time of their baseline visit. Fasting plasma glucose, height, weight,
waist circumference in centimeters, intake of beverages, leisure time activities and presence of diabetes were all assessed with participants at baseline and at 3 follow-up visits. Waist circumference was measured at the level of the umbilicus at each visit.\textsuperscript{18}

The mean time between baseline measurements and the first follow-up visit was 7.0 years. The time periods between the first and second follow-up visits, as well as the second and third follow-up visits were every 1.5 years. A subset of 598 of the participants received a dietary questionnaire at baseline. Of the original 749 baseline participants, there were 599 survivors at the time of the of the baseline visit, 474, or 79.1\% returned for their first follow-up, 413 or 73.4\% returned for the second follow-up, and 375 or 71.0\% returned for the final follow-up.\textsuperscript{18}

Diet beverage intake (DBI) was assessed by asking patients how many bottles or cans of soda they drank per week, and set to zero for those who reported no soda consumption. Participants who drank soda were then asked to distinguish whether they drank only diet sodas, regular sodas, or similar amounts of each. For those who responded that they drank similar amounts of each, DBI was set to half of their soda intake, respectively. Participants self-reported their DB use, and were subsequently categorized into two groups: “non-users” of DB (≤0.05 diet sodas/day) and “users” (≥0.05 diet sodas/day). Participants were further stratified into 2 groups: nonusers, occasional DB users (>0 and <1 sodas/day), and daily DB users (≥ 1 soda/day). DB use was re-assessed with every follow-up visit.\textsuperscript{18}

The DB user group did not differ significantly from the non-user group regarding age or sex. However, the DB participants had higher education levels, were more likely to be from the suburbs and not from the lower-income barrios, less likely to be smokers and more likely to be European American. The DB group tended to have a higher socioeconomic status, baseline BMI, waist circumference and obesity rates. These differences as well as sex, ethnic group, initial waist circumference, years of education,
lower or middle-income neighborhood, physical activity, presence of diabetes, smoking and length of follow-up interval were all adjusted for during statistical review of data.\textsuperscript{18}

Although none of the study groups experienced a significant change in BMI over the study period, all 3 groups experienced an increase in waist circumference. The mean interval change in waist circumference in all DB users was 2.11 (1.45-2.76) cm compared to 0.77 (0.29-1.23) cm for non-users; a 3-fold difference.\textsuperscript{18}

Those in the non-user DB group experienced a mean change of 0.77 (0.29-1.23) cm, occasional-users had a mean change of 1.76 (0.96-2.57) cm, and daily DB users had a mean increase of 3.04 (1.82-4.26) cm change in waist circumference. This represents a dose-response relationship in increased abdominal obesity, and an almost 4-fold increase for daily DB users compared to non-users. The cumulative adjusted change of waist circumference was 0.80 cm for non-users, 1.83 cm for occasional users, and 3.16 cm for daily users.\textsuperscript{18} See Table 2

**Nettleton et al MESA Study**

The Multi-Ethnic Study of Atherosclerosis (MESA) was a prospective observational cohort study that assessed the development of subclinical cardiovascular disease in participants who consumed diet beverages. The study evaluated the components of metabolic syndrome and development of type 2 diabetes. The study population consisted of 6814 individuals. Participants were Caucasian, African American, Hispanic and Chinese adults between 45 and 84 years. Study sites were located in Baltimore County, Maryland; Chicago, Illinois; Forsyth County, North Carolina; New York, New York; Los Angeles County, California and St. Paul, Minnesota.\textsuperscript{19}

Baseline measurements were taken for all participants, and 3 follow-up examinations were conducted. In total, the study spanned a period of 7 years. At each
visit, fasting glucose and presence of metabolic syndrome were assessed. Metabolic syndrome was defined as the presence of 3 of the following: 1) waist circumference ≥ 102 cm (men) or ≥88 cm (women), 2) triglycerides ≥150 mg/dl, 3) high density lipoprotein (HDL) cholesterol ≤40 (men) or ≤50 (women) 4) blood pressure ≥130/85 or antihypertensive treatment, 5) fasting glucose ≥100 mg/dl or antidiabetic treatment. Waist circumference was measured at the umbilicus using a measuring tape. Participants with either type 2 diabetes or metabolic syndrome at baseline were excluded from the study.19

Dietary intake was assessed only at the baseline visit via a food frequency questionnaire. Participants were asked, if they drank “diet soft drinks, unsweetened mineral water.” These beverages were classified as diet beverages. They were also asked if they drank “regular soft drinks, soda, sweetened mineral water (not diet), nonalcoholic beer.” These beverages were classified as sugar-sweetened beverages. Participants’ beverage intake was further quantified, and they were put into the following categories: rare/never, >rare/never but <1 serving/week, ≥1 serving/week but <1 serving/day, and ≥1 serving/day. 19

Cox proportional hazards regressions were used to calculate hazard ratios (HRs) for all groups. Two models were used with adjustments for 1) baseline age, sex, race, ethnicity, examination site, and energy intake, and 2) all previously mentioned adjustments and attained education, time spent in inactive and active pursuits during leisure, smoking status, pack years, and regular dietary supplement use. In addition, adjustments were made for dietary intake such as whole and refined grains, nuts, seeds, fruits, vegetables, potatoes, salty snacks, desserts, red meat, processed meat, dairy, sugar-sweetened soda, and nutrient intake (fiber, calcium, phosphorus, potassium, magnesium, and sodium).19
Compared with non-consumers, HRs for waist circumference enlargement meeting criteria for metabolic syndrome (≥102 cm for males and ≥88 cm for females) increased in a dose-response to diet beverage intake. The HR for DB consumption more often than rare/never, but <1 serving per week HR was 1.12 (0.88-1.44). Participants reporting DB consumption ≥1 serving per week to <1 serving per day HR was 1.22 (0.93-1.55). The HR for participants who consumed ≥1 serving of DB per day was 1.59 (1.23-2.07). See Table 3

DISCUSSION

The Fowler et al\textsuperscript{18} SALSA study and the Nettleton et al\textsuperscript{17} MESA study both found striking dose-dependent response gradients between DB intake and increased waist circumference. (See Table 2 and Table 3) Fowler et al\textsuperscript{18} found only minor changes in participant BMI. However, the study revealed an almost 4-fold increase in waist circumference expansion in the daily DB use group compared to those who rarely or never consumed DB. Nettleton et al\textsuperscript{19} identified an increasing HR for enlarged waist circumference in those who consumed increasing amounts of DB. The risk of developing a waist circumference meeting criteria for metabolic syndrome (≥102 cm in men, and ≥88 cm in women) was 59\% greater for those who regularly consumed DBs compared to those who rarely or never consumed DBs.

Unfortunately, prospective cohort studies such as these are limited in their abilities to identify a causal link between DB and increased waist circumference. Being observational in nature, neither study could eliminate possible confounding variables that may have influenced patient outcomes. Although, both studies\textsuperscript{18,19} went to great lengths to correct for them. Despite this, the dose-response between increasing amounts of DB consumption and expanding waist circumferences strengthens their possible association. Given the numerous detrimental effects of increased abdominal adiposity,
the findings of these studies are significant enough to merit further investigation of the possible co-morbidities associated with DB consumption.

There is sufficient evidence regarding the detriments of SSBs, that clinicians should not hesitate to counsel patients regarding the numerous harms of chronic SSB use. Recent research\textsuperscript{20} suggests that other alternatives such as water or other diet modifications can prevent or reduce the incidence of the metabolic problems associated with SSB consumption. Some providers have simply assumed that a beverage low in sugar would yield similar benefits. As evidence for this approach, in an intent-to-treat analysis, Tate et al\textsuperscript{15} suggested using either water or artificially-sweetened beverages could be beneficial in staving off metabolic complications. These findings contradict the SALSA\textsuperscript{18} and MESA\textsuperscript{19} data. However, the study arms in Tate’s research of just over 100 participants each and the duration of the study only lasting 6 months. The small sample size and short follow-up duration may decrease the validity of the Tate et al study. Further research and more extensive studies are needed to investigate the possible association between DB intake and waist circumference.

In addition, research is also lacking for DB impact on children and adolescents. Both the SALSA\textsuperscript{18} and MESA\textsuperscript{19} studies evaluated the effect of DB consumption only on adults. More information regarding the long-term effects of DB use in childhood and adolescence may broaden our understanding of the effects of DB on development and long-term metabolism trends. Additional investigation of the effect of individual artificial sweeteners is also lacking. The SALSA and MESA studies both identified DB drinkers as a whole, and did not assess the effect of specific artificial sweeteners. It is possible that each sweetener could influence metabolism in a different manner, and future studies could evaluate the effect of each individually instead of considering them all together.

The relationship, if it exists at all, between diet beverage intake and increased abdominal girth is not well understood. Investigators have begun to look for potential
mechanisms of damage that artificial sweeteners may cause to human metabolism. Recent research has begun to identify potential areas of concern associated with consuming artificial sweeteners. In an animal study on Wistar rats, Feijó et al. found that rats given food sweetened with saccharin or aspartame instead of sucrose experienced increased weight gain. They also found this weight gain was seemingly independent of caloric intake. They postulate that the rats may have experienced decrease in energy expenditure. Other research suggests nonnutritive sweeteners may interfere with body glucose control, disrupt gut microbiota, alter sweet-taste receptors throughout the digestive tract or alter reward systems in the brain. Unfortunately, metabolic studies directly investigating the effect of diet beverages on human metabolism and brain chemistry are not plentiful.

Due to the incongruent body of evidence regarding the effects of DBs on truncal obesity and associated comorbidities, clinicians may consider refraining from recommending DBs as a healthy alternative to SSBs until their long-term effect on metabolism is better established.

CONCLUSION
As evidence builds revealing the metabolic detriments of SSB use, many patients are replacing their favorite sugary drinks with diet beverages (DBs). Unfortunately, research regarding the effect of artificial sweeteners on human metabolism is lacking. The SALSA and MESA studies both propose a link between DB consumption and central abdominal obesity, suggesting visceral adiposity may increase with frequent DB use. However, a smaller case-control trial by Tate et al suggests DBs may be similar to water in their ability to prevent central abdominal obesity. Other research suggests DBs may alter energy expenditure, interfere with body glucose control, disrupt gut microbiota and alter taste receptors. More extensive trials are needed to fully investigate the connection
DB intake may have with central obesity and associated comorbidities, and practitioners may consider refraining from suggesting their use in place of SSBs until their impact on metabolism is more thoroughly investigated.
References


Table 1: Quality Assessment of Reviewed Articles

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Downgrade Criteria</th>
<th>Upgrade Criteria</th>
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<tr>
<td></td>
<td></td>
<td>Limitations</td>
<td>Indirectness</td>
<td>Inconsistency</td>
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<td>Fowler et al</td>
<td>Prospective Cohort</td>
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<td>Not Serious</td>
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<td>Nettleton et al</td>
<td>Prospective Cohort</td>
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*aConfounders were noted; however, they were adjusted for statistically and had the potential to underestimate the treatment effect.

*bChange in waist circumference increased as diet beverage intake increased.

*cParticipants who drank ≥1 serving/day of diet beverage, had a mean waist circumference of 100.6 cm compared to 95.6 cm in the group who rarely or never drank diet beverage.

*dHazard ratios for waist circumference over 102 cm (men) or 88 cm (women) increased with increasing amounts of diet beverage intake.
### Table 2. Summary of Fowler et al. SALSA Study

<table>
<thead>
<tr>
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<th>Non-use of DB</th>
<th>Occasional DB use</th>
<th>Daily DB use</th>
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<tr>
<td>Mean WC Increase (cm)</td>
<td>0.77 (0.29-1.23)</td>
<td>1.76 (0.96-2.57)</td>
<td>3.04 (1.82-4.26)</td>
</tr>
</tbody>
</table>

Abbreviations: WC= Waist Circumference. cm= centimeters

### Table 3. Summary of Nettleton et al. MESA Study

<table>
<thead>
<tr>
<th></th>
<th>Rare or Never Use DB</th>
<th>More often than rare/never, but &lt; 1 serving DB/week</th>
<th>≥1 serving/week to &lt; 1 serving/day</th>
<th>≥1 serving/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR of WC qualifying for metabolic syndrome a</td>
<td>1.00</td>
<td>1.13 (0.82-1.57)</td>
<td>1.22 (0.95-1.55)</td>
<td>1.59 (1.23-2.07)</td>
</tr>
</tbody>
</table>

a High Waist Circumference: ≥102 cm (men) ≥88 cm (women)

Abbreviations: DB= Diet Beverage, HR= Hazard Ratio, WC= Circumference