UNDERSTANDING ASSOCIATIONS OF ALCOHOLIC BEVERAGE CONSUMPTION WITH WEIGHT STATUS

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ABSTRACT

Jennie Lauren Butler: Understanding Associations of Alcoholic Beverage Consumption with Weight Status
(Under the direction of Barry M. Popkin and Jennifer M. Poti)

Contradictory findings exist on associations between alcoholic beverage consumption with Waist Circumference (WC) and Body Mass Index (BMI). Confounding by dietary intake and variation in associations by drinking level and/or alcoholic beverage type likely contribute to mixed literature. The overarching goal of this dissertation was to shed light on inconsistencies in the alcohol and obesity literature by investigating confounding by dietary intake and associations of changes in alcohol intake with WC and BMI change.

A pooled cross-sectional analysis of data from 6,018 men and 5,885 women 20 – 79 years of age from the National Nutrition and Health Examination Survey (NHANES), 2003 – 2012 was conducted. Multivariable linear regression models were used to determine associations of alcohol intake with energy (kcal), macronutrient and sugar intakes (% kcal), WC and BMI. Associations of drinking with WC and BMI were examined with and without adjustment for dietary intake. Compared to non-drinkers, binge drinking men consumed less energy from food and heavy drinking women consumed less energy from non-alcoholic beverages. All drinking levels were inversely associated with carbohydrate and sugar intakes compared to non-drinking. Positive associations between binge drinking and WC in men were attenuated and no longer significant after adjustment for carbohydrate and sugar intakes. Negative associations between heavy drinking and WC and BMI in women were strengthened after adjustment for carbohydrate and sugar intakes.

Next a prospective study of data from 1,894 men and 2,252 women utilizing 25 years of Coronary Artery Risk Development in Young Adults (CARDIA) study data investigating associations of 5-yr changes in alcohol intake with 5-yr WC and BMI change was conducted. Random effects linear regression models were used to determine whether 5-yr changes in drinking were associated with 5-yr WC and BMI change. In men, decreasing drinking, particularly stopping excessive drinking was associated with lower 5-yr WC gains. In women, increasing wine intake and decreasing liquor intake was associated with lower 5-yr WC and BMI gains.

Our findings highlight dietary confounders of associations of alcohol intake with WC and BMI, and heterogeneity in associations by drinking level and beverage type in US adults.

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LIST OF ABBREVIATIONS AND SYMBOLS

β	Beta
%	Percent
% Carb	Carbohydrate contribution to total energy intake
% Prot	Protein contribution to total energy intake
% Fat	Fat contribution to total energy intake
AL	Alabama
ANOVA	Analysis of Variance
AUQ	Alcohol Use Questionnaire
BP	Blood Pressure
BMI	Body Mass Index
BMR	Basal Metabolic Rate
CA	California
CARDIA	Coronary Artery Risk Development in Young Adults
CDC	The Centers for Disease Control
CI	Confidence Intervals
cm	Centimeters
DGA	Dietary Guidelines for Americans
drinks/d	Drinks per day
drinks/wk	Drinks per week
EU	Exercise Units
ethanol/d	Ethanol per day
FPL	Federal Poverty Level

GED	General Equivalency diploma
grams/d	Grams per day
HbA1c	Hemoglobin A1c
h/d	Hours per day
Hg	Mercury
HS	High School
IL	Illinois
kcal	Kilocalories
kcal/d	Kilocalories per day
kg	Kilograms
kg/m^2	Kilograms per meters squared
MEC	Mobile Examination Center
Mex-Am	Mexican American
mg/DL	Milligram per deciliter
mm	Millimeters
MN	Minnesota
NHANES	National Nutrition and Health Examination Survey
NHB	Non-Hispanic black
NHW	Non-Hispanic white
NIAAA	National Institute on Alcohol Abuse and Alcoholism
Non-alc Bev	Non-alcoholic Beverage
obs	Observations
oz	Ounce
PAL	Physical Activity Level

SBP	Systolic Blood Pressure
TX	Texas
US	United States
USDA	United States Department of Agriculture
vs.	Versus
WC	Waist Circumference
WWEIA	What We Eat in America
yr	Year
y/n	Yes or no

CHAPTER 1. INTRODUCTION

Overview

The 2014 National Survey on Drug Use and Health indicates that 87.6% of US adults reported consuming alcohol in their lifetime; 71.0% reported annual and 56.9% reported monthly drinking. [1] Of those, 24.7% reported binge drinking in the past month. The history of alcoholic beverage consumption dates back centuries. Alcoholic beverages are likely one of the first processed beverages consumed in the US and are now ubiquitously consumed across the country. [2] While moderate alcoholic beverage consumption has been inversely associated with obesity, weight gain, and increases in obesity measures over time, excessive alcohol use has been positively associated with obesity risk and WC and BMI gains.[3] Yet, contradictory findings exist regarding the relationship between alcoholic beverage consumption and measures of weight status; mixed literature is likely due to a variety of factors.

One reason for inconsistent findings could be that the differing definitions of alcohol intake are used across studies. In observational research, the metrics used for alcoholic beverage consumption and obesity and weight-related outcomes vary across studies. For example, frequency, intensity and beverage type have been used to define alcoholic beverage intake. Moreover, according to the most recent literature reviews on the topic, many observational studies have used weight gain and body mass index (BMI) as obesity measures. Yet, studies using waist circumference (WC) are less common. Additionally, reviews of the associations between alcohol intakes in relation to obesity are tasked with attempting to summarize findings from weight gain, BMI, WC, waist-to-hip ratio, odds of weight gain and other obesity and weight-related measures into one conclusive statement. However, it may not appropriate to reconcile relationships between alcohol intake and various measures of weight status into one conclusive finding.

Research Aims

The overarching goal of this research project was to examine associations between alcohol intake and weight status, using two dimensions of alcohol consumption (i.e., number of alcoholic beverages and beverage type) and two weight-related outcomes (i.e., waist circumference (WC) and body mass index (BMI)), while taking into account confounding by dietary intake, changes in alcohol intake and changes in WC and BMI over time.

To this end, the proposed research project used pooled data from the National Health and Nutrition Examination Survey (NHANES) 2003-2004 through 2011-2012 and all eight waves the Coronary Artery Risk Development in Young Adults (CARDIA) study 1985-1986 through 2010-2011. NHANES is a nationally representative survey with a complex multistage, stratified probability sample. CARDIA is multicenter longitudinal US based cohort study. Both datasets include self-reported dietary intake, alcoholic beverage consumption and socio-demographic data and measured anthropometric data. By evaluating associations of alcohol intake with WC and BMI cross-sectionally using a nationally representative dataset and longitudinally in a US based cohort, each aim of our study examines potential factors contributing to inconsistencies in the alcohol-obesity literature and contributes to the limited studies on alcohol intake in relation to WC. Specific aims for this study are as follows:

Aim 1: Determine cross-sectional associations between drinking level with diet, WC and BMI among US adults.

First, we used NHANES data and a series of multivariable linear regression models to test associations between the number of drinks per day (categorized by sex-specific daily drinking levels) and total energy, food and non-alcoholic beverage energy (kcal/d) and the percent contribution of macronutrients and sugar to non-alcoholic energy (% kcal/d) in drinkers compared to non-drinkers. Next, we used multivariable linear regression models, with and without adjustment for dietary intake variables, to test associations between daily drinking level with WC and BMI in drinkers compared to non-drinkers.

Aim 2: Identify associations between change in alcoholic beverage intake and change in WC and BMI. Determine whether variation in associations exists by beverage type.

We used CARDIA data and a series of longitudinal random effects linear regression models to test whether starting to drink, increasing, decreasing, stable drinking or a stop in drinking over a 5-yr period (versus stable non-drinking) are associated with 5-year changes in WC and BMI. Next, we used a series of longitudinal random effects linear regression models to test whether categorical changes in drinking level or beverage type (versus stable non-drinking) were associated with 5-year changes in WC and BMI.

CHAPTER 2. LITERATURE REVIEW

Over the last two decades increases in alcoholic beverage intake in the US have been reported. According to NHANES data the proportion of drinkers on any given day increased from 12.8% in 1989-91 to ~23% from 2006 through 2012. Alcoholic beverage calorie intakes among drinkers increased from approximately 300 kcal/d to 441 kcal/d over the same time period. According to these estimates, drinkers in the US may consume the equivalent of 3.7 glasses of wine (18.4 oz), 2.9 cans of beer (35.3 oz) or 4.4 shots of liquor (6.6 oz of liquor) on any given day. [4] Furthermore, the percentage contribution of alcoholic beverage intake to total energy intake among consumers on any given day has increased from 14.0% to 17.2% over the last 20 years. Concurrent with these trends in alcoholic beverage calories, secular increases in waist circumference (WC) and body mass index (BMI) have been reported in the US. [5-7] Yet, associations between alcohol intake and WC and BMI are unclear.

What is known about the relationship between alcohol intake and WC and BMI?

The most recent reviews on the topic of alcohol and obesity and weight gain seem in agreement that relationships between alcohol intake and weight-related outcomes and obesity measures (i.e. waist circumference and BMI) are not well understood [8, 9]. Alcohol is a source of calories and is consumed with food, yet the breadth of evidence regarding alcohol's influence on BMI and WC is limited in comparison to studies of nutrients such as fat and sugar. There have been at least two reviews of the topic of alcohol intake and health outcomes in the past 5 years that include sections on obesity. [3, 10] One review summarized the literature by stating that, while high alcohol intake was associated with increased risk of obesity or overweight, moderate consumption has no or inverse associations with obesity or overweight. [10] The Poli review did not separate findings for alcoholic beverage intake in relation to WC, which is a measure of abdominal obesity, from that of BMI, a measure of general obesity. [10] Additionally, because WC is a measure of visceral fat it is thought to be a better indicator of cardio metabolic health risks. [11]Thus, it is important to understand whether associations of alcohol intake with WC differ from associations with BMI. Another review, presented conflicting observational evidence regarding associations between grams/d of ethanol intake and abdominal obesity (WC) vs. general obesity (BMI) in men and women. [3] Zhou et al highlighted results from using data from the European Prospective Investigation into Cancer and Nutrition study, indicating that drinking >90 grams/d and > 60 grams/d in men and women, respectively has been positively associated with abdominal obesity in both sex groups, while associations between drinking and general obesity were observed in males only. [3, 12] In a more recent review, focused specifically on alcohol and obesity, the authors stated that despite the limitations of the alcohol and obesity literature, alcohol intake may be a risk factor for obesity in some individuals. [8] In this review, Traversy explained potential mechanisms related to alcohol intake and increased obesity risk extend beyond the direct contribution of alcoholic beverage calories to total energy intake. Alcohol may increase appetite, and alter satiety hormones and inhibit fat oxidation in ways that lead to weight gain. [8] Authors of all of these reviews commented that associations between alcohol and obesity and weight-related outcomes were complex and likely subject to biased due to many confounding factors, including dietary intake and alcoholic beverage type. [3, 8-10]

Why is daily drinking important in associations of alcoholic beverage intake with WC and BMI?

The *2015-2020 Dietary Guidelines for Americans* (DGA) recommends that alcoholic beverages be consumed in moderate levels of ≤2 drinks per day (drinks/d) for men and ≤ 1 drink/d for women.[13] In fact, these recommendations have been in place since the 1990 issue of the DGA. The Centers for Disease Control (CDC) includes heavy and binge drinking behaviors under the definition of excessive drinking. Heavy drinking is defined as >2 drinks/d for men and > 1 drink/d for women. Binge drinking is defined as ≥5 drinks on a single occasion for men and ≥4 drinks on a single occasion for women. [14] Increases in excessive drinking coupled with a trend in increasing calories consumed from alcoholic beverages in the US over the past two decades have been reported. [15-17] Given that excessive drinking and overweight and obesity are of public health concern, and the theory that alcoholic beverage consumption may be a risk factor for obesity, an examination of associations between daily drinking level and weight status in the US is warranted. [7, 8] However, we could find no studies that examined associations of sex-specific DGA defined drinking levels and WC and BMI.

In studies of weight gain, the number of drinks/day and drinks/wk. were not significantly associated with weight gain in men and inversely associated with weight gain in women. [18, 19] In prospective analysis, increased 8-year weight gain has been reported in women consuming ≥ 2 drinks/d as compared to non-drinkers. [20] One cross-sectional study that did not examine associations by sex separately reported that individuals who consumed one or two drinks/d had lower odds of obesity as compared to non-drinkers. [21] Positive and null associations have been reported in men with ethanol intakes exceeding 24 g (> 1 drink/d) and BMI, compared to non-drinkers; while in women, drinkers as a group had lower BMI estimates as compared to non-drinkers .[22, 23] In another study of Australian men, those who consumed ≥ 5 drinks/d had statistically significantly higher estimates of BMI and WC as compared to non-drinkers. [24] In Korean drinkers, results seem to be more consistent across sex groups, men who consumed ≥ 7 drinks/d and women who consumed ≥ 3 drinks/d had higher odds of abdominal obesity as compared to those who drank 1 to 2 drinks/d. [25] Similarly, in a study of current drinkers in the US a statistically significant increasing trend in BMI, although small in magnitude, was observed with increasing frequency categories of drinking (from 1 drink/d to ≥ 4 drinks/d) in men and women. [26] While reviews of the literate have reported that moderate and regular consumption of alcoholic beverages may be protective against obesity and excessive drinking may contribute to obesity, the definitions of moderate and excessive drinking vary from study to study. [8, 21] Defining alcohol intake based on national recommendations makes findings more easily translatable at the policy and practice levels. A current gap in the literature is whether the sex-specific daily drinking level recommendations in the US are associated with WC and BMI as compared to non-drinkers.

Why consider confounding by dietary intake?

Dietary intake has been hypothesized to be a key confounder in associations between alcohol intake and obesity measures. [9, 27, 28] Alcoholic beverage consumption has been linked to poor diet quality, altered dietary composition and lower intake of carbohydrates, sugar and select food and non-alcoholic beverage groups as compared abstention. [29-32] Clinical studies indicate that gustatory neural pathways and opioid or dopaminergic systems related to food reward may influence food consumption following alcoholic beverage consumption. However, the biochemical pathways through which alcohol in alcoholic beverages might affect food intake remains elusive. [33-37] The current evidence indicates that there is a strong association between alcohol consumption and sweet taste, suggesting that alcoholic beverage consumption may be negatively associated with added sugar intake from highly palatable, energy dense foods. [37-39] It has been suggested that drinkers may replace food (i.e. meals and snacks) and non-alcoholic beverages with alcoholic beverages. This replacement would, in part, be evidenced by lower intake of foods and non-alcoholic beverages in drinkers as compared to non-drinkers. [22, 23, 29, 30, 40, 41] Yet, associations between alcohol intake and food, non-alcoholic beverages, macronutrient and sugar intakes are not well established. We aimed to fill this literature gap by determining associations of sex-specific daily drinking level recommendations in the US with energy, macronutrient and sugar intakes using NHANES data. These findings can be used to inform future research can be used to inform future studies elucidating associations of alcohol intake with subsequent dietary intake.

Why is alcoholic beverage type important in associations of alcoholic beverage intake with WC and BMI?

A 2011 systematic review of the literature emphasized the lack of conclusive evidence regarding associations of alcohol intake with weight gain and suggested that future research examining differing types of alcoholic beverages in associations between alcohol intake and body weight was warranted. [9] Alcoholic beverages (i.e. beer, wine, liquor and mixed drinks) contain non-alcohol ingredients that differ according to beverage type and may have differing effects on energy intake, metabolism, weight gain and adiposity. [42-47] For example, polyphenols in beer and wine have been inversely associated with body weight and BMI. [3] Specifically, resveratrol in red wine and isohumulone in beer may have beneficial effects on lipid metabolism which might lead to lower WC and BMI gains. [3, 8, 9, 48-50].

It remains unclear whether the consumption of specific types of alcoholic beverages (i.e.

beer, wine, liquor/mixed drinks) is associated with WC or BMI gains [8-10, 44, 45, 51-58]. Studies in the Mediterranean, Denmark, Japan, France and Sweden have reported conflicting and differing associations across sex groups and by alcoholic beverage subtype with WC and BMI outcomes. [47-51] A recent meta-analysis on the topic of beer consumption and obesity reported that there was inadequate evidence to determine whether beer intake at baseline or changes in beer intake was associated with WC and BMI change. [45] Prospective studies examining change in alcohol intake in relation to weight gain, although still not conclusive, tend to suggest that increasing alcohol intake, overall and by type, is associated with weight gain in men, but not associated or negatively associated with weight gain in women, over 1, 3 and 4 year study periods. [58-60] While wine intake has been negatively associated with weight gain, positive associations with liquor consumption have been reported. [9, 55, 58] Additional studies assessing beer, wine and liquor/mixed drink intake in relation to changes in WC and BMI among US adults are needed to build the evidence base. [8, 58, 59, 61-63]

Why do studies need to examine changes in alcohol intake over time in relation to WC or BMI changes?

The current evidence base is made up of prospective studies that define alcoholic beverage consumption at baseline and estimate associations with WC and BMI <5 years and up to 13 years subsequent to baseline. [8, 45] Drinking behaviors change over time and these changes may be due to immeasurable time-invariant factors such as individual health consciousness and beverage preference. Using baseline drinking and not accounting for within-person changes in drinking may result in biased estimates of association with change in WC and BMI. Yet, studies of associations of within-person changes in alcohol intake and changes in WC and BMI are limited and results for beverage types are inconsistent. Two studies found no statistically significant associations between change in alcohol intake and WC or BMI gains over 3 and 8.5 year periods. [61, 62] Of the few studies with statistically significant associations, one reported that maintaining high intakes of beer was negatively associated with 10 year BMI change in men and women. [63] Likewise, 3.7 year increases in total alcohol intake have been significantly associated with lower WC gain over the same time period with no associations by beverage type. [64] A major gap in the literature is whether or not changes in alcohol intake are related to changes in WC and BMI and if variation in associations by alcoholic beverage type exists.

Additionally, studying within-person change in alcoholic beverage intake by type may provide less biased estimates of associations by capturing immeasurable time-invariant characteristics of health and culture. [8, 9, 44] Differential associations of beer, wine and liquor intake with individual diet, lifestyle and socio-demographic characteristics have been reported. These associations may be related to underlying health consciousness in wine drinkers as compared to beer and liquor/mixed drinkers. [27] In the US wine drinking has been associated with higher intakes of food and beverage groups supported by the DGA, and whereas beer and spirit intake have been associated with foods and nutrients that should be consumed in moderation (i.e. fat, sugar, sodium). [65, 66] Wine preference has also been associated with higher educational attainment, while liquor preference has been associated with older age. [7, 66-69] Moreover, the type of alcoholic beverage consumed is likely associated with difficult to measure cultural characteristics as indicated by disparities in the predominant beverage types consumed in Western as compared to European and Mediterranean countries. [27] Using repeated measures to conduct within-person change analyses, allowing us to control for time-invariant factors, such as health consciousness and cultural characteristics, which may confound associations of alcoholic beverage type with WC and BMI.

CHAPTER 3. ASSOCIATIONS BETWEEN ALCOHOLIC BEVERAGE CONSUMPTION, DIET AND OBESITY MEASURES IN US ADULTS, NHANES 2003-2012

Overview

Higher daily drinking levels have been associated with higher obesity measures (e.g. waist circumference (WC) and body mass index (BMI)). Yet, studies examining confounding by dietary intake in these relationships are lacking. This was a cross-sectional analyses of data from 6,018 men and 5,885 women 20 – 79 years of age from five pooled cycles of the National Nutrition and Health Examination from 2003 – 2012. Multivariable linear regression models were used to determine differences in: total energy, food and non-alcoholic beverage energy (kcal/d) and the percent contribution of macronutrients and sugar to non-alcoholic energy (%), WC (cm) and BMI (kg/m^2); in drinkers (categorized by sex-specific daily drinking levels) as compared to non-drinkers. Binge drinking (≥ 5 drinks/d) men consumed less energy from food (β: -72 kcal/d; 95% CI: -142,-1) and heavy drinking (2 -3 drinks/d) women consumed less energy from non-alcoholic beverages (β: -56 kcal/d; 95% CI: -74,-38) than non-drinkers. Differences in WC and BMI in binge drinking men, compared to non-drinkers, were + 3.21 cm (95% CI: 1.02,5.40) and +1.32 kg/m^2 (95% CI: 0.43,2.21). Differences in WC and BMI between heavy drinking women and non-drinkers were -1.93 cm (95% CI: -3.55,-0.31) and -0.83 kg/m^2 (95% CI: -1.55,-0.11). Differences in dietary intake by sex and drinking level contribute to differential confounding by diet in associations of alcoholic beverage consumption and obesity measures.

Introduction

Between 2012 and 2013, 70.7% of adults in America reported alcoholic beverage consumption and 68.8% were considered to be overweight or obese. [70, 71] There is a wealth of conflicting epidemiologic findings regarding the relationship between alcoholic beverage consumption and obesity measures such as waist circumference (WC) and body mass index (BMI). Differences in dietary intake between drinkers and non-drinkers have been cited as one reason for inconclusive results. [8, 9, 27] The 2015-2020 Dietary Guidelines for Americans (DGA) recommends that alcoholic beverages be consumed in moderate levels of ≤2 drinks per day (drinks/d) for men and ≤ 1 drink/d for women.[13] While moderate and regular consumption of alcoholic beverages may be protective against obesity, excessive drinking may contribute to obesity among some individuals. [8, 21] The Centers for Disease Control (CDC) includes heavy and binge drinking behaviors under the definition of excessive drinking. Heavy drinking is defined as >2 drinks/d for men and > 1 drink/d for women. Binge drinking is defined as ≥5 drinks on a single occasion for men and ≥4 drinks on a single occasion for women. [14] Increases in excessive drinking coupled with a trend in increasing calories consumed from alcoholic beverages in the US over the past two decades have been reported. [15-17] Given that excessive drinking and overweight and obesity are of public health concern, an examination of associations between daily drinking level, diet and obesity measures in the US is warranted. [8]

Alcoholic beverage consumption has been linked to poor diet quality, altered dietary composition and lower intake of carbohydrates, sugar and select food and non-alcoholic beverage groups as compared abstention. [29-32] It has been suggested that drinkers may replace food (i.e. meals and snacks) and non-alcoholic beverages with alcoholic beverages. This replacement would, in part, be evidenced by lower intake of foods and non-alcoholic beverages in drinkers as compared to non-drinkers. [22, 23, 29, 30, 40, 41] Yet, associations between drinking level, as defined by the DGA and CDC recommendations with food, non-alcoholic beverages, macronutrient and sugar intakes are not known.

In men, positive, inverse and null findings have been reported across studies of alcohol and obesity measures. [8, 9, 26, 40] In women, numerous studies have reported that drinking ≥ 2 drinks/d is negatively associated with obesity measures. [9, 19, 22, 28, 72, 73] Residual confounding by dietary intake has been cited as one reason for conflicting findings because some studies fail to adjust for dietary components as confounders in statistical analyses. [8, 9, 27, 28] The overarching aim of this study was to determine the associations of alcoholic beverage consumption with WC and BMI utilizing the current US sex-specific daily drinking level recommendations to categorize drinkers. Associations between drinking level and total energy, non-alcoholic energy (food plus non-alcoholic beverages), food, non-alcoholic beverages and macronutrient and sugar contributions to non-alcoholic energy were determined. To examine the robustness of relationships between drinking level and obesity measures, associations were examined with and without adjustment for dietary intake variables.

Methods

The National Health and Nutrition Examination Survey (NHANES) is a repeated, cross-sectional survey of the civilian, non-institutionalized US population administered by the National Center for Health Statistics division of the Center for Disease Control and Prevention and USDA. The NHANES utilizes a multistage, stratified area probability sampling design to select participants representative of the US population. NHANES combines in-person interviews and physical examinations via a Mobile Examination Center (MEC). NHANES dietary recalls are interviewer-administered using the USDA Automated Multiple-Pass Method and include one in-person 24-hour dietary recall and a second recall collected 3 to 10 days later by phone. [74-78] The MEC physical examinations includes anthropometric measurements of height, weight and waist circumference administered by trained professionals. [79, 80]

The current study subsample was derived from adults aged 20 - 79 years with complete alcoholic beverage intake questionnaires and 2 days of dietary recall data deemed reliable by study investigators from five pooled cycles of NHANES from 2003 – 2012 (n=17,182). Adults missing anthropometric outcomes were excluded (WC: n=405; BMI: n=29). Pregnant and breastfeeding women and adults who reported following a medical or intentional weight loss diet in the past year or those missing information on intentional weight loss were excluded (n=3,888). Participants missing complete covariate data (n=957) were excluded. The final analytic sample included 11,903 men (n=6,018) and women (n=5,885). This secondary data analysis was exempt from institutional review board approval. Analyses were conducted in the Fall of 2015.

Measures

NHANES collects lifetime and current alcohol use data (alcohol use over the past 12 months) for respondents ≥ 20 years of age as part of the MEC examinations using an Alcohol Use Questionnaire (AUQ). [81-85] Respondents who reported ≥ 1 drink/d in the past year were considered current drinkers. Respondents who reported drinking in their lifetime but did not report drinks/d (n=1930) were coded as non-drinkers. Respondents were further categorized into sex-specific categories based on DGA and CDC recommendations of moderate and excessive (i.e. heavy and binge) drinking in the US. [13, 14, 86] Men were classified as "non-drinker", "moderate drinker (1 to 2 drinks/day)", "heavy drinker (3 to 4 drinks/day)"or "binge drinker (≥5 drinks/day)"; women were classified as "non-drinker", "moderate drinker (1 drink/day)", "heavy drinker (2 to 3 drinks/day)" or "binge drinker (≥ 4 drinks/day)". [13, 14, 86]

Dietary intake data were utilized from What We Eat in America (WWEIA) portion of NHANES. USDA Nutrient information for WWEIA-NHANES comes from the USDA Food and Nutrient Database for Dietary Studies , based on nutrient values in the USDA National Nutrient Database for Standard Reference**.** [87] Non-alcoholic energy intake was calculated as the sum of non-alcoholic beverages plus food kilocalories per capita per day (kcal/d). Non-alcoholic beverage intake was calculated as the sum of calories from all beverages excluding beer, wine, liquor and mixed drinks (kcal/d). Macronutrient intakes were calculated as the sum of the grams of each macronutrient from food and non-alcoholic beverage groups, multiplied by 4 kcal/g, 4 kcal/g and 9 kcal/g for carbohydrates, protein and fat, respectively. Sugar intake was calculated as the total grams of sugar from food and non-alcoholic beverage groups foods multiplied by 4 kcal/g. The final carbohydrate intake variable was calculated by subtracting sugar intake from total carbohydrate intake. All dietary intake variables were calculated from the average of two 24-hour dietary recalls. Implausible energy intakes are an inherent limitation of using dietary recall data to estimate energy intakes. [88-90] The revised Goldberg method was used to identify implausible energy intakes and categorize adults as dietary underreporters, overreporters, or accurate reporters, as described in Appendix 3.1.

Body height, weight and WC (measured midway between the lowest rib margin and the iliac crest at the mid-axillary line) were measured in replicate (height to the nearest 0.1 cm via SECA stadiometer, weight measured to the nearest 0.1 pound and converted to kilograms via Toledo digital scale, waist circumference to the nearest 1 mm via measuring tape). Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

For unadjusted descriptive analyses weight status was categorized as healthy weight (BMI <= 24.99 kg/m^2), overweight (BMI 25.0 - 29.99 kg/m^2), or obese (BMI >=30 kg/m^2). Abdominal obesity was defined as WC >88 cm (women) or >102 cm (men).

Statistical Analyses

All analyses used survey commands within Stata, version 14 (Stata Corp, College Station, TX) to account for complex survey design and incorporate survey weights. Analyses were stratified by sex and included the following covariates: age group (20–39, 40–59, 60-79 years), race/ethnic group (non-Hispanic white [NHW], non-Hispanic black (NHB), Mexican American (Mex-Am), and other races/ethnicities), education (less than high school (< HS), high school graduate (HS), greater than high school education (>HS)), family income based on the federal poverty level (FPL) thresholds for supplemental assistance programs available to adults (0–130% FPL, 131–299% FPL, ≥ 300% FPL), smoking status (current, never, or former), marital status (single/never married, formerly married, currently married/cohabitating), physical activity level (low, moderate, high), average hours of sedentary activity per day (continuous), dietary misreporting status (over reporter, accurate reporter, under reporter), survey year of data collection (2003-2004, 2005-2006, 2007-2008, 2009-2010, 2011-2012), self-reported history of major chronic disease (cardiovascular disease, stroke or cancer(y/n)), day of first dietary recall (weekend/weekday), and day of second dietary recall (weekend/weekday).

Chi^2 tests were used to test whether the survey weighted unadjusted distribution of categorical covariates and diet and anthropometric outcomes in each drinking category differed from the distributions of non-drinkers. For continuous variables, pair-wise comparisons were conducted using t-tests to compare means in each drinking category to that of non-drinkers.

Statistical significance was defined based on P<0.05, with Bonferroni correction for multiple comparisons.

To test associations between daily drinking level and diet and obesity measures of each drinking level category compared to non-drinkers, a series of multivariable linear regression models were used to regress outcome variables (continuous) on drinking level (indicator variables for non-drinker (0/1), moderate (0/1), heavy (0/1) and binge (0/1) drinking categories). Models with dietary outcomes as dependent variables were adjusted for age, race/ethnicity, education, physical activity level, survey year, chronic disease status, day of dietary recall 1, day of dietary recall 2, smoking, and dietary misreporting status. Models with obesity measures as dependent variables were adjusted for age, race/ethnicity, education, marital status, physical activity level, survey year, day of recall 1, day of recall 2, daily sedentary time, smoking status, FPL% and dietary misreporting status. A change in estimate of >10% was used as an *a priori* criterion to indicate confounding bias from dietary intake variables in regression models.

Results

The survey weighted distribution of covariates by sex and drinking level are presented in Table 3.1. The unadjusted associations of diet and obesity measures by sex and drinking level are presented in Table 3.2.

Adjusted differences in diet by drinking level compared to non-drinkers are presented in Table 3.3. Compared to non-drinkers, binge drinking men and women consumed 192 kcal/d (95% CI: 115,268) and 77 kcal/d (95%CI: 3,150), respectively, more in total energy. Heavy and binge drinking men consumed fewer calories, β: -92 kcal/d (95% CI: -163,-21) and β:-100 kcal/d (95% CI: -180,-20), respectively, in non-alcoholic energy sources than non-drinkers. Binge drinking men consumed less energy from food (β: -72 kcal/d; 95% CI:-142,-1) than their non-drinking counterparts. Heavy drinking (2 -3 drinks/d) women consumed less energy from non-alcoholic beverages (β: -56 kcal/d; 95% CI: -74,-38) than non-drinkers. Carbohydrates and sugar contributed less to total non-alcoholic energy intake all drinking subgroups as compared to non-drinkers.

Adjusted differences in obesity measures of drinkers compared to non-drinkers are presented in Table 3.4. Differences in WC and BMI in binge drinking men, compared to non-drinkers, were + 3.21 cm (95% CI: 1.02,5.40) and +1.32 kg/m^2 (95% CI: 0.43,2.21) (Model 1). Associations were strengthened after adjustment for food intake (Model 2) and attenuated and not significant for WC after adjustment for carbohydrate and sugar intakes (Model 3).

Compared to non-drinkers, WC was 1.93 cm (95% CI: -3.55,-0.31) and 2.44 cm (95% CI: -4.07,-0.82) lower in heavy drinking women in Model 1 and Model 3, respectively. Differences in BMI were -0.83 kg/m^2 (95% CI: -1.55,-0.11) and -1.10 kg/m^2 (95% CI: -1.82,-0.37) in heavy drinking women, compared to non-drinkers, in Model 1 and Model 3, respectively (Table 3.4). In comparison to non-significant associations for binge drinkers in Model 1 and Model 2, differences between binge drinkers and non-drinkers were strengthened and significant (β: -2.09 cm; 95% CI: -4.11,-0.07 and -1.18 kg/m^2; 95% CI: -2.09,-0.27) for WC and BMI, respectively) after adjustment for non-alcoholic beverage energy (Model 3).

Discussion

Interesting differences in associations between drinking level and dietary intake by sex were observed. For example, alcoholic beverage intake may be additive to total energy intake in binge drinking men coupled with decreased energy from food (i.e. meals and snacks); whereas heavy drinking women may replace non-alcoholic beverages with alcoholic beverages with no difference in total energy intake, as compared to non-drinkers. These differences may provide important insight into why associations between alcoholic beverage consumption and obesity measures differ by drinking level and sex.

Contrasting differences in intake from non-alcoholic energy sources with differences in total energy intake, within drinking subgroups, informs previous research suggesting that drinkers may compensate for alcoholic beverage consumption with altered dietary intake. [41, 91] The adjusted results of the this study indicate that excessive drinking men consumed less from non-alcoholic energy sources and more in total energy compared to non-drinkers. Conversely, lower non-alcoholic energy intake in heavy drinking women was paired with no difference in total energy intake, as compared to non-drinkers. When food and non-alcoholic beverages were examined separately, the displacement of non-alcoholic energy appears to come largely from food in binge drinking men and from non-alcoholic beverages in heavy drinking women. Results for binge drinking women were not significant, but do suggest that drinkers in this subgroup may attempt to balance alcoholic beverage intake with a parallel decrease in non-alcoholic energy sources, as described in a recent review by Poppit.[41] Differences in total energy intake and non-alcoholic energy in binge drinking women were +77 kcal/d and -74 kcal/d, respectively, compared to non-drinkers. Moreover, our results indicate that carbohydrates and sugar contribute less to the food and non-alcoholic beverage diet composition of all drinkers as compared to non-drinkers. There is a wealth of clinical research linking carbohydrate intake to suppressed alcohol intake and sweet preference (among alcoholics). Alcohol and carbohydrates, specifically sugar, may compete for the same neuronal receptors leading to suppressed intake of one nutrient for intake of the other. [36, 92] These results are supported by previous findings that drinkers may replace carbohydrates, with alcoholic beverages, contributing to differential diet composition in drinkers as compared to non-drinkers. [22, 23, 29, 30] The current study adds to these findings by suggesting that differences in diet composition may be related to differential substitution of food in binge drinking men and non-alcoholic beverages in heavy drinking women.

Associations between excessive drinking and dietary intake, support the hypothesis that diet confounds associations between alcoholic beverage consumption and obesity measures. [93] Furthermore, differential confounding by dietary intake in men compared to women was observed in this study. Positive associations between binge drinking and obesity measures in men were strengthened after adjustment for food intake and attenuated and no longer significant after adjustment for carbohydrate and sugar intakes. Negative associations between heavy drinking and obesity measures in women were strengthened after adjustment for carbohydrate and sugar intakes and not significant after adjustment for non-alcoholic beverage intake. Biological and observational research support contrasting associations observed by sex in the current study. [94, 95] There is a strong body of evidence indicating that ethanol metabolism, bioavailability and a dose response of alcohol's effect on body processes differs between men and women, even after adjustment for body weight. Women have higher body fat composition and lower body water content than men of the same body weights which has been linked to differential sex-specific ethanol metabolism. [94, 95] Moreover, female sex has been associated with wine consumption; whereas beer consumption has been associated with male sex. [17] The ethanol by volume content of wine is higher than that of beer and high ethanol intakes could alter lipid metabolism leading to loss of adipose tissue and negative associations between drinking level and obesity measures observed among women. [9, 28]

Moreover, distinct associations between drinking level and dietary intake by sex observed in the current study indicate differential food and beverage replacement behaviors in men and women drinkers. These differences might contribute to contrasting relationships between alcoholic beverage consumption and obesity measures by sex. Concurrent with lower food intakes, excessive drinking men had higher total energy intakes as compared to their non-drinking counterparts which might equate to excess energy intake and ultimately weight gain. [31, 40, 91] On the other hand, heavy drinking appears to be associated with substitution of non-alcoholic beverages in women which might lead to negative energy balance and negative differences in obesity measures as compared to non-drinkers. [22, 32, 40] However, the cross-sectional nature of this study precludes inferences of causation. Future research aimed at elucidating the effects of food, non-alcoholic beverage and carbohydrate and sugar intake, by sex, on associations between drinking level and obesity measures among excessive drinkers is warranted.

A strength of this study was the use of WC and BMI as obesity measures. The use of varying definitions of anthropometry across studies could be one reason for inconsistent findings regarding the relationship between alcoholic beverage consumption and obesity. Furthermore, the current study identified drinkers based on the use of the NHANES AUQ which captured drinking behaviors over the past 12 months. While misclassification of drinkers is still possible, the use of a long term questionnaire captures drinkers who might have been misclassified as non-drinkers with a shorter term assessment tool. The dietary intake data used in this study were obtained from 24-hour recalls which may be subject to systematic underreporting bias.[96] A strength of this study was the use of the revised Goldberg method to adjust for dietary misreporting in analyses. Yet, the Goldberg method is not without limitation. Using the Goldberg method to identify dietary misreporters in this study relied on BMR calculated using self-reported physical activity data. An inherent limitation of using self-reported physical activity data is that such data may be subject to recall bias bias which may lead to misclassification of dietary misreporters. A strength of this study was that the magnitude and direction of associations for excessive drinking men and heavy drinking women and diet and obesity outcomes were robust to a series of supplemental analyses (see Appendix 3.2-5). Additionally, the current study is nationally representative and multiple surveys were pooled to ensure adequate sample size to examine drinking subgroups by sex.

These results suggest altered intake of meals and snacks in binge drinking men and non-alcoholic beverages in heavy drinking women as compared to non-drinkers. Differences in dietary intake by sex and drinking level may contribute to differential confounding by diet in associations of alcoholic beverage consumption and obesity measures. Additional research is needed to understand the determinants of differences in diet and obesity measures in excessive drinking subgroups of men and women in the US.

Table 3.1 Survey weighted distribution of covariates by sex and daily drinking level, NHANES 2003-2012[a]

	Men				Women			
Drinking Level	**Non-Drinker**	**Moderate**	**Heavy**	**Binge**	**Non-drinker**	**Moderate**	**Heavy**	**Binge**
N	817	2,627	1,345	1,229	1,767	1,826	1,744	548
%	11.4 ± 0.7	45.4 ± 1.1*	22.9 ± 0.9*	20.3 ± 0.9*	23.3 ± 1	33.6 ± 1*	33.2 ± 0.9*	9.8 ± 0.5*
Age group								
20-39 years	37.2 ± 2.7	34.0 ± 1.7	48.1 ± 2.0	62.2 ± 2.3	31.6 ± 1.6	27.1 ± 1.5	49.6 ± 1.9	66.2 ± 2.8
40-59 years	35.4 ± 2.5	42.6 ± 1.5	39.0 ± 2.0	31.4 ± 1.9	36.6 ± 1.6	44.7 ± 1.6	38.8 ± 1.8	30.5 ± 2.7
60-79 years	27.4 ± 2.3	23.4 ± 1.4	12.9 ± 1.1	6.4 ± 1.1	31.8 ± 1.8	28.1 ± 1.4	11.6 ± 0.9	3.4 ± 0.7
p-value		0.0566	**<0.0001**	**<0.0001**		0.1198	**<0.0001**	**<0.0001**
Race/ethnicity[c]								
NHW	65.7 ± 3.3	77.1 ± 1.7	71.4 ± 1.8	63.6 ± 3.0	59.5 ± 3.0	77.8 ± 1.6	74.8 ± 1.6	69.6 ± 3.2
NHB	14.6 ± 1.9	9.1 ± 0.9	10.4 ± 1.1	7.3 ± 1.0	16.6 ± 1.7	9.6 ± 0.9	10.3 ± 1.0	11.0 ± 1.8
Mex-Am	5.6 ± 0.9	4.9 ± 0.5	9.1 ± 1.1	18.1 ± 2.1	10.6 ± 1.4	4.5 ± 0.6	6.0 ± 0.7	10.9 ± 2.0
Other	14.1 ± 2.0	8.8 ± 1.0	9.1 ± 1.1	10.9 ± 1.4	13.2 ± 1.4	8.2 ± 0.9	8.8 ± 0.9	8.5 ± 1.3
p-value		**0.0001**	**0.0013**	**<0.0001**		**0.0065**	**<0.0001**	**0.0019**
Education[d]								
<HS	20.1 ± 2.0	9.9 ± 0.8	14.5 ± 1.4	23.7 ± 1.5	23.9 ± 1.6	8.9 ± 0.7	10.9 ± 1.0	19.3 ± 2.7
HS	30.4 ± 2.8	18.9 ± 1.4	22.2 ± 1.4	32.7 ± 2.3	29.3 ± 1.8	18.3 ± 1.4	21.2 ± 1.4	29.7 ± 3.2
>HS	49.5 ± 3.0	71.2 ± 1.6	63.3 ± 1.9	43.7 ± 2.5	46.7 ± 1.9	72.7 ± 1.7	68.0 ± 1.7	51.0 ± 3.9
p-value		**<0.0001**	**0.0003**	0.1974		**0.0012**	**<0.0001**	0.3620
Household income[e]								
0-130%	21.0 ± 2.0	11.9 ± 0.9	17.7 ± 1.7	28.3 ± 1.8	30.5 ± 1.6	12.4 ± 1.0	17.0 ± 1.4	37.4 ± 3.4
131-299%	34.3 ± 2.3	21.4 ± 1.1	26.3 ± 1.8	30.2 ± 2.1	33.4 ± 1.7	25.1 ± 1.6	25.7 ± 1.5	26.7 ± 2.9
≥300%	44.7 ± 2.4	66.8 ± 1.6	56.0 ± 2.1	41.5 ± 2.5	36.2 ± 2.1	62.5 ± 1.7	57.3 ± 1.9	35.9 ± 3.2
p-value		**<0.0001**	**0.0035**	**0.0208**		**0.0226**	**<0.0001**	**0.0891**
Marital Status								
Never married	23.0 ± 2.3	16.2 ± 1.3	26.0 ± 2.1	31.2 ± 2.3	15.2 ± 1.6	12.2 ± 1.1	20.2 ± 1.7	31.8 ± 3.6
Formerly married	8.7 ± 1.3	9.8 ± 0.9	11.4 ± 1.2	14.8 ± 1.7	21.8 ± 1.4	19.5 ± 1.2	19.7 ± 1.3	16.0 ± 1.8
Currently married	68.3 ± 2.2	74.0 ± 1.3	62.6 ± 2.2	54.0 ± 2.7	63.1 ± 2	68.2 ± 1.5	60.1 ± 1.9	52.2 ± 3.6

	Men				Women			
Drinking Level	**Non-Drinker**	**Moderate**	**Heavy**	**Binge**	**Non-drinker**	**Moderate**	**Heavy**	**Binge**
p-value		**0.0050**	0.1532	**< 0.0001**		0.2364	0.0543	**<0.0001**
Smoking Status								
Never Smoker	67.6 ± 2.2	54.9 ± 1.6	39.8 ± 2.3	35.6 ± 2.2	75.8 ± 1.9	64.1 ± 1.4	50.7 ± 1.9	37.6 ± 3.9
Former Smoker	19.6 ± 1.8	30.0 ± 1.4	26.6 ± 1.9	20.1 ± 1.7	11.1 ± 1.3	23.9 ± 1.4	22.8 ± 1.7	14.6 ± 2.1
Current Smoker	12.8 ± 1.4	15.1 ± 1	33.6 ± 2.1	44.4 ± 2.2	13.1 ± 1.3	12.0 ± 1.2	26.5 ± 1.5	47.8 ± 3.6
p-value		**<0.0001**	**<0.0001**	**<0.0001**		**0.0172**	**<0.0001**	**<0.0001**
History of Chronic Disease[f]								
No	84.7 ± 1.8	84.8 ± 1	90.5 ± 1.2	95.4 ± 0.7	85.0 ± 1.3	87.5 ± 1	89.5 ± 1.1	89.7 ± 1.9
Yes	15.3 ± 1.8	15.2 ± 1	9.5 ± 1.2	4.6 ± 0.7	15.0 ± 1.3	12.5 ± 1	10.5 ± 1.1	10.3 ± 1.9
p-value		0.9749	**0.0044**	**<0.0001**		0.3812	**0.0151**	0.0619
Dietary Misreporting[g]								
Accurate Reporter	66.5 ± 2.7	74.1 ± 1.3	70.1 ± 1.8	69.3 ± 2.0	65.4 ± 1.5	71.6 ± 1.5	70.6 ± 1.6	65 ± 3.2
Under Reporter	23.5 ± 2.0	16.4 ± 0.9	17.3 ± 1.5	14.9 ± 1.6	28.6 ± 1.5	19.5 ± 1.3	20.8 ± 1.5	23.7 ± 2.9
Over Reporter	10.1 ± 1.9	9.5 ± 0.9	12.6 ± 1.2	15.8 ± 1.6	6.0 ± 0.8	8.9 ± 0.9	8.5 ± 0.9	11.2 ± 1.8
p-value		**0.0171**	0.0712	**0.0060**		**0.0145**	**0.0002**	**0.0262**
PAL[h]								
Low	71.9 ± 2.4	63.7 ± 1.6	70.3 ± 1.8	71.3 ± 1.8	80.5 ± 1.4	70.3 ± 1.8	70.3 ± 2.1	70.0 ± 3.2
Moderate	17.7 ± 2.0	18.6 ± 1.1	15.4 ± 1.4	12.5 ± 1.6	14.1 ± 1.3	20.5 ± 1.8	18.6 ± 1.3	18.3 ± 2.5
High	10.4 ± 1.5	17.7 ± 1.5	14.2 ± 1.6	16.2 ± 1.6	5.4 ± 0.8	9.2 ± 1	11.1 ± 1.4	11.7 ± 2
p-value		**0.0012**	0.1615	**0.0160**		**0.0505**	**<0.0001**	**0.0005**
Sedentary Time (h/d)								
Mean ± SE	4.0 ± 0.1	3.9 ± 0	3.8 ± 0.1	4.0 ± 0.1	3.8 ± 0.1	3.8 ± 0.1	3.9 ± 0	3.9 ± 0.1

[a] Data for United States (US) men (n=6,018) and women (n=5,885) 20 – 79 years of age. Values are % ± SE unless mean specified. All values take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES);

[b] P-values for chi^2 tests of survey weighted unadjusted percentage distributions of categorical covariates in drinkers compared to the percentage distribution of covariates in each drinking category. For continuous covariates and one-way tabulations, paired t-tests were used to compare means of non-drinkers to moderate, heavy or binge drinkers. Differences were considered statistically significant at P<0.05, after Bonferroni correction for multiple comparisons as indicated in boldface.

[c] Non-Hispanic White (NHW); Non-Hispanic Black (NHB); Mexican American (Mex-Am)
[d] Graduated from high school (HS) or obtained general equivalency diploma (GED)
[e] Household income expressed as percentage of the Federal Poverty Level (FPL)
[f] Self-reported history of cardiovascular disease, stroke or cancer
[g] Implausible energy intakes were identified using the revised Goldberg method
[h] Physical Activity Level (PAL)
[*] Different than non-drinkers ($P<0.05$, after Bonferroni correction for multiple comparisons)

Table 3.2 Associations between daily drinking level, diet and obesity measures, NHANES 2003-2012[a,b]

	Drinking Level							
	Men				**Women**			
Drinking Level	**Non-drinker**	**Moderate**	**Heavy**	**Binge**	**Non-drinker**	**Moderate**	**Heavy**	**Binge**
Diet Outcomes								
Total Energy (kcal/d)	2365 ± 40	2506 ± 23*	2620 ± 33*	2797 ± 46*	1718 ± 21	1811 ± 19*	1881 ± 22*	1960 ± 44*
Non-alcoholic Energy (kcal/d)[c]	2365 ± 40	2403 ± 21	2406 ± 31	2486 ± 37	1718 ± 21	1770 ± 19	1792 ± 21*	1801 ± 43
Food Energy (kcal/d)[c]	1990 ± 36	2068 ± 20	2027 ± 27	2057 ± 31	1441 ± 20	1528 ± 19*	1539 ± 19*	1478 ± 35
Non-alcoholic Beverage Energy (kcal/d)[c]	375 ± 11	335 ± 7*	378 ± 10	429 ± 14*	278 ± 8	242 ± 9*	253 ± 6*	323 ± 14*
% Fat Contribution[c]	33.4 ± 0.4	34.1 ± 0.2	33.2 ± 0.3	32.1 ± 0.3*	33.2 ± 0.3	33.9 ± 0.2	33.9 ± 0.2	32.5 ± 0.5
% Protein Contribution[c]	15.6 ± 0.2	16.1 ± 0.1*	15.6 ± 0.1	15.5 ± 0.1	15.5 ± 0.2	15.7 ± 0.1	15.5 ± 0.1	14.7 ± 0.3*
% Carbohydrate Contribution[c,d]	28.9 ± 0.4	26.4 ± 0.2*	24.6 ± 0.2*	23.4 ± 0.3*	28.2 ± 0.3	27.0 ± 0.2*	26.2 ± 0.2*	24.2 ± 0.4*
% Sugar Contribution[c]	23.5 ± 0.4	20.7 ± 0.2*	19.6 ± 0.3*	20.0 ± 0.4*	24.8 ± 0.3	23.0 ± 0.3*	21.2 ± 0.3*	22.1 ± 0.6*
Obesity Measures								
Abdominal Obesity (%)								
No	53.2 ± 2.9	58.7 ± 1.6	60.8 ± 2.1	61.7 ± 2.2	30.6 ± 1.6	42.8 ± 2	47.1 ± 1.9	48.7 ± 3.7
Yes	46.8 ± 2.9	41.3 ± 1.6	39.2 ± 2.1	38.3 ± 2.2	69.4 ± 1.6	57.2 ± 2	52.9 ± 1.9	51.3 ± 3.7
p-value		0.0789	**0.0296**	**0.0231**		**0.0167**	**<0.0001**	**<0.0001**
Waist Circumference (cm)								
Mean ± SE	101.4 ± 0.9	100.3 ± 0.4	98.9 ± 0.6	100.3 ± 0.8	96.9 ± 0.6	92.9 ± 0.7*	91.5 ± 0.6*	92.3 ± 0.9*
Weight Status (%)								
BMI <= 24.99	29.7 ± 2.5	29.2 ± 1.4	29.2 ± 1.8	28.7 ± 1.8	29.9 ± 1.7	41.6 ± 1.9*	46.4 ± 1.8*	45.4 ± 3.9*
BMI 25.0 - 29.99	34.0 ± 2.5	41.4 ± 1.4	40.3 ± 1.8	36.8 ± 2.1	30.3 ± 1.6	29.2 ± 1.5	25.4 ± 1.7	24.5 ± 3.1
BMI >=30	36.4 ± 2.6	29.4 ± 1.5	30.5 ± 1.9	34.6 ± 2.1	39.8 ± 1.5	29.2 ± 1.5*	28.1 ± 1.7*	30.0 ± 2.4*
p-value		**0.0221**	0.0824	0.7120		**0.0260**	**<0.0001**	**0.0002**
BMI (kg/m^2)								
Mean ± SE	28.7 ± 0.3	28.1 ± 0.2	28 ± 0.2	28.7 ± 0.3	29.5 ± 0.2	27.8 ± 0.3*	27.2 ± 0.2*	27.4 ± 0.4*

[a] Data for United States (US) men (n=6,018) and women (n=5,885) 20 – 79 years of age. Values are % ± SE unless mean ± SE specified. All values take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES)
[b] P-values for chi^2 tests of survey weighted unadjusted percentage distributions of categorical variables in drinkers compared to the percentage distribution of covariates in each drinking category. For continuous covariates and one-way tabulations, paired t-tests were used to compare means of non-drinkers to moderate, heavy or binge drinkers. Differences were considered statistically significant at $P<0.05$, after Bonferroni correction for multiple comparisons as indicated in boldface.
[c] Excludes energy from alcoholic beverages
[d] Excludes energy from sugar
[*] Different than non-drinkers ($P<0.05$, after Bonferroni correction for multiple comparisons)

Table 3.3 Differences in energy intake (kcal/d) and macronutrient contributions (%) between drinkers and non-drinkers, NHANES 2003-2012[a]

	Men		Women	
	β	**95% CI**	β	**95% CI**
A				
Total Energy (kcal/d)				
Non-Drinker	Ref	(0,0)	Ref	(0,0)
Moderate Drinker	51	(-16,118)	-22	(-58,15)
Heavy Drinker	**100**	**(28,172)**	22	(-21,66)
Binge Drinker	**192**	**(115,268)**	**77**	**(3,150)**
B				
Non-alcoholic Energy (kcal/d)[b]				
Non-Drinker	Ref	(0,0)	Ref	(0,0)
Moderate Drinker	-34	(-102,34)	**-48**	**(-86,-9)**
Heavy Drinker	**-92**	**(-163,-21)**	**-54**	**(-100,-9)**
Binge Drinker	**-100**	**(-180,-20)**	-74	(-153,6)
C				
Food Energy (kcal/d)[b]				
Non-Drinker	Ref	(0,0)	Ref	(0,0)
Moderate Drinker	-1	(-62,60)	-16	(-54,21)
Heavy Drinker	-60	(-124,5)	1	(-45,48)
Binge Drinker	**-72**	**(-142,-1)**	-47	(-113,20)
D				
Non-alcoholic Beverage Energy (kcal/d)[b]				
Non-Drinker	Ref	(0,0)	Ref	(0,0)
Moderate Drinker	**-33**	**(-60,-7)**	**-31**	**(-52,-11)**
Heavy Drinker	**-32**	**(-62,-3)**	**-56**	**(-74,-38)**
Binge Drinker	-29	(-64,7)	-27	(-62,9)
E				
% Fat Contribution[b]	Ref	(0,0)	Ref	(0,0)
Non-Drinker	0.40	(-0.47,1.27)	0.18	(-0.46,0.82)

	Men		Women	
Moderate Drinker	-0.28	(-1.25,0.70)	0.34	(-0.32,1.00)
Heavy Drinker	-0.95	(-1.91,0.02)	-0.78	(-1.90,0.33)
Binge Drinker				
F				
% Protein Contribution[b]	Ref	(0,0)	Ref	(0,0)
Non-Drinker	**0.56**	**(0.16,0.96)**	0.30	(-0.08,0.68)
Moderate Drinker	0.22	(-0.20,0.64)	0.30	(-0.08,0.68)
Heavy Drinker	0.26	(-0.10,0.62)	-0.17	(-0.75,0.42)
Binge Drinker				
G				
% Carbohydrate Contribution[b,c]	Ref	(0,0)	Ref	(0,0)
Non-Drinker	**-2.29**	**(-3.13,-1.45)**	**-0.74**	**(-1.43,-0.06)**
Moderate Drinker	**-3.85**	**(-4.81,-2.89)**	**-1.28**	**(-1.99,-0.57)**
Heavy Drinker	**-5.36**	**(-6.31,-4.40)**	**-3.02**	**(-3.93,-2.12)**
Binge Drinker				
H				
% Sugar Contribution[b]	Ref	(0,0)	Ref	(0,0)
Non-Drinker	**-2.32**	**(-3.28,-1.35)**	**-1.27**	**(-2.14,-0.40)**
Moderate Drinker	**-4.05**	**(-5.03,-3.07)**	**-3.75**	**(-4.57,-2.93)**
Heavy Drinker	**-4.33**	**(-5.39,-3.27)**	**-3.82**	**(-5.39,-2.25)**

[a] Data for United States (US) men (n=6,018) and women (n=5,885) 20 – 79 years of age. Estimates obtained from a series of sex-specific multivariable linear regression models which take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES); All models adjusted for age, race/ethnicity, education, physical activity level, survey year, chronic disease status, day of recall 1, day of recall 2, dietary misreporting and smoking. Continuous dietary outcomes vary for each regression model as follows: A: total energy; B: non-alcoholic energy (food plus non-alcoholic beverage energy); C: energy from food; D: energy from non-alcoholic beverages; E: percentage contribution from fat to non-alcoholic energy; F: percentage contribution from protein non-alcoholic energy; G: percentage contribution from carbohydrates to non-alcoholic energy; H: percentage contribution from sugar to non-alcoholic energy. Estimates are the difference in kilocalories per capita per day (kcal/d) or percentage contribution compared to non-drinkers (%).

[b] Excludes energy from alcoholic beverages

[c] Excludes energy from sugar

Table 3.4 Differences in WC (cm) and BMI (kg/m^2) of drinkers compared to non-drinkers, NHANES 2003-2012[a]

	Men					
	Model 1[b]		**Model 2[c]**		**Model 3[d]**	
A						
WC (cm)	β	95% CI	β	95% CI	β	95% CI
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.71	(-2.34,0.92)	-0.68	(-2.25,0.89)	-1.20	(-2.79,0.40)
Heavy Drinker	-0.10	(-1.91,1.70)	0.29	(-1.52,2.10)	-0.94	(-2.73,0.85)
Binge Drinker	**3.21**	**(1.02,5.40)**	**3.63**	**(1.45,5.82)**	2.11	(-0.04,4.26)
B	**Model 4[b]**		**Model 5[c]**		**Model 6[d]**	
BMI (kg/m^2)						
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.33	(-0.96,0.30)	-0.32	(-0.94,0.31)	-0.5	(-1.11,0.12)
Heavy Drinker	0.07	(-0.68,0.81)	0.21	(-0.54,0.95)	-0.23	(-0.97,0.51)
Binge Drinker	**1.32**	**(0.43,2.21)**	**1.47**	**(0.57,2.37)**	**0.93**	**(0.05,1.81)**
	Women					
	Model 7[b]		**Model 8[e]**		**Model 9[d]**	
A						
WC (cm)	β	95% CI	β	95% CI	β	95% CI
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	**-1.59**	**(-3.15,-0.03)**	-1.43	(-2.98,0.12)	**-1.79**	**(-3.34,-0.24)**
Heavy Drinker	**-1.93**	**(-3.55,-0.31)**	-1.58	(-3.19,0.03)	**-2.44**	**(-4.07,-0.82)**
Binge Drinker	-1.32	(-3.26,0.62)	-1.11	(-3.03,0.80)	**-2.09**	**(-4.11,-0.07)**
B						
BMI (kg/m^2)	**Model 10[b]**		**Model 11[e]**		**Model 12[d]**	
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.54	(-1.24,0.15)	-0.49	(-1.18,0.20)	-0.64	(-1.33,0.04)
Heavy Drinker	**-0.83**	**(-1.55,-0.11)**	-0.70	(-1.42,0.02)	**-1.10**	**(-1.82,-0.37)**
Binge Drinker	-0.79	(-1.67,0.10)	-0.71	(-1.60,0.17)	**-1.18**	**(-2.09,-0.27)**

[a] Data for United States (US) men (n=6,018) 20 – 79 years of age. β co-efficients obtained from multivariable linear regression models which take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES);

Continuous anthropometric outcomes vary for each regression model as follows: A: Waist Circumference (WC); B: Body Mass Index (kg/m^2). All estimates are the difference in cm^2 or kg/m^2 for WC and BMI, respectively, as compared to non-drinkers.

[b] adjusted for age, race/ethnicity, education, marital status, physical activity level, dietary misreporting, survey year, day of recall 1, day of recall 2, daily sedentary time, smoking status, FPL%

[c] adjusted for covariates plus food intake (continuous)

[d] adjusted for covariates plus percentage contribution of carbohydrates to total energy intake (continuous) and percentage contribution of sugar to total energy intake (continuous)

[e] adjusted for covariates plus energy from non-alcoholic beverages (continuous)

CHAPTER 4. ASSOCIATIONS OF 5-YEAR CHANGES IN ALCOHOLIC BEVERAGE INTAKE WITH 5-YEAR CHANGES IN WAIST CIRCUMFERENCE AND BMI IN THE CORONARY ARTERY RISK DEVELOPMENT IN YOUNG ADULTS (CARDIA) STUDY

Overview

Contradictory associations of alcohol intake with Waist Circumference (WC) and Body Mass Index (BMI) are likely due to residual confounding, selection bias and variation in associations by drinking level and alcoholic beverage type. This study aimed to shed light on inconsistent findings by examining 5-yr changes in alcohol intake in relation to 5-yr WC and BMI change. This prospective study included 4,146 participants (1,894 men and 2,252 women) enrolled in the Coronary Artery Risk Development in Young Adults (CARDIA) study at baseline (1985-1986) and followed over 25 years (2010-2011). Longitudinal random effects linear regression models were used to test whether changes in alcohol intake (versus stable non-drinking) over a 5-yr period were associated with 5-yr WC and BMI change. Associations with changes in drinking level and changes by beverage type were also examined. In men, a 5-yr decrease in total alcohol intake, particularly stopping excessive drinking (β:-0.78 cm; (95% CI: -1.53, -0.03 cm) was associated with lower 5-yr WC gains (β:-0.70 cm (95% CI: -1.19, -0.22 cm) compared to stable non-drinking. In women, compared to stable non-drinkers, increasing wine (β:-0.57 cm; 95% CI: -1.06, -0.09 cm) and decreasing liquor/mixed drink (β:-0.87 cm; 95% CI: -1.43, -0.31 cm) intake was associated with lower 5-yr WC gains. In women, contrasting associations with change in alcohol intake in relation WC and BMI change were observed. In men, stopping excessive drinking may be beneficial in managing WC and BMI gains.

Introduction

An increasing trend in energy consumed from alcoholic beverages coupled with secular increases in waist circumference (WC) and body mass index (BMI) have been reported in the US over the past two decades. [5-7] Yet, positive, null and negative associations of alcohol intake with WC, BMI, and changes in WC and BMI have been reported. Residual confounding, selection bias and variation in associations by drinking level and alcoholic beverage type have been cited as potential contributors to contradictory findings. [8, 41, 97]

Residual confounding by unmeasured characteristics that differ within and across drinking categories may underlie inconsistent findings. [8, 98, 99] Non-drinkers have been reported to engage in less physical activity, consume more calories and belong to lower socio-economic subgroups as compared to drinkers [100] Further, in the US wine drinking has been associated with higher educational attainment and higher intakes of food and beverage groups supported by the Dietary guidelines for Americans [101]. Beer and liquor intake has been associated with foods and nutrients that should be consumed in moderation (i.e. fat, sugar, sodium) and excessive drinking. [7, 66-69, 101, 102] Thus, dietary intake and physical activity may be key omitted confounders in epidemiologic studies of alcohol and obesity outcomes. [8, 45] People may self-select into alcohol consumption behavior patterns based on socio-demographic characteristics and inherent individual traits. [103, 104] If unaccounted for, residual confounding and self-selection may bias associations of alcohol intake with WC and BMI and contribute to inconsistencies in the alcohol and obesity literature. [98, 105]

In addition, variation in associations by drinking level and alcoholic beverage type may add to the mixed literature. Positive and null associations of excessive drinking and BMI gains have been reported. [8, 25, 26] There is evidence that stopping heavy drinking or maintaining stable light or moderate drinking may underlie positive and negative associations of within-person changes in total alcohol intake with WC and BMI change in men and women, respectively. [20, 55] With regard to alcoholic beverage type, the non-alcohol components (i.e., polyphenols) of beer and wine have been inversely associated with weight and BMI. [3] Yet, positive and negative associations of beer intake and changes in beer intake with weight and BMI gains have been found. [45, 63] While wine intake has been negatively associated with weight gain, positive associations with liquor consumption have been reported for both sexes. [9, 58] However, results are limited and inconclusive regarding associations of within-person changes in alcohol consumption levels and alcoholic beverages by type (i.e. decreasing beer or wine intake) and changes in WC and BMI. [8-10, 44, 45, 51-58]. Furthermore, we could find no study that examined within-person changes in drinking level in relation to changes in WC in men and women.[8]

To address these gaps in the literature, we used time-varying data on alcoholic beverage intake, diet, physical activity and socio-demographic covariates over 25 years from the Coronary Artery Risk Development in Young Adults (CARDIA) study to determine whether changes in WC and BMI differ between non-drinkers and drinkers. Using within-person change analyses to control for time-invariant unobserved individual characteristics, we examined changes in drinking level and changes in intake by beverage type in relation to changes in WC and BMI. We hypothesized that starting to consume alcohol in excess over a 5-yr period would be positively associated with WC and BMI change. Additionally, we hypothesized that 5-yr increases in beer or wine intake would be negatively associated with WC and BMI change and increases in liquor/mixed drinks positively associated with 5-yr WC and BMI change.

Methods

The CARDIA study is an ongoing, prospective study of the determinants and evolution of cardiometabolic risk starting in young adulthood. A total of 5,115 young adults aged 18-30 years were enrolled at baseline in 1985–1986 with balance according to race (African American and white), sex, education (≤high school and >high school), and age (18-24 and 25-30 years) from the population in each of four metropolitan areas: Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. Follow-up examinations occurred in 1987-1988 (Exam Year 2), 1990-1991 (Exam Year 5), 1992-1993 (Exam Year 7), 1995-1996 (Exam Year 10), 2000-2001 (Exam Year 15), and 2005-2006 (Exam Year 20) and 2010-2011 (Exam Year 25); retention at each exam year was 91% 90%, 86%, 81%, 79%, 74%, 72% and 72%, respectively. The CARDIA study methods are described in detail elsewhere. [106, 107] Each study participant provided written informed consent, and data were collected under protocols approved by the Institutional Review Boards at each study center and at the University of North Carolina at Chapel Hill.

This study included six CARDIA exams (1985–1986, 1990-1991, 1995-1996, 2000-2001, 2005-2006, 2010-2011). All adults with socio-demographic data at baseline were considered eligible participants excluding one participant who withdrew from the study (N=5,114). As has been done in previous studies, to minimize bias resulting from illness that may affect body weight, we excluded participants with hypertension (≥6.5% or taking medication for diabetes; N=29) or cancer (self-reported diagnosis; N=137) at baseline. [44, 108] Further, we excluded participants who were missing data on diabetes, hypertension, self-reported cancer diagnoses (N=113), waist circumference (N=17) or BMI (N=4) at baseline. We also excluded participants with only one exam (N=351). Individuals with excluded observations at every exam were excluded from the analytic sample (N=61). For individuals included in the analytic sample, observations were excluded at given exam years if participants were pregnant or breastfeeding (obs=278) or had implausible energy intakes (<600 kcal/d or >6000/d kcal for women and <800 kcal/d or >8000 kcal/d for men) (n= 322) at an exam or if they were missing exposure (obs=1,311 alcohol intake), outcome (obs = 32 WC, 130 BMI), or covariate data at a given exam year (obs=1 education, 4 marital status, 80 smoking, 47 physical activity, 1,130 dietary intake). We excluded observations at exams where participants were missing data on disease diagnosis (=90) and censored participants with diabetes, hypertension or self-reported cancer during follow-up at the year in which the disease was reported (obs =3,230). Our final analytic sample consisted of 4,257 participants (men and women) n=4,146 at year 0; 3,471 at year 5; 2,461 at year 10; 2,028 at year 15; 1,628 at year 20 and 1,311 at year 25 for a total 15,045 person observations.

Excluded participants (N=857) were more likely to be black, obese and belong to the lowest education subgroup at year 0 as compared to those included (Table 4.1).

CARDIA assessed alcoholic beverage consumption at each examination using an Alcohol Use Questionnaire (AUQ) that queried participants regarding annual, monthly, weekly and daily alcoholic beverage intake. Alcoholic beverage consumption was defined based on the following questions: “Did you drink any alcoholic beverages in the past year?”; “How many drinks of wine (5 oz glass) do you usually have per week?”; “How many drinks of beer (12 oz glass) do you usually have per week?”; “How many drinks per week do you usually have of hard liquor (1 1/2 oz)?”

To describe the distribution of socio-demographic and lifestyle characteristics of drinkers compared to non-drinkers at baseline, participants were categorized into sex-specific drinking categories using alcoholic beverage intake at exam year 0. Category definitions were based on the National Institute on Alcohol Abuse and Alcoholism (NIAAA) guidance on drinking levels. [54, 61, 109-111] Based on the sum of the usual intake of beer, wine, and liquor/mixed drinks per week (drinks/wk) as reported on the AUQ at exam year 0, men were classified as "non-drinker", "light drinker" (<7 drinks/wk), "moderate drinker" (7 to 14 drinks/wk), or "excessive drinker" (>14 drinks/wk), and women were classified as "non-drinker", "light drinker" (<4 drinks/wk), "moderate drinker" (4 to 7 drinks/wk), or "excessive drinker (> 7 drinks/wk). [109, 110]

Changes in total alcohol intake

Alcoholic beverage intake data were collected at all examinations. To capture 5-yr changes in alcohol intake we chose to use alcohol intake data from the six examinations administered with 5-yr time intervals from one exam to the next (i.e. exam years 0, 5, 10, 15, 20 and 25). Participants were categorized by the 5-yr change in total drinks/wk from one exam year to the next as follows: "Stable non-drinking" (0 drinks/wk at previous and current exam), "Start drinking" (change from 0 drinks/wk at previous exam to > 0 drinks/wk at current exam), "Increase drinking" (drinks/wk at previous exam < drinks/wk at current exam), "Stable drinking" (drinks/wk > 0 and drinks/wk at previous exam equal to drinks/wk at current exam), "Stop drinking" (change from >0 drinks/wk at previous exam to 0 drinks/wk at current exam), "Decrease drinking" (drinks/wk at previous exam > drinks/wk at current exam).

Changes in drinking level

To investigate associations between 5-yr changes in drinking level and 5-yr changes in WC and BMI, participants were categorized by the change in NIAAA-based drinking levels from one exam year to the next as follows: "Stable non-drinking" (0 drinks/wk at previous and current exam), “Start light/moderate drinking” (non-drinker at previous exam and light or moderate drinker at current exam), “Start excessive drinking” (non-, light or moderate drinker at previous exam and excessive drinker at the current exam), “Stable light/moderate drinking (light or moderate drinker at previous exam and light or moderate drinker at current exam), “Stable excessive drinking (excessive drinker at previous exam and excessive drinker at current exam), “Stop light/moderate drinking” (light or moderate drinker at previous exam and non-drinker at current exam), “Stop excessive drinking” (excessive drinker at previous exam and non-, light or moderate drinker at the current exam).

Changes in alcoholic beverage type

To examine associations between 5-yr changes in beer, wine and liquor/mixed drink intake with changes in WC and BMI over the same period, participants were categorized according to weekly consumption of each beverage type as follows: “Stable non-drinking” (0 drinks/wk at previous and current exam), “Increase” (beer, wine or liquor/mixed drinks/wk at previous exam < beer, wine or liquor/mixed drinks/wk at current exam), “Stable” (no change in beer, wine or liquor/mixed drinks/wk from previous to current exam), “Decrease” (beer, wine or liquor/mixed drinks/wk at previous exam > beer, wine or liquor/mixed drinks/wk at current exam).

Anthropometrics

At each exam, height, weight, and WC were measured in replicate in light clothing without shoes according to standardized protocol. [106, 112] Height was measured to the nearest 0.2 cm via portable Seca stadiometer, and weight was measured to the nearest 0.1 kg via calibrated balance beam scale. WC was measured midway between the iliac crest and the lowest lateral portion of the rib cage (anteriorly at the point midway between the xiphoid process of the sternum and the umbilicus) using a Seca tape measure, and an average of 2 measures to the nearest 0.5 cm was used. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Statistical Analyses

All data analyses were conducted using Stata, version 14 (Stata Corp, College Station, TX).

Initial unadjusted descriptive analyses tested whether demographic, socioeconomic, and behavioral characteristics and anthropometric outcomes at baseline in 1985-1986 in non-drinkers differed from drinkers in each NIAAA-based drinking category. Chi square tests were used to determine differences in the distribution of categorical covariates and analysis of variance (ANOVA) was used to test means of continuous covariates.

Longitudinal random effects linear regression models, which account for correlation between repeated measures within individuals across time, were used to determine whether 5-yr changes in alcohol intake were associated with changes in WC and BMI during the same time period. Linear models regressed 5-yr WC or BMI change on 5-yr change in total alcoholic drinks/wk over the same time period (categorized with stable non-drinkers as the referent group).

Separate models were used to test whether associations between 5-yr changes in NIAA-based drinking level and 5-yr changes in WC and BMI differed from that of stable non-drinkers. Separate models were also used to test whether 5-yr changes in each type of alcoholic beverage in drinkers were associated with 5-yr changes in WC and BMI. Models for each beverage type were adjusted for time-varying continuous changes in intake of each other alcoholic beverage within each 5-yr interval.

Covariates

All models adjusted for several demographic, socioeconomic, and behavioral factors that were assessed at each examination. The time invariant covariates were: baseline age (18-24 years or 25-30 years); baseline WC (when change in WC was the outcome) or baseline BMI (when change in BMI was the outcome); and race (black or white). We adjusted for time-varying education (<= high school (HS) diploma; >HS); income (≤$24,999; $25,000 - $74,999; ≥$75,000); smoking status (never, former or current) at the start of each 5-yr interval. Because < 10% of participants within each drink change category experienced changes in income, education or smoking status, we did not adjust for changes in these covariates within each 5-yr period. We adjusted for time-varying changes in marital status (stable single, stable married or change in marital status); physical activity score (continuous); and diet quality score (continuous) within each 5-yr period. Physical activity was assessed using the CARDIA physical activity questionnaire, a validated and reliable assessment of physical activity. [113] Dietary intake data for this study was derived from a validated interviewer-administered comprehensive diet history questionnaire administered at exam years 0, 7, and 20. [114, 115] For those years that dietary intake was not assessed, data from the previous year was carried forward. Diet quality was defined using the a-priori diet quality score previously developed and used as a valid predictor of clinical cardiovascular disease, myocardial infarction and diabetes. [116-118] This summary score of diet quality was constructed by classifying 46 food groups according to investigator ratings of hypothesized health effects. Twenty food groups were identified as beneficial, 13 as adverse, and 13 as neutral. Within the CARDIA dataset, this 'a-priori' diet quality score has been associated with lipid peroxidation and age, gender, race and education. [119, 120] In this study, alcoholic beverages were excluded from the calculation of the diet quality score.

Because the existing literature suggests that alcohol intake has differential associations with adiposity among men and women, all analyses were stratified by sex.

Results

The unadjusted proportions of black, married, less educated, and non-smokers were higher in non-drinking as compared to moderate and excessive drinking men (Table 4.2) and women (Table 4.3). Excessive drinking men had significantly higher WC compared to non-drinkers. In women, non-drinkers had significantly higher WC than drinkers. Non-drinkers had significantly higher total energy intake coupled with lower diet quality and physical activity as compared to all drinking levels among men and women.

Among men who reported non-drinking over a 5-yr period (stable non-drinking), the adjusted mean 5-yr WC change was a gain of 3.83 ± 0.18 cm and the adjusted mean 5-yr BMI change was a gain of 1.19 ± 0.06 kg/m^2 (data not shown). All results in men are compared with these stable non-drinkers. In men, compared to stable non-drinkers, statistically significantly lower 5-yr WC and BMI gains were observed with a 5-yr decrease in total drinks/wk (β:-0.70 cm (95% CI: -1.19, -0.22 cm) and (β:-0.22 kg/m^2; 95% CI: -0.39, -0.05 kg/m^2), respectively. (Figure 4.1)

When changes in drinking level were examined, compared to stable non-drinking, statistically significantly lower 5-yr WC gains were observed in men who stopped excessive drinking over a 5-yr period (β:-0.78 cm; (95% CI: -1.53, -0.03 cm). (Figure 4.2) When changes in beverage type were examined, no statistically significant associations were observed between 5-yr changes in beer, wine or liquor/mixed drink intakes and 5-yr WC or BMI gains. (Figure 4.3).

Among women who reported non-drinking over a 5-yr period (stable non-drinking), the adjusted mean 5-yr WC change was a gain of 3.80 ± 0.14 cm and the adjusted mean 5-yr BMI change was a gain of 1.48 ± 0.06 kg/m^2 (data not shown). Compared to stable non-drinking, statistically significantly lower 5-yr WC and BMI gains were observed in women who started to drink over a 5-yr period (β:-1.08 cm (95% CI: -1.55, -0.51 cm) and (β:-0.44 kg/m^2; 95% CI: -0.69, -0.19 kg/m^2), respectively. Compared to stable non-drinking, statistically significantly lower 5-year WC gains were observed in women who stopped drinking (β: -0.56 cm; 95% CI: -1.11, -0.01 cm over a 5-yr period. A 5-yr decrease in total drinks/wk was associated with borderline statistically significantly lower WC (β: -0.52 cm; 95% CI: -1.06, 0.02 cm; p=0.06) and statistically significantly lower 5-yr BMI gains (β:-0.32 kg/m^2; 95% CI: -0.55, -0.08 kg/m^2) compared to stable non-drinking in women. (Figure 4.1)

When changes in drinking level were examined, compared to stable non-drinking, statistically significantly lower 5-yr WC and BMI gains were observed in women who started light/moderate drinking over a 5-yr period (β:-0.75 cm; 95% CI: -1.27, -0.23 cm) and (β:-0.39 kg/m^2; 95% CI: -0.62, -0.16 kg/m^2), respectively. In women who reported stable light or moderate drinking levels over a 5-yr period, statistically significantly lower 5-yr WC gains were observed (β:-0.54 cm; 95% CI: -1.06, -0.02 cm) compared to stable non-drinkers. (Figure 4.2)

When changes in beverage type were examined, statistically significantly lower 5-yr WC gains were observed in women drinkers who reported stable or increasing wine drinks/wk (β:-0.68 cm; 95% CI: -1.14, -0.23 cm) and (β:-0.57 cm; 95% CI: -1.06, -0.09 cm), respectively, as compared to stable non-drinking over a 5-yr period. Lower 5-yr WC gains were observed in women drinkers with stable or decreasing liquor/mixed drink intake over a 5-yr period (β:-0.49 cm; 95% CI: -0.90, -0.09 cm) and (β:-0.87 cm; 95% CI: -1.43, -0.31 cm), respectively, compared to stable non-drinkers. Results for beer were conflicting, with stable, increasing, and decreasing intake associated with lower 5-yr WC gains compared to stable non drinkers.

Results were similar for 5-yr changes in each alcoholic beverage type and 5-yr BMI change. (Figure 4.4)

Discussion

We observed that associations of 5-yr changes in total alcohol intake and 5-yr WC and BMI change differed between men and women and across drinking subgroups in women. In men, we found that decreasing intake, particularly stopping excessive consumption, was associated with lower 5-yr WC gains. In women, starting to drink, specifically starting light/moderate consumption or increasing wine or beer intake was associated with lower WC and BMI gains. In contrast, decreasing consumption, particularly decreasing liquor/mixed drink intake, was also associated with lower 5-yr WC and BMI gains in women. Associations of 5-yr changes in alcoholic beverage intake by type with 5-yr WC and BMI change were observed in women but not men. The magnitude of associations of alcohol change with WC and BMI changes was small for both sexes and may not be clinically meaningful.

In men, decreasing total weekly alcoholic beverage intake over a 5-yr period was associated with lower 5-yr WC and BMI gain. Excessive drinking, more common in men, has been associated with weight and BMI gains [95, 121]. Thus it is conceivable that stopping excessive drinking is associated with lower BMI and WC gains for some men as we found in this study. [3, 8, 121] In contrast, a previously published study of middle-aged British men found 5-yr weight gain did not differ from non-drinkers for those who stopped heavy drinking during the same time period. [55] In this prior study, heavy drinking was defined as consuming > 12 drinks/wk (e.g. > 21 British units of alcohol/wk), whereas, in our study excessive drinking was defined as >14 drinks/wk. Differences in exposure definitions may contribute to inconsistent findings across studies. Furthermore, we found that stopping excessive drinking was associated with WC but not BMI change for men. Yet, stable excessive drinking was associated with lower BMI but not WC change. This contrast, suggests that the use of varying obesity measure may yield differing results across studies. Chronic excess alcoholic intake has been shown to be associated with osteopenia, decreased muscle and lean mass. [28, 40, 122] Such conditions likely impact overall body size (BMI) but not necessarily waist girth (WC). Future prospective research examining changes in excessive drinking levels in relation to changes in obesity measures with consistent exposure definitions and standardized outcomes are needed to establish the evidence base. [11, 123, 124]

Light and moderate drinking, more common in women, has been associated with the prevention of weight gain. [3, 8, 121] Starting to consume alcohol, specifically starting light/moderate drinking, was associated with lower 5-yr WC and BMI change for women in our study. Similarly, increasing alcohol intake up to moderate daily levels over an 8-yr period has been associated with lower 8-yr weight gain in US women. [20] Furthermore, we found that in women drinkers increasing wine or beer intake over a 5-yr period was associated with lower WC and BMI gains as compared to non-drinkers. The polyphenolic compounds in red wine (i.e., resveratrol) and beer (i.e., isohumulone) may have beneficial effects on lipid metabolism which might lead to lower WC/BMI gains. [3, 8, 9, 48-50]. Taken together our results suggest that light/moderate drinking patterns in women coupled with polyphenols may contribute to lower WC and BMI gains as compared to stable non-drinkers.

In contrast to findings that starting to consume alcohol and increasing beer or wine intake were associated with lower WC and BMI gains, we found that decreasing total alcohol intake, particularly decreasing beer or liquor/mixed drink intake, was associated with lower 5-yr WC and BMI gains in women. Compared to those with no change in intake, decreasing liquor intake has been associated with lower 4-yr weight gain in women.[58] Similar to our findings, Mozafarrian found an association between increasing and decreasing beer intake with lower 4-yr weight gain compared to non-drinkers. [58] Our findings add to previous reports that liquor and beer consumption may contribute to increases in obesity-related outcomes over time. [9] In a 2004 study of Danish men and women, compared to non-drinkers, women who drank ≥ 4 drinks/wk of beer or spirits had higher subsequent 6-year WC changes. [125] In a later study using follow-up data from the same cohort, spirit consumption was positively associated with 5-yr changes in WC in women. [126] Furthermore, beer and liquor drinking have been associated with excessive drinking in the US. [68, 127] It could be the case that decreasing beer or liquor/mixed drinks subsequent to excessive levels of consumption might contribute the management of WC and BMI gains in women who drink. Further research in excessive drinking women is needed to substantiate this hypothesis.

Similar to our study, reported differences in obesity-related outcomes between drinkers and stable non-drinkers are generally small and may not be clinically meaningful. [20, 59, 64, 128] Yet, small population level changes in WC and BMI could translate to improved health in a large number of people. Given recent increasing trends in alcoholic beverage intake in the US, population level efforts aimed at decreasing alcohol intake as part of obesity-related disease prevention programs may be a warranted.[7, 129] Future studies using clinically meaningful endpoints, such as differences in the prevalence or incidence of obesity in relation to within-person changes in alcoholic beverage intake using nationally representative data are needed to build the evidence base.

This study was observational, and we cannot make causal inferences or rule out residual confounding bias of the observed associations. Even after adjustment for multiple time-varying lifestyle and socio-demographic characteristic and controlling for time-invariant unobserved individual characteristics, conflicting findings persisted across categories of 5-yr alcohol change in relation to 5-yr WC and BMI, particularly in women. There is a strong body of evidence indicating that ethanol metabolism, bioavailability and a dose response of alcohol's effect on body processes differs between men and women, even after adjustment for body weight. Women have higher body fat composition and lower body water content than men of the same body weights which has been linked to differential sex-specific ethanol metabolism. [94, 95] As such it is possible that conflicting findings in women, may be attributed to residual confounding from immeasurable time-varying factors related to the physiology of ethanol metabolism.[28] Further, it has been hypothesized that light and moderate drinkers live healthier lifestyles due to inherent immeasurable individual characteristics that might lead to lower WC gains as compared to non-drinkers. [8, 9, 44] To address this bias we used discrete interval change analyses controlling for unmeasured time-invariant characteristics associated with alcohol intake, WC, BMI, physical activity, diet quality and marital status. [130, 131]. Additionally, those who start to drink or chose not to drink may have unmeasured underlying time-varying health conditions associated with changes in WC or BMI. [132] To address this possible bias, individuals with diabetes, hypertension and other chronic diseases at baseline were excluded and individuals who developed these diseases were censored during follow-up. In studies of associations of moderate alcohol intake with cardiovascular disease risk factors and mortality there is evidence suggesting that restriction to healthy individuals might induce selection bias. [98, 133] Yet, these findings have not been widely accepted and additional research is necessary to understand how restriction based on health status impacts associations of excessive and light drinking levels with obesity measures. [134] Additionally, dietary intake was assessed at only three time points in this study and residual confounding bias by diet is likely.

A strength of this study is the use of six longitudinal assessments of alcoholic beverage intake and measured anthropometric data. Multiple measurements of exposure and outcome data increase the precision of estimates. Furthermore, to address residual confounding we adjusted for a number of time-varying lifestyle and socio-demographic factors. While we cannot rule out misclassification bias of the self-reported alcoholic beverage exposure, the CARDIA AUQ captures usual weekly drinking behavior and is less likely to misclassify participants in comparison to a shorter term assessment tool.

This is one of the first studies to examine changes in WC and BMI in relation to changes in alcoholic beverage consumption by drinking level and beverage type in a US-based cohort. Our findings add to previous reports that starting light and moderate drinking, increasing wine intake, and decreasing liquor/mixed drink intake are significantly associated with WC and BMI change in women. Yet, these complex relationships require further study. In men, findings were more consistent indicating that decreasing total alcohol intake, with an emphasis on stopping excessive drinking may be warranted as part of nutrition intervention efforts to manage WC and BMI gains.

Table 4.1 Distribution of select baseline characteristics of individuals according to inclusion and exclusion status[a]

	Included	Excluded	p-value
N	4,257	857	
%	83.2	16.8	
Sex (N)	4,257	857	
Female	54.6	54.1	0.82
Male	45.4	45.9	
Race (N)	4,257	857	
White	50.8	36.5	<0.0001
Black	49.2	63.5	
Age cohort at baseline (N)	4,257	857	
18-24 yrs	45.0	42.6	0.19
25-30 yrs	55.0	57.4	
Education (N)	4,256	855	
≤ High School	67.3	73.2	<0.0001
> High School	32.7	26.8	
Marital Status (N)	4,256	852	
Single/widowed/divorced	77.8	77.1	0.64
Married/co-habitating	22.2	22.9	
Total drinks/wk (N)	4,256	855	
Non-drinker	39.2	37.9	0.05
Light	31.3	28.5	
Moderate	17.7	18.6	
Excessive	11.8	15.0	
Beer drinks/wk (N)	4,256	855	
Non-drinker	39.2	37.9	0.54
Light	29.9	28.4	
Moderate	10.1	11.2	
Excessive	5.7	6.7	
Drinker – no beer	15.2	15.8	

	Included	Excluded	p-value
Wine drinks/wk (N)	4,256	855	
Non-drinker	39.2	37.9	0.01
Light	25.5	23.5	
Moderate	3.5	6.0	
Excessive	1.0	1.4	
Drinker – no wine	30.8	31.2	
Liquor/Mixed drinks/wk (N)	4,256	855	
Non-drinker	39.2	37.9	0.54
Light	23.8	24.2	
Moderate	3.0	3.7	
Excessive	1.5	2	
Drinker - no liquor/mixed drinks	32.7	32.2	
Baseline Weight Status (kg/m^2)[b]	4,257	840	
BMI < 25.0	66.3	60.1	<0.0001
BMI ≥ 25 to < 30	22.8	23.7	
BMI ≥ 30	10.9	16.2	
Baseline Abdominal Obesity [c]	4,257	837	
No	92.9	88.1	<0.0001
Yes	7.1	11.9	

[a] Data for 5,114 men and women included in the CARDIA study at baseline; one enrolled participant who dropped out is omitted. Values are percentages unless N specified. Sample sizes vary for baseline covariates because the data are an unbalanced panel with some participant observations missing at baseline and included in future waves. P-values for chi^2 tests of the unadjusted percentage distributions of categorical covariates of included individuals compared to the percentage distribution of covariates of excluded individuals.

[b] Body Mass Index (BMI)

[c] Abdominal obesity defined as waist circumference (WC) >102 cm for men and >88 cm for women.

Table 4.2 Baseline characteristics of men in the CARDIA study 1985-1986, according to baseline alcoholic beverage intake (total drinks/wk)[a]

Total drinks/wk	**Non-drinker**	**0> to <7**	**7 to 14**	**>14**	***p***
N	550	681	401	262	
(%)	29.0	36.0	21.2	13.8	
Race					
White	43.8	53.9	59.6	59.9	<0.0001
Black	56.2	46.1	40.4	40.1	
Age cohort					
17-24 yrs	50.4	47.1	36.4	39.3	<0.0001
25-35 yrs	49.6	52.9	63.6	60.7	
Marital status					
Single, Widowed or Divorced	75.6	78.7	83.5	84.4	0.004
Married or Cohabitating	24.4	21.3	16.5	15.6	
Smoking status					
Non-smoker	72.0	59.3	47.6	34.0	<0.0001
Former	10.4	11	17.2	16	
Current	17.6	29.7	35.2	50	
Physical Activity (EU)[b] (mean ± SE)	469.2 ± 298.1	514.7 ± 305.1	545.3 ± 312.9	545.5 ± 324.1	<0.0001
Education					
≤ High School	72.4	64.8	61.6	72.5	0.001
> High School	27.6	35.2	38.4	27.5	
Income					
≤ $24K24,999	38.7	36.4	32.7	38.5	0.107
$25K25,000 to $74,999	53.8	53.9	54.4	50.8	
≥ $75K75,000	7.5	9.7	13	10.7	
Obesity Measures[c]					

(mean ± SE)					
BMI (kg/m^2)	24.5 ± 4.3	24.1 ± 3.7	24.3 ± 3.3	24.5 ± 3.7	0.18
WC (cm)	81.6 ± 10.2	80.7 ± 8.7	81.7 ± 8.3	83.1 ± 8.9	<0.0001
Alcoholic Beverage Intake (mean ± SE)					
Total drinks/wk	0	3.4 ± 1.8	10.0 ± 2.3	25.8 ± 11.9	<0.0001
Beer drinks/wk	0	2.2 ± 1.9	6.9 ± 3.6	19.0 ± 12.3	<0.0001
Wine drinks/wk	0	0.6 ± 0.9	1.2 ± 1.9	2.2 ± 4.9	<0.0001
Liquor/Mixed drinks/wk	0	0.6 ± 1.1	1.8 ± 2.3	4.5 ± 6.0	<0.0001
Dietary Intake Variables (mean ± SE)					
Total Energy (kcal)	3224 ± 1360	3321 ± 1392	3596 ± 1445	3944 ± 1406	<0.0001
Non-alcoholic Energy (kcal)[d]	3209 ± 1354	3235 ± 1383	3376 ± 1408	3472 ± 1329	0.03
Solid Food Energy (kcal)[d]	2601 ± 1108	2672 ± 1173	2815 ± 1218	2879 ± 1155	<0.0001
Non-alc Bev Energy (kcal)[d]	608 ± 465	563 ± 398	561 ± 376	593 ± 374	0.19
% Carb[e]	47.5 ± 7.2	44.3 ± 6.8	40.8 ± 6.7	37.1 ± 6.7	<0.0001
% Prot [e]	14.7 ± 2.4	14.9 ± 2.3	14.8 ± 2.4	14.1 ± 2.4	<0.0001
% Fat [e]	38.3 ± 6	38.6 ± 5.5	38.1 ± 5.2	36.2 ± 5.6	<0.0001
Diet Quality Score	55.2 ± 11.3	57.7 ± 12	58.3 ± 11.1	57.3 ± 10.4	<0.0001

[a] Data for 1,894 men included in the analytic sample at study at exam year 0 (1985-1986) categorized according to National Institutes on Alcohol Abuse and Alcoholism (NIAA) guidance on drinking levels. Light drinking defined as 0> to <7 drinks/wk for men; moderate drinking defined as 7 to 14 drinks/wk; excessive drinking defined as >14 drinks/wk. Values are means ± SD for continuous covariates and percentages for categorical covariates. P-values for chi^2 tests of the unadjusted percentage distributions of categorical covariates and uncorrected overall p-value for analysis of variance (ANOVA) for means of continuous covariates.

[b] Exercise Units (EU) per week

[c] Body Mass Index (BMI); Waist Circumference (WC)

[d] Non-alcoholic energy excludes energy from alcoholic beverages; Non-alcoholic beverage (Non-alc Bev);

[e] Carbohydrate contribution to total energy intake (% Carb); Protein contribution to total energy intake (% Prot); Fat contribution (% Fat) to total energy intake.

Table 4.3 Baseline characteristics of women in the CARDIA study 1985-1986, according to baseline alcoholic beverage intake (total drinks/wk)[a]

Total drinks/wk	**Non-drinker**	**0> to < 4**	**4 to 7**	**> 7**	***p***
N	1,073	618	336	225	
(%)	47.6	27.4	14.9	10.0	
Race					
White	38.9	53.2	61.0	72.9	<0.0001
Black	61.1	46.8	39.0	27.1	
Age cohort					
17-24 yrs	49.6	44.0	41.7	32.0	<0.0001
25-35 yrs	50.4	56.0	58.3	68.0	
Marital status					
Single, Widowed or Divorced	75.2	76.2	81.8	81.3	0.029
Married or Cohabitating	24.8	23.8	18.2	18.7	
Smoking status					
Non-smoker	68.7	58.4	42.3	32.4	<0.0001
Former	11.7	13.4	19.3	17.8	
Current	19.6	28.2	38.4	49.8	
Physical Activity (EU)b (mean ± SE)	310.2 ± 238.2	355.7 ± 252.3	356.7 ± 251.5	396.2 ± 253	<0.0001
Education					
≤ High School	72.5	61.7	60.1	62.7	<0.0001
> High School	27.5	38.3	39.9	37.3	
Income					
≤ $24K24,999	42.9	33.7	37.8	34.7	<0.0001
$25K25,000 to $74,999	50.9	56.3	50	49.3	
≥ $75K75,000	6.2	10	12.2	16.0	
Obesity Measures[c] (mean ± SE)					
BMI (kg/m^2)	24.9 ± 6	24.0 ± 4.9	24.0 ± 5.3	23.4 ± 4.6	<0.0001
WC (cm)	74.7 ± 11.9	72.9 ± 10.4	73.8 ± 11.2	72.9 ± 9.7	0.01
Alcoholic Beverage Intake (mean ± SE)					
Total drinks/wk	0	1.8 ± 0.8	5.2 ± 1.1	14.5 ± 10.5	<0.0001
Beer drinks/wk	0	0.7 ± 0.9	2.3 ± 2.0	7.0 ± 8.2	<0.0001

Wine drinks/wk	0	0.8 ± 0.8	1.8 ± 1.7	3.7 ± 4.5	<0.0001
Liquor/Mixed drinks/wk	0	0.4 ± 0.7	1.1 ± 1.5	3.8 ± 6.0	<0.0001
Dietary Intake Variables (mean ± SE)					
Total Energy (kcal)	2226 ± 981	2247 ± 973	2418 ± 1011	2513 ± 982	<0.0001
Non-alcoholic Energy (kcal)[d]	2217 ± 980	2213 ± 969	2334 ± 998	2326 ± 931	0.11
Solid Food Energy (kcal)[d]	1796 ± 822	1809 ± 813	1917 ± 849	1896 ± 793	0.06
Non-alc Bev Energy (kcal)[d]	421 ± 346	404 ± 292	418 ± 312	430 ± 312	0.68
% Carb[e]	48.6 ± 7.7	46.7 ± 7.2	44.2 ± 7	41.2 ± 7.7	<0.0001
% Prot [e]	14.7 ± 2.9	15.1 ± 2.9	14.6 ± 2.6	14.5 ± 2.7	0.01
% Fat [e]	37.6 ± 6.3	37.3 ± 6.1	37.2 ± 6.1	35.6 ± 5.9	<0.0001
Diet Quality Score	59.2 ± 12.1	63 ± 12.8	62.9 ± 12.8	63.9 ± 12.1	<0.0001

[a] Data for 2,252 women included in the analytic sample at study at exam year 0 (1985-1986) categorized according to National Institutes on Alcohol Abuse and Alcoholism (NIAA) guidance on drinking levels. Light drinking defined as 0> to < 4 drinks/wk; moderate drinking defined as 4 to 7 drinks/wk for women; excessive drinking defined as > 7 drinks/wk for women. Values are means ± SD for continuous covariates and percentages for categorical covariates. P-values for chi^2 tests of the unadjusted percentage distributions of categorical covariates and uncorrected overall p-value for analysis of variance (ANOVA) for means of continuous covariates.

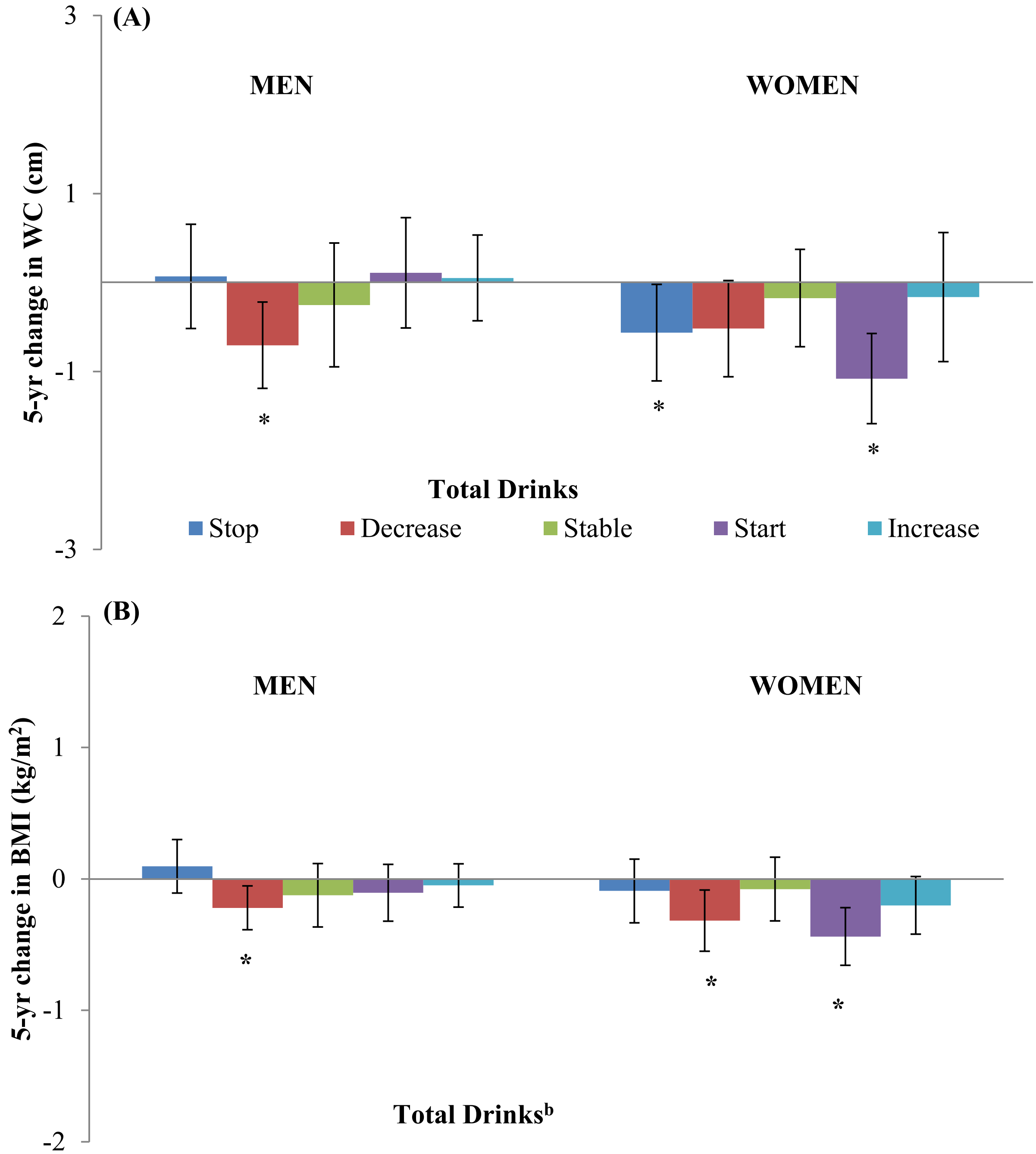
[b] Exercise Units (EU) per week

[c] Body Mass Index (BMI); Waist Circumference (WC)

[d] Non-alcoholic energy excludes energy from alcoholic beverages; Non-alcoholic beverage (Non-alc Bev);

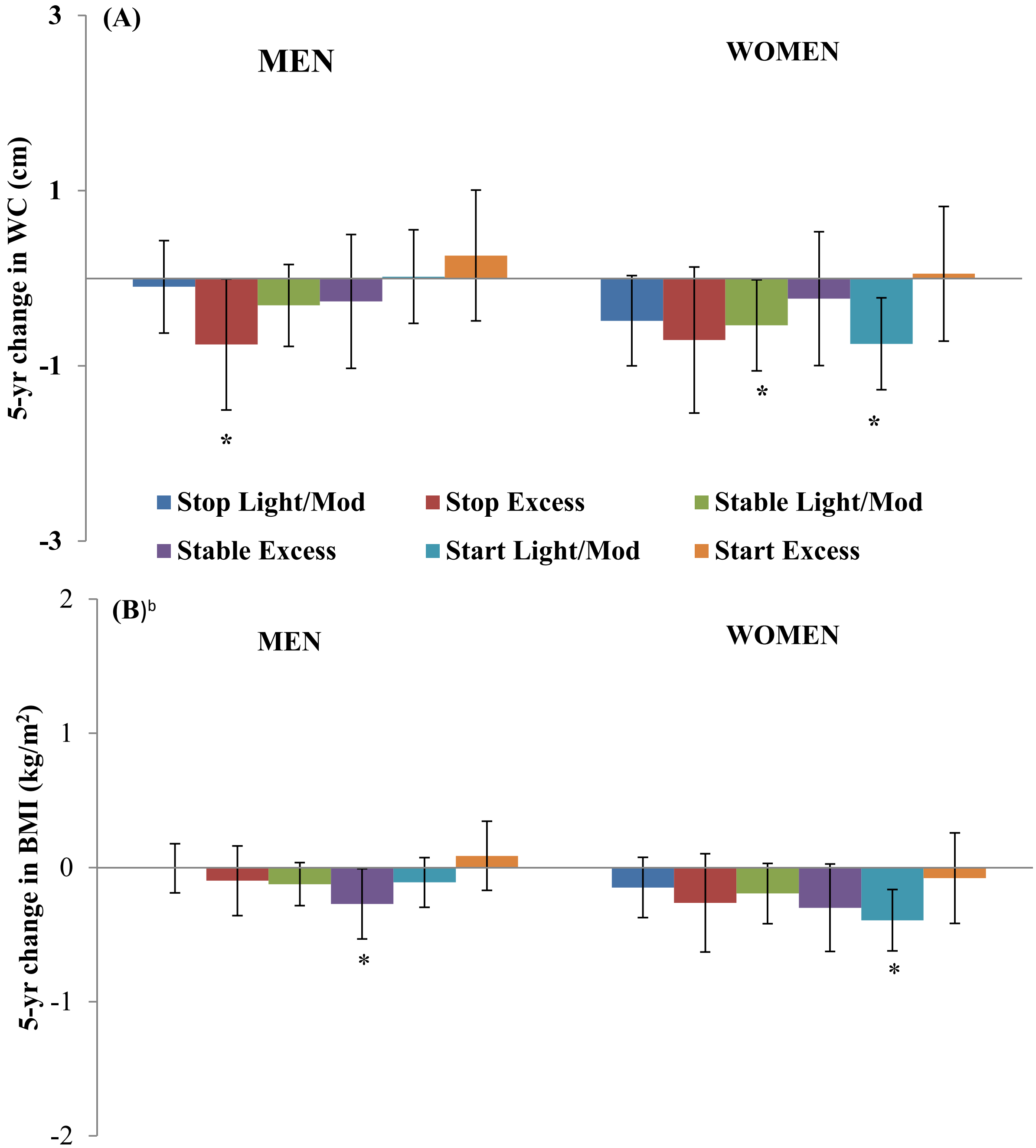
[e] Carbohydrate contribution to total energy intake (% Carb); Protein contribution to total energy intake (% Prot); Fat contribution (% Fat) to total energy intake.

Figure 4.1 Adjusted associations of 5-year changes in total alcoholic beverage intake with 5-year changes in (A) Waist Circumference (WC) (cm) and (B) Body Mass Index (BMI) (kg/m^2) for men and women in the CARDIA Study[a]



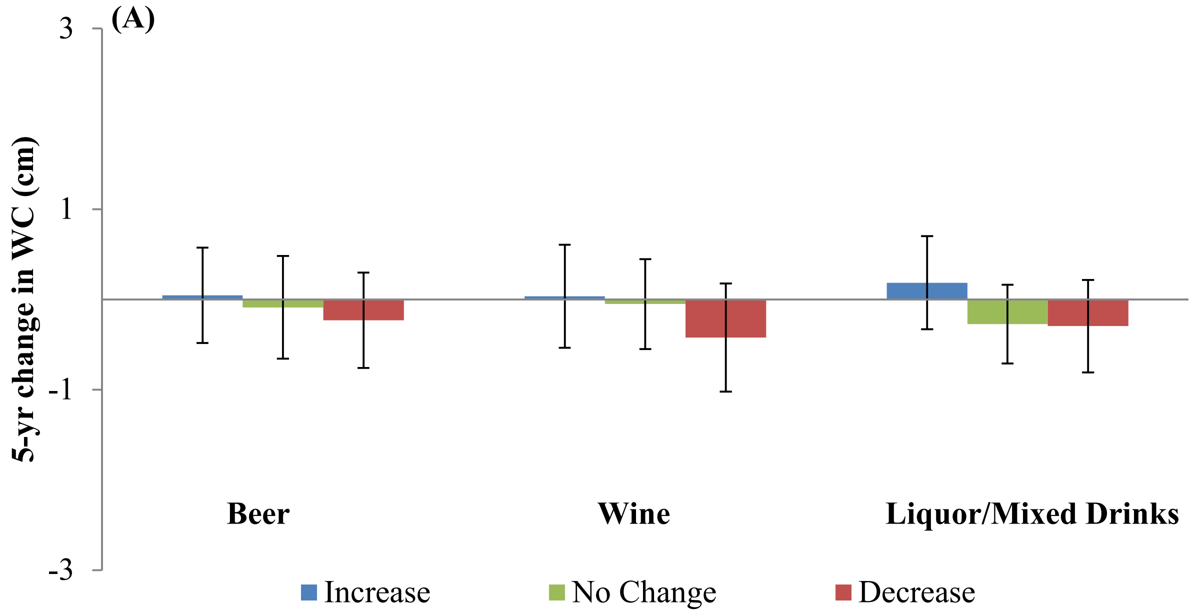
[a]Data from men (N=1,711) and women (N=2,055) for 5-year changes in (A) WC and (B) BMI from CARDIA exam years 5, 10, 15, 20 and 25.Values are β coefficients (95% CI) obtained from longitudinal random effects linear regression models adjusted for baseline age cohort membership, baseline WC, race and study center and time-varying income, education, smoking status and time-varying changes in marital status, physical activity and diet quality score.
*P<0.05 compared to the reference category "stable non-drinker"
[b]Adjusted for baseline BMI instead of baseline WC

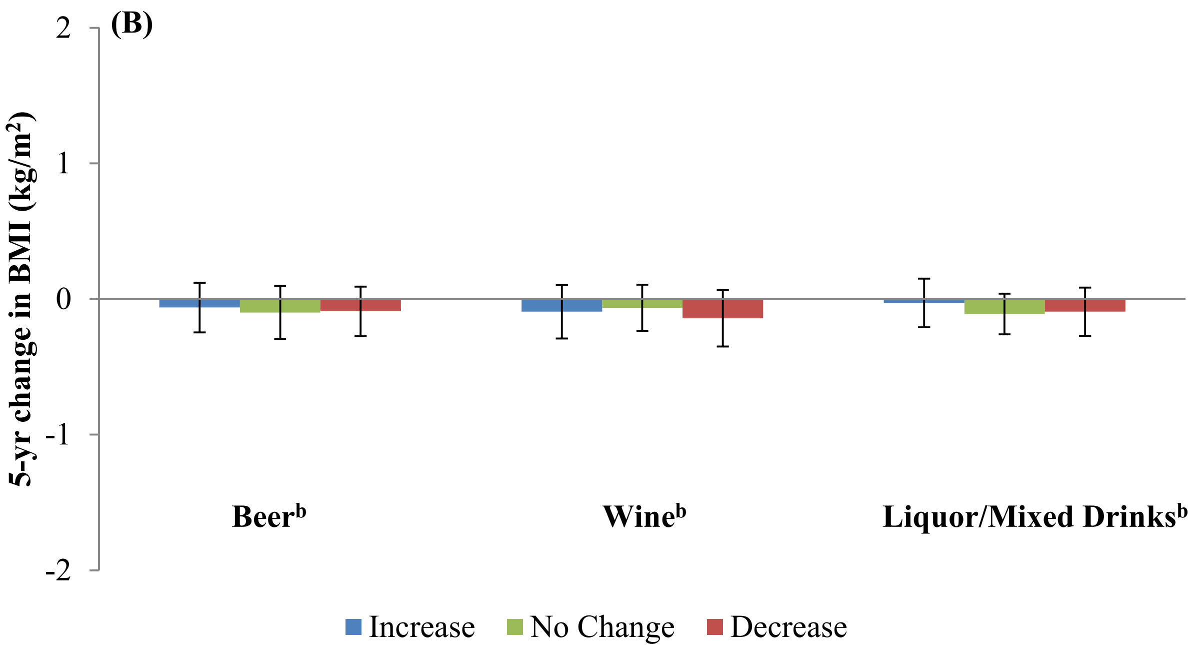
Figure 4.2 Adjusted associations of 5-year changes in drinking level with 5-year changes in (A) Waist Circumference (WC) (cm) and (B) Body Mass Index (BMI) (kg/m^2) for men and women in the CARDIA Study[a]



[a]Data from men (N=1,711) and women (N=2,055) for 5-year changes in (A) WC and (B) BMI from CARDIA exam years 5, 10, 15, 20 and 25.Values are β coefficients (95% CI) obtained from longitudinal random effects linear regression models adjusted for baseline age cohort membership, baseline WC, race and study center and time-varying income, education, smoking status and time-varying changes in marital status, physical activity and diet quality score.
*P<0.05 compared to the reference category "stable non-drinker"
[b]Adjusted for baseline BMI instead of baseline WC.

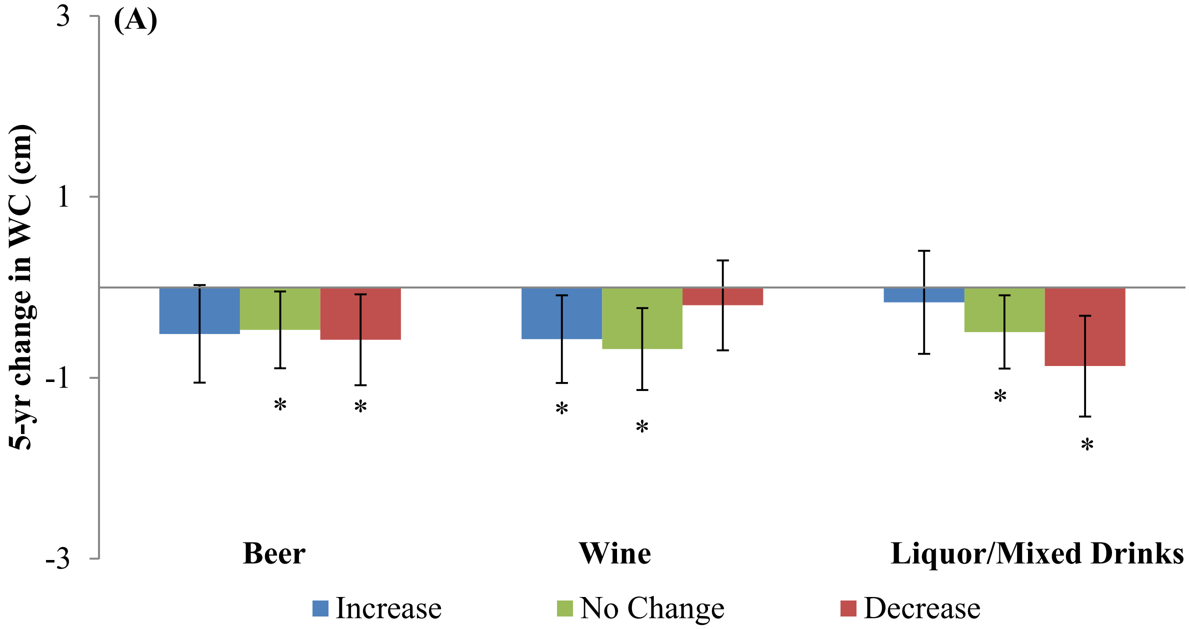
Figure 4.3. Adjusted associations of 5-year changes in alcoholic beverage intake by type with 5-year changes in (A) Waist Circumference (WC) (cm) and (B) Body Mass Index (BMI) (kg/m^2) in men in the CARDIA Study[a]

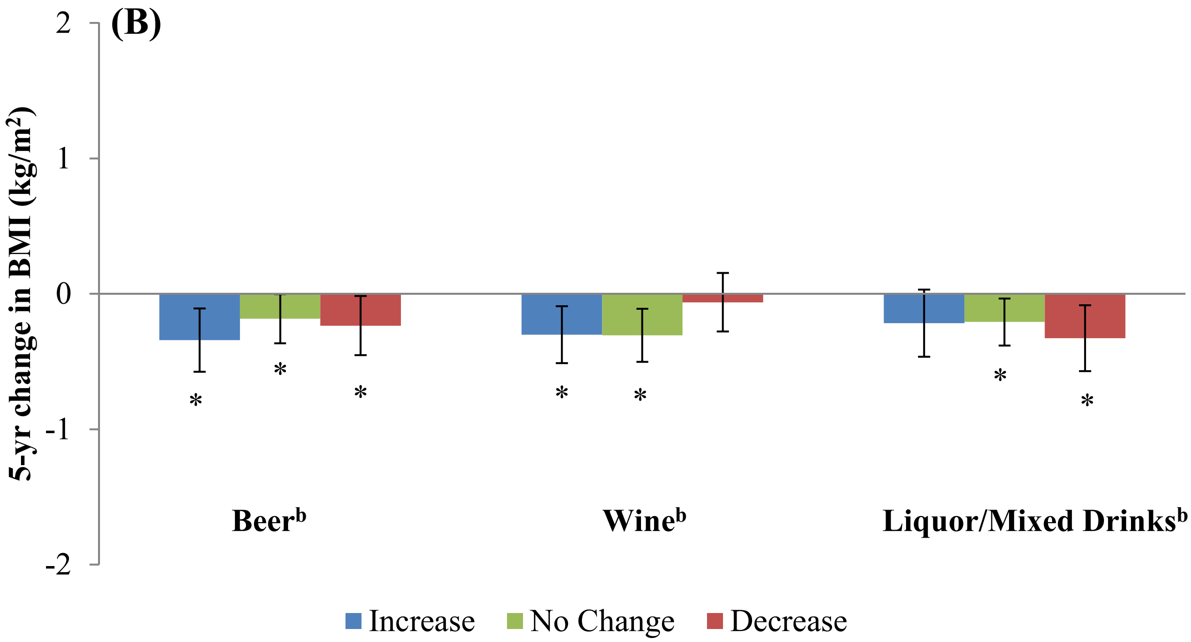




[a]Data from men (N=1,711) for 5-year changes in WC from CARDIA exam years 5, 10, 15, 20 and 25.Values are β coefficients (95% CI) obtained from longitudinal random effects linear regression models adjusted for baseline age cohort membership, baseline WC, race and study center and time-varying income, education, smoking status and time-varying changes in marital status, physical activity, diet quality and intake of each other alcoholic beverage type.
*$P<0.05$ compared to the reference category "stable non-drinker"
[b]Adjusted for baseline BMI instead of baseline WC.

Figure 4.4 Adjusted associations of 5-year changes in alcoholic beverage intake by type with 5-year changes in (A) Waist Circumference (WC) (cm) and (B) Body Mass Index (BMI) (kg/m^2) for women in the CARDIA Study[a]





[a]Data from women (N=2,055) for 5-year changes in BMI from CARDIA exam years 5, 10, 15, 20 and 25. Values are β coefficients (95% CI) obtained from longitudinal random effects linear regression models adjusted for baseline age cohort membership, baseline WC, race and study center and time-varying income, education, smoking status and time-varying changes in marital status, physical activity, diet quality and intake of each other alcoholic beverage type.
*P<0.05 compared to the reference category "stable non-drinker"
[b]Adjusted for baseline BMI instead of baseline WC.

CHAPTER 5. SYNTHESIS

Overview of findings

The overarching aim of this research was to shed light on inconsistencies in the literature on associations of alcoholic beverage consumption with weight status. A primary goal of this research was to investigate the use of different parameters of alcoholic beverage intake and weight status. To this end, in addition to sex-specific daily drinking level recommendations used to define alcohol intake with NHANES data, we defined alcoholic beverage consumption using beverage type and change in alcohol intake using CARDIA data. Additionally we used both WC and BMI as measures of weight status rather than just one anthropometric outcome. Furthermore, we examined associations taking into account confounding by dietary intake. Importantly, in our prospective analysis, we used within-person changes in alcohol intake and change in WC and BMI in order to account for changes in drinking over time and control for residual confounding by time-invariant factors. Our results can be used to inform the design of future epidemiologic studies examining alcoholic beverage consumption in relation to general and abdominal obesity.

Our research suggests that alcohol intake in men is positively associated with WC and BMI in comparison to not drinking. Among women, our results indicate that alcohol intake is inversely associated with WC and BMI as compared to not drinking. In cross-sectional analyses, we found that, compared to non-drinkers, men who consumed alcoholic beverages in excessive amounts daily had higher WC and BMI. Longitudinal analyses revealed that men who decreased the total number of drinks/wk., overall and by type, had lower 5-year WC and BMI gains a compared to non-drinkers. Cross-sectional results for women suggest that alcohol intake at all daily drinking levels was associated with lower WC and BMI as compared to non-drinkers. In longitudinal analyses, women who started to drink had lower 5-year WC gains as compared to non-drinkers. Together findings from these two studies support the hypothesis that alcohol intake is associated with higher WC and BMI in men who drink as compared to non-drinkers. Additional research is necessary to understand interactions of drinking level and beverage type on WC and BMI, particularly in binge drinking men. For women our research supports the hypothesis alcohol intake is inversely associated with WC and BMI. Future work is needed to establish causality and to replicate our findings of variation in associations of alcohol intake with WC and BMI by beverage type in larger, better powered studies.

Understanding dietary intake in associations of alcohol intake with WC and BMI

The results of this research support the theory that confounding by dietary intake contributes to inconsistencies in the alcohol and obesity literature. To understand whether dietary intake biased associations between alcohol intake and WC and BMI, we used two different analytic approaches. First, we established whether cross-sectional associations between alcohol intake and dietary factors existed. To do this, we used multivariable linear regression models to test whether absolute calorie intake and the percentage contribution of macronutrients and sugar intake differed between drinkers and non-drinkers using NHANES data. Interesting differences in associations between drinking level and dietary intake by sex were observed. For example, our results suggest that alcoholic beverage intake was additive to total energy intake in binge drinking men. Men who drink in excess may also be more likely to eat in excess due to underlying psychosocial factors such as reduced self-restraint. Results for heavy drinking women suggest no difference in total energy intake, but lower non-alcoholic beverage energy intake, as compared to non-drinkers. It could be the case that heavy drinking women intentionally choose to drink alcoholic beverages in place of non-alcoholic beverages. Yet, additional research is needed to fully understand dietary behaviors related to food and non-alcoholic beverage choices in drinkers. Moreover, our results indicate that carbohydrates and sugar contribute less to the food and non-alcoholic beverage diet composition of all drinkers as compared to non-drinkers. Alcohol and carbohydrates, specifically sugar, may compete for the same neuronal receptors leading to suppressed intake of one nutrient for intake of the other. [36, 92] These results are supported by previous findings that drinkers may replace carbohydrates, with alcoholic beverages, contributing to variation in the non-alcoholic carbohydrate composition of the diet in drinkers as compared to non-drinkers. [22, 23, 29, 30]

Next we examined cross-sectional associations between daily drinking levels and WC and BMI with and without adjustment for dietary factors. Positive associations between binge drinking and obesity measures in men were strengthened after adjustment for food intake, but attenuated and no longer significant after adjustment for carbohydrate and sugar intakes. Negative associations between heavy drinking and obesity measures in women were strengthened after adjustment for carbohydrate and sugar intakes, but not significant after adjustment for non-alcoholic beverage intake. Taken together we concluded that in men and women, food intake and non-alcoholic beverage, respectively, confounded associations of excessive drinking with WC and BMI. Yet, the percentage carbohydrates and sugar appeared to confound associations between alcohol intake and WC and BMI in both sex groups. Variation in confounding by food vs non-alcoholic beverages in men and women, respectively, suggests sex dependent differences in dietary as mentioned above. Confounding by the percent contribution from carbohydrates in both men and women is supported by clinical evidence of sex-independent biochemical, neuronal links between alcohol intake and carbohydrate and sugar consumption. [36, 92]

While food and non-alcoholic beverage intake appeared to confound cross-sectional associations, we could not rule out a causal relationship between alcohol intake and WC and BMI that is mediated by energy intake. Thus, we further considered how to adjust for diet in longitudinal analyses. If men who drink add energy from alcoholic beverages to their usual energy intake, this might lead to excess energy intake and ultimately weight gain. [31, 40, 91] On the other hand, substitution of non-alcoholic beverages with alcoholic beverages in women might equate to lower usual energy intake and thus lower estimates of WC and BMI in drinkers as compared to non-drinkers. [22, 32, 40] The results of our NHANES analyses, the hypothesis that energy intake is on the causal pathway from alcohol intake to changes in WC and BMI, and the wealth of scientific evidence of a strong inverse association of alcohol consumption with carbohydrates, informed our choice to use the percent contribution of carbohydrates (including sugar), as opposed to absolute energy intake, as a dietary control variable in longitudinal analyses. [37-39, 58]

As confirmatory analyses, a change in estimate of >10% was used as an *a priori* criterion to indicate confounding bias from the percentage contribution of carbohydrates (including sugar) in longitudinal random effects regression models used with CARDIA data. Confirmatory analyses indicated that adjustment for carbohydrate intake (% kcal) in longitudinal models would result in ≥10% change-in-estimate compared to models not adjusted for diet.

Differential associations of alcohol intake with WC and BMI by sex

In cross-sectional and longitudinal studies, we found interesting differences in associations of alcohol intake with WC and BMI in men vs. women. In cross-sectional analyses, null associations with WC and BMI were observed for moderate and heavy drinking men, while positive associations were observed for binge drinkers. On the other hand, negative associations between all drinking levels and WC and BMI were observed in women. In longitudinal analyses, decreasing drinking in men and starting to drink in women were associated with lower 5 year WC and BMI gains. These differences might be related to variation in the role of dietary intake in alcohol and WC/BMI associations by sex. For example, energy intake may have direct effects on WC/BMI associations in men, but not women. Assuming that we adequately controlled for dietary intake in both studies, observed differences are likely due to other factors. To that point, biological and observational research support the contrasting associations observed by sex in both the cross-sectional and prospective studies we conducted. [94, 95] There is a strong body of evidence indicating that ethanol metabolism, bioavailability and a dose response of alcohol's effect on body processes differs between men and women, even after adjustment for body weight. Women have higher body fat composition and lower body water content than men of the same body weights, and this difference has been linked to differential sex-specific ethanol metabolism. [94, 95] Moreover, female sex has been associated with wine consumption; whereas beer consumption has been associated with male sex. [17] The ethanol by volume content of wine is higher than that of beer; high ethanol intakes could alter lipid metabolism, leading to loss of adipose tissue and negative associations between drinking level and obesity measures observed among women. [9, 28] Furthermore, the frequency and amount of alcoholic beverages consumed is typically higher in men compared to women. [121] While light and moderate drinking have been associated with the prevention of weight gain, excessive drinking, more common in men, has been associated with WC and BMI gains, as we observed in cross-sectional NHANES analyses.[3, 8] Light to moderate drinking patterns coupled with the polyphenolic compounds in red wine (i.e. resveratrol) and beer (i.e. isohumulone) may have beneficial effects on lipid metabolism which might lead to lower WC gains. [3, 8, 9, 48-50] The biochemical pathways through which the ethanol and non-ethanol components in alcoholic beverages might interact with food and beverage metabolism and energy balance is complex, and future research in this area is needed.

Associations between daily drinking level and changes in alcohol intake with WC and BMI

Our cross-sectional results support previous reports of differential associations of alcoholic beverage consumption with WC and BMI according to categories defined by the number of drinks consumed per day in men but not women. Binge drinking (≥ 5 drinks/d) was statistically significantly positively associated with WC and BMI as compared to non-drinking in men. Moderate or heavy drinking in men was not statistically significantly associated with WC and BMI. Furthermore, estimates for moderate and heavy drinking in men were generally small and close to the null. These findings shed light on previous reports of null associations in cross-sectional studies of alcohol intake alcohol intake with weight gain, WC and BMI in men. In at least three other cross-sectional analyses of data from US men that reported null findings, men drinking ≥ 5 drinks/d were not analyzed as a distinct drinking category. [18, 19, 73, 135] In studies that did include drinking categories of ≥ 5 drinks/d, similar to our findings, positive associations in men were reported. [21, 26] These results suggest that there is not a dose-response relationship between alcohol intake and weight-related outcomes among men; rather, only very high levels of drinking may be related to higher WC or BMI gain. In this way, daily drinking level modifies associations of alcohol intake with WC and BMI; future studies should employ sex-specific categories, similar to ours, to define alcohol intake among men in the US. Our cross-sectional findings do not support differential associations of drinking level categories with WC and BMI in women. Despite a lack of statistical significance for some associations, all estimates were negative in women. These results support the many observational studies that have reported inverse associations between alcohol intake, defined continuously and categorically according to drinks/d or grams of, with weight gain, WC and BMI in women. [9, 19, 22, 28, 72, 73]

Furthermore, our prospective analyses build upon these cross-sectional observations for both sex groups. When associations of changes in alcohol intake, overall and by type, with change in WC and BMI were examined, decreasing the total drinks/wk. from one exam year to the next was associated with lower 5-year WC gain compared to non-drinking in men. While both cross-sectional and prospective analyses indicate statistically significant associations of drinking with alcohol intake, the direction and interpretation of these findings differ slightly. Cross-sectional results indicate that at a given time, higher levels of daily drinking (i.e. binge drinking) are positively associated with WC, compared to non-drinking in men. Prospective analyses suggest that decreasing drinking may contribute to lower WC and BMI gain over time in men. Taken together, these studies can be used to generate specific hypotheses about the associations between the magnitude of changes in alcohol intake that might be associated with changes in WC and BMI. For example, building on our general findings for decreases in drinking, we could hypothesize more specifically that a decrease from binge drinking to lower levels of drinking is associated with lower WC and BMI gains in men over time.

In women, the cross-sectional results indicate that all drinking levels were associated with lower WC as compared to non-drinkers. Prospective analyses showed that changing from stable non-drinking to drinking (starting to drink) resulted in lower 5-year WC gains as compared to non-drinkers. Again, increasing drinking and stable drinking categories were not statistically significantly associated with 5-year WC gain, but negative estimates were observed.

Variation in findings by alcoholic beverage type

Our findings for change in alcohol intake in relation to WC and BMI change support the theory that differences in the relationships for different alcoholic beverage subtypes may contribute to inconsistencies in the alcohol and obesity literature. In men, decreasing the total drinks/wk. was associated with lower 5-year WC and BMI gains as compared to stable non-drinking from one CARDIA exam year to the next. While decreases by type were associated with lower 5-year WC gain, decreases by type were not associated with 5-year BMI gain. These findings suggest that alcoholic beverage types may have different relationships with WC gain than with BMI gain. Consequently, studies using BMI outcomes may not yield significant associations consistently for total alcohol intake and for alcoholic beverage types. On the other hand, because decreasing the total number of drinks/wk. and decreasing all types were associated with lower 5-year WC gains, it seems that using change in total drinks/wk. or change in beer, wine or liquor/mixed drinks per week would yield associations of similar magnitude and directions. This suggests that alcoholic beverage type may not contribute substantially to inconsistencies in findings of change in alcohol intake in relation to change in WC for men.

In women, starting to drink and starting to drink beer were associated with lower 5-year WC gain. Yet, only starting to drink beer was associated with lower 5-year BMI gains as compared to stable non-drinkers. This contrast suggests that previous studies of changes in alcohol intake and changes in BMI that did not examine changes by alcoholic beverage subtype may have missed associations with beer intake. However, future studies are needed to build the evidence based on changes in alcohol intake by type in relation to WC and BMI change in men and women.

Strengths and Limitations

An important limitation of both of these studies is their observational design; therefore, causal inferences cannot be made, and residual confounding bias cannot be ruled out. For example, it has been hypothesized that moderate drinkers live healthier lifestyles due to inherent immeasurable individual characteristics that might lead to lower WC gains as compared to non-drinkers. [8, 9, 44] Additionally, those who start to drink or chose not to drink may have underlying health conditions associated with changes in WC or BMI. [132] To address this bias, individuals with diabetes, hypertension and chronic disease at were excluded from prospective analyses. Furthermore, reverse causality bias may be present in cross-sectional analyses, and to address this bias, adults who reported following a medical or intentional weight loss diet in the past year or those missing information on intentional weight loss were excluded from analyses.

An additional limitation of this research study as a whole was that we were not able examines interactions of race due to limited sample sizes across drinking subgroups and sex. Because of the multi-factorial and multi-dimensional nature of alcoholic beverage consumption, larger sample sizes are needed to examine associations of multiple dimensions of drinking with WC and BMI by sex and race/ethnic subgroups. Furthermore, the use of continuous WC and BMI as obesity measures limits our availability to translate to our findings to clinically meaningful endpoints, such as differences in the prevalence or incidence of obesity in drinkers compared to non-drinkers.

A strength of the work as a whole is that the prospective analysis using CARDIA data was informed by and built upon the preliminary cross-sectional NHANES research, and results of both studies support the hypothesis that alcoholic beverage intake is associated with lower estimates of WC and BMI in women who drink, as compared to non-drinkers. The use of varying anthropometric outcomes and varying referent groups across studies could be one reason for inconsistencies in the alcohol and obesity literature. An additional strength of this study was the use of measured WC and BMI and the use of the same referent group (non-drinkers) in both cross-sectional and prospective studies. Furthermore, drinkers were identified based on the use of the NHANES AUQ and the CARDIA AUQ which captured drinking behaviors over the past 12 months and over the past week, respectively. While misclassification of drinkers is still possible, the use of a long term questionnaire captures drinkers who might have been misclassified as non-drinkers with a shorter term assessment tool. As such, these assessment tools may provide a more precise estimate of usual alcoholic beverage intake.

As a whole this research has methodological strengths. NHANES is nationally representative, and multiple surveys were pooled to ensure adequate sample size to examine drinking subgroups by sex. Using daily drinking level recommendations makes this research translatable to the *Dietary Guidelines for Americans 2015-2020*. Furthermore, the prospective study used eight waves of alcoholic beverage intake data collected over a 25 year period, and multiple measurements of exposure and outcome data increase the precision of estimates. Our analysis took advantage of these repeated measures to conduct within-person change analyses, allowing us to control for time-invariant factors, such as health consciousness or genetic variation in ethanol metabolism, which may confound associations.

Overall, a key strength of our study is that these findings provide insights for the design and implementation of future research with larger sample sizes investigating multiple dimensions of drinking (i.e. changes in drinking frequency, beverage type and amount) in relation to incident abdominal and general obesity within population subgroups.

Significance and public health impact

The 2014 national Survey on Drug Use and Health indicates that nearly three fourths of US adults are annual alcoholic beverage consumers. [1] Furthermore, it has been reported that among adult drinkers in the US alcoholic beverages contribute ~17% to total energy intake. [7] These statistics illustrate that alcoholic beverages are widely consumed in the US and contribute substantially to energy intake. Our findings underscore the *Dietary Guidelines for Americans 2015-2020* recommendations to consume alcoholic beverages moderately and to account for calories from alcoholic beverages so as not exceed individual calorie needs. [101] Our findings for men suggest that future research is needed to determine the way in which men consume alcoholic beverages in relation to the rest of the diet. Additionally, decreasing alcoholic beverage intake in men was associated with lower WC and BMI gain, and these findings could be used to inform nutrition intervention and education aimed at male drinkers. For women, our findings support observational studies that alcohol intake is inversely related to obesity; however, such findings should not be translated into public health messaging that encourages alcohol intake among women. There is a strong body of evidence indicating that ethanol metabolism, bioavailability and a dose response of alcohol's effect on body processes differs between men and women, even after adjustment for body weight. Women have higher body fat composition and lower body water content than men of the same body weights which has been linked to differential sex-specific ethanol metabolism. [94, 95] Differences in ethanol metabolism leave women vulnerable to sex-specific adverse health effects of alcohol use, such as the development of breast cancer and increased risk of alcohol dependency. [136] Public health practitioners cannot be sure that the potential benefits of increasing alcohol intake would outweigh any associated health risks. Thus advice for women to start drinking or to increase alcohol intake would not be ethical. [137]

Future Directions

The type of alcoholic beverage consumed among US consumers differs by age, sex and socio-demographic characteristics. [138] Our findings support the theory that dietary intake confounds associations of alcohol intake and WC and BMI. Yet, the question remains as to whether or not the relationship between alcohol and diet may differ according to alcoholic beverage subtype among US adults. Diet can be defined in a variety of meaningful ways (e.g. food and beverage group intake, nutrient intake); however, only dietary pattern analysis allows for inferences related to the synergistic effect that foods and beverages consumed together might have on disease outcomes. [139, 140] A major gap in the literature is whether alcoholic beverage consumption is associated with and changes in diet quality over time.

Furthermore, we found in both studies that the contribution from carbohydrates was consistently negatively associated with drinking level and alcoholic beverage type. An inverse dose response between carbohydrate intakes and alcohol has been previously reported. [22] Moreover, the prevalence of use and intakes of sugar, candy and sweets has been seen to decline with increasing alcohol consumption up to a threshold of 50 grams of ethanol/d. [23] There is a wealth of clinical research indicating that alcohol consumption is associated with lower carbohydrate intake but increased sweet taste preferences among alcoholics. Alcohol and carbohydrates, specifically sugar, may compete for the same neuronal receptors leading to suppressed intake of one nutrient for intake of the other. [36, 92] It is not known whether these associations have long term effects on food choice and taste preferences over time. Findings from our research can be used to inform experimental studies aimed at elucidating the neuronal pathways involved in alcohol and sugar metabolism. A promising new area of research involves the use of imaging studies to discern the neurochemical links between alcohol intake and sweet foods or taste preferences. [28, 141]

In addition to biological differences in alcohol metabolism, sex-specific differences in dietary intake and drinking subgroups were found in our study and have been reported elsewhere. [30, 32, 142, 143]   Despite their lower food intakes, excessive drinking men had higher total energy intakes as compared to their non-drinking counterparts, which might equate to excess energy intake and ultimately weight gain. [31, 40, 91] On the other hand, heavy drinking appears to be associated with substitution of non-alcoholic beverages in women, which might lead to negative energy balance and more favorable obesity measures as compared to non-drinkers. [22, 32, 40] These theories support the hypothesis that diet may be on the causal pathway to higher weight status in men and lower weight status in women as compared to non-drinkers. Future studies using structural equation modeling (SEM) to examine diet as a potential mediator in the alcoholic beverage and obesity associations are warranted.

Due to limited sample size, we were not able to fully explore frequency of drinking by beverage type. Next steps should include larger sample sizes or pooled analyses of men and women examining the joint effects of drinking frequency and alcoholic beverage type on obesity outcomes. One way to incorporate both drinking frequency and type would be to employ latent class trajectory modeling which would allow for defining drinkers based multiple drinking dimensions. A latent class trajectory approach would not necessarily suffer from the same sample size restrictions as examining frequency, type and sex using stratified models or other contemporary modeling strategies. An additional research question for exploration would be how to define drinkers based on a latent construct of drinking behavior defined using multiple dimensions such as type of beverage, frequency and quantity. With regard to beverage type, it would be interesting to define classes of beverage preference. For example, individuals may choose to drink multiple beverages or may preferentially choose to drink only one kind of beverage. Examining such patterns and changes in these patterns over time as they relate to changes in WC and BMI could inform behavioral health interventions.

Lastly, there is a wealth of alcoholic beverage consumption data which indicates that, while the prevalence of alcoholic beverage consumption tends to be higher among socio-demographic majority subgroups (i.e. younger, non-Hispanic white, males, high income, high education), race/ethnic disparities in the amount consumed are evident. For example, excessive and binge drinking behaviors appear to disproportionately occur in socio-demographic minority subgroups (i.e. Hispanic race/ethnic, low income, low education). [144] Disparities in the incidence and prevalence of obesity and obesity-related disease among minority groups is well known. Yet, the concurrent burden of obesity-related disease and excessive alcohol use among low socio-economic and ethnic minority groups remains unknown. Findings from our study, particularly findings of positive associations of binge drinking with WC and BMI in men, could be used to inform future research aimed at investigating obesity-related outcomes in excessive drinkers across minority subpopulations.

APPENDIX 3.1: SUPPLEMENTAL METHODS

The revised Goldberg method was used to identify implausible energy intakes and categorize adults as dietary underreporters, overreporters, or accurate reporters, as described elsewhere. [90, 145, 146] Briefly, for adults in energy balance, the ratio of reported total energy intake to basal metabolic rate (BMR) should be equivalent to physical activity level (PAL). Age, weight, and height were used to calculate BMR using sex-specific Mifflin-St. Jeor equations. [147] NHANES 2003-2006 collected physical activity data using an interviewer administered physical activity questionnaire that queried on intensity, duration and frequency of physical activity over the past 30 days. In 2007, the Global Physical Activity Questionnaire (GPAQ) replaced the previously used NHANES physical activity questionnaire. The GPAQ collects data on recreational, work and travel activities. PAL was categorized using total MET-minutes/week of physical activity and assigned as sedentary=1.4 , light active=1.55, and active=1.75 based on Food and Agriculture Organization guidelines [148]. Confidence limits were calculated for each individual allowing rEI:BMR to differ from reported PAL by 1.5 standard deviations (SD)[90, 146]. Adults with rEI:BMR below or above these confidence limits were classified as dietary underreporters and overreporters, respectively.

APPENDIX 3.2: SUPPLEMENTAL ANALYSES

To examine the robustness of the observed relationships between drinking level and diet and obesity measures, using alternative methods to account for dietary misreporting, a series of supplemental analyses were conducted. First analyses were performed with stratification by dietary reporting status by including an interaction term for daily drinking level x dietary misreporting status categories in all models. [90] Stata's margins command and dydx option were used to estimate the average marginal effect of each drinking level category, compared to non-drinking, among accurate reporters only. [149] As an alternative method of accounting for implausible energy intakes, men and women who reported energy intakes ± 2 standard deviations from the mean energy intakes for each sex subgroup were excluded from all multivariable regression analyses.[58, 150] A similar method of restriction has been used in studies of diet and disease to control for bias associated with under- and overreporting of self-reported dietary intake.[58, 150] A comparative study of this method with adjusting for implausible energy intakes using the revised Goldberg method has been previously published. [90]

APPENDIX 3.3: TABLE OF DIFFERENCES IN ENERGY INTAKE (KCAL/D) AND MACRONUTRIENT CONTRIBUTIONS (%) BETWEEN DRINKERS AND NON-DRINKERS, NHANES 2003-2012[a]

	Men				**Women**			
	Accurate Reporters[b]		***Excluding Outliers[c]***		***Accurate Reporters[b]***		***Excluding Outliers[c]***	
	β	**95% CI**	β	**95% CI**	β	**95% CI**	β	**95% CI**
A								
Total Energy (kcal/d)								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	70	-13,152	**91**	**6,175**	-14	-63,34	**73**	**27,119**
Heavy Drinker	**113**	**33,193**	**141**	**55,226**	24	-30,78	**76**	**27,125**
Binge Drinker	**202**	**121,283**	**256**	**160,352**	**94**	**12,175**	**116**	**39,193**
B								
Non-alcoholic Energy (kcal/d)[d]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	-22	-107,62	7	-78,91	-43	-93,7	44	-2,90
Heavy Drinker	**-93**	**-173,-13**	-53	-137,31	**-59**	**-115,-3**	-3	-52,47
Binge Drinker	-65	-143,13	-27	-120,66	-50	-141,41	-17	-94,60
C								
Food Energy (kcal/d)[d]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	2	-73,77	29	-49,108	-13	-60,35	64	23,106
Heavy Drinker	-69	-140,2	-31	-105,42	-6	-62,49	47	-0.4,94
Binge Drinker	-52	-125,20	-19	-104,66	-32	-114,49	16	-47,78
D								
Non-alcoholic Beverage Energy (kcal/d)[d]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	-24	-60,11	-23	-51,5	**-31**	**-56,-5**	-20	-41,1
Heavy Drinker	-13	-55,29	-22	-52,9	**-53**	**-75,-30**	**-50**	**-70,-30**
Binge Drinker	-44	29,0	-8	-44,28	-18	-62,26	-32	-68,4
E	β	**95% CI**	β	**95% CI**	β	**95% CI**	β	**95% CI**
% Fat Contribution[d]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	0.01	-0.87,0.89	0.42	-0.44,1.29	0.02	-0.55,0.59	0.45	-0.17,1.07
Heavy Drinker	-0.39	-1.38,0.60	-0.23	-1.18,0.73	0.25	-0.56,1.05	0.44	-0.28,1.16
Binge Drinker	-0.90	-1.89,0.09	-0.77	-1.67,0.14	-0.83	-0.02,-2.06	-0.52	-1.66,0.62
F								
% Protein Contribution[d]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	0.47	0.01,0.93	0.55	0.13,0.96	0.37	-0.04,0.78	0.21	-0.16,0.57
Heavy Drinker	0.02	-0.47,0.52	0.21	-0.23,0.65	0.16	-0.27,0.58	0.22	-0.19,0.64
Binge Drinker	-0.05	-0.51,0.42	0.13	-0.27,0.52	-0.04	-0.83,0.75	-0.14	-0.81,0.53
G								
% Carbohydrate Contribution[d,e]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	**-2.26**	**-3.3,-1.22**	**-2.27**	**-3.07,-1.46**	**-0.71**	**-1.54,0.13**	**-0.86**	**-1.6,-0.13**
Heavy Drinker	**-4.32**	**-5.49,-3.14**	**-3.96**	**-4.88,-3.04**	**-1.39**	**-2.21,-0.58**	**-1.44**	**-2.17,-0.71**

	Men				Women			
	Accurate Reporters[b]		***Excluding Outliers[c]***		***Accurate Reporters[b]***		***Excluding Outliers[c]***	
Binge Drinker	**-5.33**	**-6.40,-4.25**	**-5.49**	**-6.43,-4.54**	**-3.09**	**-4.17,-2.00**	**-3.13**	**-4.05,-2.22**
H								
% Sugar Contribution[d]								
Non-Drinker	Ref		Ref		Ref		Ref	
Moderate Drinker	**-2.03**	**-3.21,-0.84**	**-2.33**	**-3.29,-1.36**	**-1.3**	**-2.26,-0.33**	**-1.38**	**-2.20,-0.56**
Heavy Drinker	**-3.64**	**-4.67,-2.61**	**-4.06**	**-5.04,-3.08**	**-3.51**	**-4.46,-2.57**	**-3.73**	**-4.62,-2.84**
Binge Drinker	**-3.72**	**-4.96,-2.48**	**-4.19**	**-5.27,-3.1**	**-3.6**	**-5.5,-1.7**	**-3.71**	**-5.33,-2.09**

[a] β co-efficients obtained from multivariable linear regression models which take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES); All models adjusted for age, race/ethnicity, education, physical activity level, survey year, chronic disease status, day of recall 1, day of recall 2 and smoking. Continuous dietary outcomes vary for each regression model as follows: A: total energy; B: non-alcoholic energy (food plus non-alcoholic beverage energy); C: energy from food; D: energy from non-alcoholic beverages; E: percentage contribution from fat to non-alcoholic energy; F: percentage contribution from protein non-alcoholic energy; G: percentage contribution from carbohydrates to non-alcoholic energy; H: percentage contribution from sugar to non-alcoholic energy. Estimates are the difference in kilocalories per capita per day (kcal/d) or percentage contribution compared to non-drinkers (%).
[b] For accurate reporter analyses, all models included an interaction term for the number of drinks/d x dietary misreporting status. Data for United States (US) men (n=6,018) and women (n=5,885) 20 – 79 years of age.
[c] For analyses excluding outliers, participants who consumed ± 2SD of the mean total energy intake (kcal/d) of each sex group were excluded. Data for US men (n=5,783) and women (n=5,624) 20 – 79 years of age; models are not adjusted for dietary misreporting status;
[d] Excludes energy from alcoholic beverages
[e] Excludes energy from sugar

APPENDIX 3.4 TABLE OF DIFFERENCES IN WC (CM) AND BMI (KG/M^2) OF DRINKERS COMPARED TO NON-DRINKERS IN MEN, NHANES 2003-2012[a]

	***Accurate Reporters*[b]**					
	Model 1		**Model 2**		**Model 3**	
	β	95% CI	β	95% CI	β	95% CI
WC (cm)						
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.24	-2.00,1.51	-0.23	-2.01,1.55	-0.71	-2.41,0.99
Heavy Drinker	0.27	-1.63,2.18	0.73	-1.28,2.73	-0.63	-2.50,1.25
Binge Drinker	**4.02**	**1.50,6.53**	**4.32**	**1.75,6.89**	**2.94**	**0.46,5.41**
	***Excluding Outliers*[c]**					
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.87	-2.63,0.89	-0.88	-2.64,0.88	-0.71	-2.41,0.99
Heavy Drinker	-0.16	-2.14,1.81	-0.15	-2.13,1.83	-0.63	-2.50,1.25
Binge Drinker	**3.00**	**0.58,5.42**	**3.00**	**0.58,5.43**	**2.94**	**0.46,5.41**
	***Accurate Reporters*[b]**					
	Model 4		**Model 5**		**Model 6**	
BMI (kg/m^2)	β	95% CI	β	95% CI	β	95% CI
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.14	-0.81,0.54	-0.14	-0.83,0.56	-0.30	-0.95,0.34
Heavy Drinker	0.25	-0.54,1.04	0.41	-0.40,1.23	-0.07	-0.85,0.72
Binge Drinker	**1.69**	**0.68,2.71**	**1.80**	**0.76,2.85**	**1.32**	**0.31,2.32**
	***Excluding Outliers*[c]**					
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.40	-1.10,0.29	-0.40	-1.10,0.29	-0.53	-1.22,0.16
Heavy Drinker	0.03	-0.80,0.86	0.03	-0.80,0.86	-0.20	-1.02,0.62
Binge Drinker	**1.23**	**0.22,2.25**	**1.23**	**0.21,2.25**	0.94	-0.07,1.96

[a] β co-efficients obtained from multivariable linear regression models which take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES);
[b] For accurate reporter analyses, all models included an interaction term for the number of drinks/d x dietary misreporting status. Data for United States (US) men (n=6,018) 20 – 79 years of age.
[c] For analyses excluding outliers, participants who consumed ± 2SD of the mean total energy intake (kcal/d) of each sex group were excluded. Data for US men (n=5,783) 20 – 79 years of age; models are not adjusted for dietary misreporting status.
Model 1and Model 4 adjusted for age, race/ethnicity, education, marital status, physical activity level, survey year, day of recall 1, day of recall 2, daily sedentary time, smoking status, FPL%;
Model 2 and Model 5 adjusted for covariates plus food intake (continuous);
Model 3 and Model 6 adjusted for covariates plus percentage contribution from carbohydrates and percentage contribution from sugar to total energy intake (continuous).

APPENDIX 3.5: TABLE OF DIFFERENCES IN WC (CM) AND BMI (KG/M^2) OF DRINKERS COMPARED TO NON-DRINKERS IN WOMEN, NHANES 2003-2012[a]

	Accurate Reporters[b]					
	Model 1		**Model 2**		**Model 3**	
	β	95% CI	β	95% CI	β	95% CI
WC (cm)						
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-1.30	-3.32,0.72	-1.15	-3.14,0.85	-1.50	-3.48,0.48
Heavy Drinker	**-2.26**	**-3.90,-0.62**	**-1.93**	**-3.55,-0.30**	**-2.76**	**-4.40,-1.13**
Binge Drinker	-1.33	-3.64,0.97	-1.18	-3.52,1.16	-2.09	-4.46,0.28
	Excluding Outliers[c]					
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	**-1.98**	**-3.62,-0.34**	**-1.96**	**-3.61,-0.32**	**-2.13**	**-3.76,-0.51**
Heavy Drinker	**-2.29**	**-3.96,-0.61**	**-2.23**	**-3.90,-0.56**	**-2.67**	**-4.35,-0.99**
Binge Drinker	**-1.93**	**-3.97,0.12**	-1.88	-3.94,0.17	**-2.46**	**-4.61,-0.31**
	Accurate Reporters[b]					
	Model 4		**Model 5**		**Model 6**	
BMI (kg/m^2)	β	95% CI	β	95% CI	β	95% CI
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	-0.44	-1.35,0.46	-0.39	-1.28,0.51	-0.54	-1.43,0.34
Heavy Drinker	**-1.09**	**-1.83,-0.35**	**-0.96**	**-1.71,-0.22**	**-1.35**	**-2.09,-0.60**
Binge Drinker	-0.70	-1.78,0.38	-0.64	-1.73,0.45	-1.08	-2.17,0.01
	Excluding Outliers[c]					
Non-Drinker	Ref		Ref		Ref	
Moderate Drinker	**-0.72**	**-1.42,-0.01**	**-0.72**	**-1.43,-0.01**	**-0.80**	**-1.50,-0.10**
Heavy Drinker	**-1.03**	**-1.78,-0.28**	**-1.03**	**-1.78,-0.28**	**-1.24**	**-1.99,-0.49**
Binge Drinker	**-1.04**	**-2.00,-0.07**	**-1.04**	**-2.01,-0.07**	**-1.33**	**-2.32,-0.34**

[a] β co-efficients obtained from multivariable linear regression models which take into account survey design and sample weights. National Health and Nutrition Examination Survey (NHANES);
[b] For accurate reporter analyses, all models included an interaction term for the number of drinks/d x dietary misreporting status. Data for United States (US) women (n=5,885) 20 – 79 years of age.
[c] For excluding outliers analyses, participants who consumed ± 2SD of the mean total energy intake (kcal/d) of each sex group were excluded. Data for US women (n=5,624) 20 – 79 years of age; models are not adjusted for dietary misreporting status.
Model 1 and Model 4 adjusted for age, race/ethnicity, education, marital status, physical activity level, survey year, day of recall 1, day of recall 2, daily sedentary time, smoking status, FPL%;
Model 2 and Model 5 adjusted for covariates plus NAB intake (continuous);
Model 3 and Model 6 adjusted for covariates plus percentage contribution from carbohydrates (continuous) and percentage contribution from sugar to total energy intake (continuous).

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