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ORIGINAL RESEARCH

Association of Alcohol Intake With Hypertension in Type 2 Diabetes Mellitus: The ACCORD Trial

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BACKGROUND: Heavy alcohol consumption has a well-established association with hypertension. However, doubt persists whether moderate alcohol consumption has a similar link. This relationship is not well-studied in patients with diabetes mellitus. We aimed to describe the association of alcohol consumption with prevalent hypertension in participants in the ACCORD (Action to Control Cardiovascular Risk in Diabetes) trial.

METHODS AND RESULTS: Alcohol consumption was categorized as none, light (1–7 drinks/week), moderate (8–14 drinks/week), and heavy (≥15 drinks/week). Blood pressure was categorized using American College of Cardiology/American Heart Association guidelines as normal, elevated blood pressure, stage 1 hypertension, and stage 2 hypertension. Multivariable logistic regression was used to explore the association between alcohol consumption and prevalent hypertension. A total of 10 200 eligible participants were analyzed. Light alcohol consumption was not associated with elevated blood pressure or any stage hypertension. Moderate alcohol consumption was associated with elevated blood pressure, stage 1, and stage 2 hypertension (odds ratio [OR], 1.79; 95% CI, 1.04–3.11, *P*=0.03; OR, 1.66; 95% CI, 1.05–2.60, *P*=0.03; and OR, 1.62; 95% CI, 1.03–2.54, *P*=0.03, respectively). Heavy alcohol consumption was associated with elevated blood pressure, stage 1, and stage 2 hypertension (OR, 1.91; 95% CI, 1.17–3.12, *P*=0.01; OR, 2.49; 95% CI, 1.03–6.17, *P*=0.03; and OR, 3.04; 95% CI, 1.28–7.22, *P*=0.01, respectively).

CONCLUSIONS: Despite prior research, our findings show moderate alcohol consumption is associated with hypertension in patients with type 2 diabetes mellitus and elevated cardiovascular risk. We also note a dose-risk relationship with the amount of alcohol consumed and the degree of hypertension.

Key Words: ACCORD ■ alcohol consumption ■ blood pressure ■ essential hypertension ■ type 2 diabetes mellitus

Hypertension is the leading cause of premature cardiovascular morbidity and death; it accounts for tens of millions of disability-adjusted life-years lost annually through its effects on ischemic heart disease, hemorrhagic and ischemic stroke, and chronic kidney disease.[1] In 2010, the global estimated prevalence of hypertension was 1.4 billion, representing ≈31.1% of adults, with a projection to increase substantially, mostly in low- and middle-income countries.[2] However, disease prevalence over the past decade had been declining in high-income countries until the American College of Cardiology/American Heart Association (ACC/AHA) published the updated guidelines for hypertension in 2017 which lowered the threshold defining hypertension. Because of the change in the ACC/AHA guidelines, many more people meet the threshold which now defines hypertension.[2–4] As hypertension is a primary driver of cardiovascular and kidney disease, it continues to be a major global public health concern.[5]

Heavy alcohol consumption has been linked to high blood pressure since 1915.[6] However, light and moderate alcohol consumption lack a strong correlation with hypertension and, compared with abstainers, has been associated with improved cardiovascular outcomes, described as a U-shaped

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CLINICAL PERSPECTIVE

What Is New?

- Although prior research has not demonstrated an association of moderate alcohol consumption with hypertension, we show in a large cohort that moderate alcohol consumption is associated with hypertension in patients with type 2 diabetes mellitus and elevated cardiovascular risk.

What Are the Clinical Implications?

- These findings shed light on a modifiable risk factor (moderate alcohol consumption) for which clinicians can counsel patients.

Nonstandard Abbreviations and Acronyms

ACCORD	Action to Control Cardiovascular Risk in Diabetes
SBP	systolic blood pressure
DBP	diastolic blood pressure

curve in numerous epidemiological studies.[7–10] In fact, because of the benefit in cardiovascular risk via decreased atherosclerosis, blood clotting, and platelet aggregation resulting in decreased rates of coronary artery disease, many have recommended light and moderate alcohol consumption as beneficial and cardioprotective in the prevention of cardiovascular disease.[11,12] In 2 recent studies, in which patients with diabetes mellitus were not specifically selected, it has been noted through meta-analyses that a linear relationship exists with the amount of alcohol consumed and the degree of hypertension.[13,14]

However, the effects of alcohol as a risk factor for hypertension in patients with type 2 diabetes mellitus has not been adequately studied. Given the disease burden of both hypertension and type 2 diabetes mellitus, and the potential for a relatively simple but meaningful prospective intervention, we aimed to explore the association of alcohol consumption and hypertension in the participants of the ACCORD (Action to Control Cardiovascular Risk in Diabetes) trial.[15]

METHODS

Study Design and Population

The design and conduct of the ACCORD study has been previously described.[16] Briefly, ACCORD was a randomized trial designed to assess whether cardiovascular disease event rates could be reduced in a patient with type 2 diabetes mellitus via 3 main interventions targeting cardiovascular disease risk factors: tight glycemic control, intensive blood pressure control, and intensive lipid control. This hypothesis was tested by randomizing patients to 1 of 2 strategies for each intervention: glycemic control (intensive versus standard), blood pressure control (intensive versus standard), and lipid control (simvastatin plus fenofibrate versus simvastatin plus placebo). Intense glycemic control was defined by targeting a glycated hemoglobin level of <6.0% or <42 mmol/mol. Standard glycemic control was via therapy targeting a glycated hemoglobin level of 7.0% to 7.9% or 53 to 63 mmol/mol. The intense blood pressure control arm was defined by medication dose titration or addition of another drug whenever systolic blood pressure (SBP) was ≥120 mm Hg.

Inclusion criteria for the trial was a history of type 2 diabetes mellitus, a glycated hemoglobin level ≥7.5% or 58 mmol/mol, and either age ≥40 years with prevalent cardiovascular disease or age ≥55 years with a substantial amount of atherosclerosis, albuminuria, left ventricular hypertrophy, or ≥2 additional risk factors from the following set: dyslipidemia, hypertension, smoking, or obesity. Exclusion criteria included a body mass index >45 kg/m^2, a serum creatinine level >1.5 mg per dL, and other serious illnesses. The study was conducted at 77 clinical sites throughout the United States and Canada and was approved by the relevant institutional review boards. The study was sponsored by the National Heart, Lung, and Blood Institute.

The trial enrolled 10 251 participants with type 2 diabetes mellitus at high risk of cardiovascular events. Participants gave informed consent. All participants were randomly assigned to either the intensive or standard glycemic control groups as part of the ACCORD glycemia trial. Of these ACCORD participants, 5518 were in tandem randomized to either simvastatin plus fenofibrate or simvastatin plus placebo. The remaining 4733 participants in ACCORD were randomized into either intensive or standard blood pressure control strategies.

For the purpose of this analysis, all ACCORD participants were included who had baseline self-reported alcohol consumption (n=10 246) and baseline blood pressure measurements (n=10 205). After all exclusions, there were 10 200 eligible participants.

Qualified researchers trained in human subject confidentiality protocols may request access to the data that support the findings of this study by contacting the National Heart, Lung, and Blood Institute Biological Specimen and Data Repository Information Coordinating Center.

Variables

Baseline covariates were defined by participant self-report at study enrollment. Self-reported alcohol consumption was assessed by participant response to the question "How many alcoholic drinks do you consume in a typical week?" with instructions that "A drink is a 12-ounce beer, 6 ounces of wine, or 1.5 ounces of liquor." Light, moderate, and heavy alcohol consumption were defined as 1 to 7 drinks/week, 8 to 14 drinks/week, and ≥15 drinks/week, respectively. Blood pressure readings were taken with an automated sphygmomanometer (Omron 907) and the reported values are the average of 3 measurements taken with the participant in the seated position.

Among participants not taking antihypertensive medications at baseline, blood pressures were categorized according to the ACC/AHA 2017 guidelines as normal when SBP was <120 mmHg and diastolic blood pressure (DBP) was <80 mmHg, elevated blood pressure when SBP was 120 to 129 mmHg and DBP was <80 mmHg, stage 1 hypertension when SBP was 130 to 139 mmHg or DBP was 80 to 89 mmHg, and stage 2 hypertension when SBP was ≥140 mmHg or DBP was ≥90 mmHg. Among participants taking 1 antihypertensive medication at baseline, blood pressure was categorized as elevated blood pressure when SBP was <120 mmHg, stage 1 hypertension when SBP was 120 to 129 mmHg or DBP was 80 to 89 mmHg, and stage 2 hypertension when SBP was ≥130 mmHg or DBP was ≥90 mmHg. Among participants taking ≥2 antihypertensives at baseline, blood pressure was categorized as elevated blood pressure when SBP was <120 mmHg, stage 1 hypertension when SBP was 120 to 129 mmHg, and stage 2 hypertension when SBP was ≥130 mmHg or DBP was ≥80 mmHg.

Statistical Analysis

Baseline characteristics of the study population with varying levels of alcohol consumption were compared using mean±SD for continuous variables and frequency (percentage) for categorical variables. Alcohol consumption and stages of hypertension were both modeled as categorical variables. Multivariable logistic regression was used to explore the relationship between alcohol consumption and prevalent hypertension. Initial analysis (model 1) was unadjusted, with subsequent analyses iteratively adjusting for covariates believed to be of clinical importance. Model 2 adjusted for age, sex, and race. Model 3 added body mass index, prevalent cardiovascular disease (defined as history of myocardial infarction, stroke, coronary revascularization, carotid or peripheral revascularization, or positive stress test), smoking status (current smoking), and years with type 2 diabetes mellitus. Two-sided $P<0.05$ were considered to be statistically significant. All statistical analyses were conducted at Wake Forest University School of Medicine using SAS version 9.4 (Cary, NC).

RESULTS

Among the 10 200 eligible participants, the baseline characteristics of the study population are presented in Table 1. Groups were similar among categories of alcohol consumption in years with type 2 diabetes mellitus, prior cardiovascular disease, waist circumference, DBP, heart rate, total cholesterol, low-density lipoprotein, very-low-density lipoprotein, triglycerides, or glomerular filtration rate. Differences between groups were noted in sex, race, current and prior smoking, body mass index, SBP, heart rate, total cholesterol, creatinine, and urinary albumin.

The results for the 3 models of multivariable logistic regression analysis are shown in Tables 2–4. Table 2 describes the association of alcohol consumption and elevated blood pressure. Light alcohol consumption was not associated with elevated blood pressure (OR, 1.11; 95% CI, 0.93–1.31, $P=0.25$). Both moderate and heavy alcohol consumption were associated with elevated blood pressure (OR, 1.79; 95% CI, 1.04–3.11, $P=0.03$; and OR, 1.91; 95% CI, 1.17–3.12, $P=0.01$, respectively). Table 3 describes the association of alcohol consumption and stage 1 hypertension. There was no association with light alcohol consumption and stage 1 hypertension (OR, 1.11; 95% CI, 0.85–1.45, $P=0.45$). Both moderate and heavy alcohol consumption were associated with stage 1 hypertension (OR, 1.66; 95% CI, 1.05–2.60, $P=0.03$; and OR, 2.49; 95% CI, 1.03–6.17, $P=0.03$, respectively). Table 4 describes the association of alcohol consumption and stage 2 hypertension. Light alcohol consumption was not associated with stage 2 hypertension (OR, 1.02; 95% CI, 0.88–1.19, $P=0.76$). Moderate and heavy alcohol consumption were associated with stage 2 hypertension (OR, 1.62; 95% CI, 1.03–2.54, $P=0.03$; and OR, 3.04; 95% CI, 1.28–7.22, $P=0.01$, respectively).

DISCUSSION

In this analysis of patients with type 2 diabetes mellitus enrolled in the ACCORD trial, we found that moderate alcohol consumption was associated with elevated blood pressure, stage 1, and stage 2 hypertension. We confirmed prior findings that heavy alcohol consumption was also associated with elevated blood pressure, stage 1, and stage 2 hypertension. Additionally, we demonstrated a dose-risk relationship with the amount of alcohol consumed and the degree of hypertension

Table 1. Characteristics of ACCORD Study Participants (n=10 200)

	Alcohol Intake				
	None n=7767 (76.1%)	Light n=2124 (20.8%)	Moderate n=232 (2.3%)	Heavy n=77 (0.8%)	*P* Value*
Age, y	62.8±6.7	62.6±6.6	62.6±6.2	62.9±6.1	0.51
Sex (% male)	55.4%	77.8%	100%	100%	<0.0001
Race (%White)	60.1%	68.3%	74.1%	100%	<0.0001
With diabetes mellitus, y	10.9±7.6	10.6±7.4	10.0±7.9	10.1±7.1	0.09
Smoking, current (%)	13.4%	14.9%	23.3%	18.0%	<0.0001
Smoking, prior (%)	48.2%	61.5%	79.6%	76.6%	<0.0001
Prior cardiovascular disease (%)	35.6%	33.8%	34.1%	37.2%	0.47
Weight, kg	93.0±18.6	94.7±17.9	97.4±16.4	99.2±16.6	<0.0001
Height, cm	169.2±9.9	172.8±9.0	176.8±6.6	176.9±6.6	<0.0001
Waist circumference, cm	106.6±13.8	106.8±13.2	107.5±11.9	109.6±11.7	0.20
BMI, kg/m^2	32.42±5.50	31.64±5.11	31.12±4.49	31.72±4.54	<0.0001
Systolic BP, mmHg	136.5±17.3	135.6±16.4	136.4±15.5	140.7±15.9	0.02
Diastolic BP, mmHg	74.7±10.7	75.2±10.4	75.7±10.1	76.6±10.3	0.07
Heart rate	72.8±11.8	72.1±11.6	72.8±11.6	72.6±11.8	0.09
Total cholesterol, mg/dL	183.7±42.0	182.2±41.9	179.9±38.2	190.1±37.6	0.14
HDL, mg/dL	41.8±11.6	42.0±11.7	42.8±11.6	45.1±12.9	0.04
LDL, mg/dL	105.3±34.0	104.2±33.8	99.7±31.5	104.3±32.0	0.07
VLDL, mg/dL	36.6±24.2	36.0±24.9	37.4±23.3	40.7±23.6	0.28
Triglycerides, mg/dL	190.3±142.3	187.0±166.1	201.3±163.7	222.7±177.5	0.11
Hemoglobin A1c, %	8.32±1.07	8.26±1.02	8.16±0.96	7.98±0.86	0.0009
Creatinine, mg/dL	1.05±0.43	1.09±0.44	1.10±0.30	1.13±0.33	0.004
eGFR, $mL \times min^{-1} \times m^{-2}/1.73$	76.9±24.8	77.9±22.3	78.3±24.1	79.7±25.3	0.27
Urinary albumin, mg/dL	13.2±51.1	17.1±64.8	10.7±28.4	14.7±37.2	0.05

Demonstrates baseline characteristics compared across groups of those who do not consume alcohol, and those who consume alcohol stratified by amount of consumption. Continuous variables described as mean±SD. Categorical variables described as frequency (percentage). Estimated glomerular filtration rate as calculated by the 4-variable modified diet in renal disease equation. ACCORD indicates Action to Control Cardiovascular Risk in Diabetes; BMI, body mass index; diastolic BP, diastolic blood pressure; eGFR, estimated glomerular filtration rate; HDL, high-density lipoprotein; LDL, low-density lipoprotein; systolic BP, systolic blood pressure; and VLDL, very-low-density lipoprotein.

**P* value as calculated by ANOVA for continuous and χ^2 for categorical variables.

in our patients with type 2 diabetes mellitus and elevated cardiovascular risk.

The association of alcohol consumption with hypertension dates back >100 years and has since been studied in >50 epidemiologic studies. This link is strong and independent of age, smoking, obesity, salt intake, education level, and type of alcoholic beverage.[17–20] The link has also been confirmed in a small intervention study in hypertensive hospitalized men.[21] Though the relationship is strong, the

Table 2. Association of Alcohol Intake With Elevated Blood Pressure

Alcohol Intake	Model 1 Unadjusted Odds Ratio (95% CI; *P* Value)	Model 2 Demographic-Adjusted Odds Ratio (95% CI; *P* Value)	Model 3 Fully Adjusted Odds Ratio (95% CI; *P* Value)
None	Reference	Reference	Reference
Light (1–7 drinks/wk)	1.11 (0.93–1.31) *P*=0.25	1.12 (0.94–1.33) *P*=0.19	1.11 (0.93–1.31) *P*=0.25
Moderate (8–14 drinks/wk)	1.43 (0.51–4.04) *P*=0.49	1.75 (1.05–2.89) *P*=0.03	1.79 (1.04–3.11) *P*=0.03
Heavy (15+ drinks/wk)	1.91 (1.17–3.12) 0.01	1.96 (1.20–3.21) *P*=0.01	1.91 (1.17–3.12) *P*=0.01

Demonstrates the association of the degree of alcohol consumption with elevated blood pressure. Analysis was conducted by logistic regression performed with 3 models as above. Model 1 is unadjusted. Model 2 adjusts for age, sex, and race. Model 3 adjusts for the covariates in model 2, plus prevalent cardiovascular disease, body mass index, smoking status, years with diabetes mellitus, glycated hemoglobin, creatinine, and urinary albumin.

Table 3. Association of Alcohol Intake With Stage 1 Hypertension

Alcohol Intake	Model 1 Unadjusted Odds Ratio (95% CI; *P* Value)	Model 2 Demographic-Adjusted Odds Ratio (95% CI; *P* Value)	Model 3 Fully Adjusted Odds Ratio (95% CI; *P* Value)
None	Reference	Reference	Reference
Light (1–7 drinks/wk)	0.90 (0.81–0.99) *P*=0.03	0.96 (0.87–1.07) *P*=0.46	1.11 (0.85–1.45) *P*=0.45
Moderate (8–14 drinks/wk	1.01 (0.77–1.32) *P*=0.95	1.14 (0.87–1.50) *P*=0.32	1.66 (1.05–2.60) *P*=0.03
Heavy (15+ drinks/wk)	1.48 (0.94–2.33) *P*=0.03	1.78 (1.13–2.81) *P*=0.01	2.49 (1.03–6.17) *P*=0.03

Demonstrates the association of the degree of alcohol consumption with stage 1 hypertension. Analysis was conducted by logistic regression performed with 3 models as above. Model 1 is unadjusted. Model 2 adjusts for age, sex, and race. Model 3 adjusts for the covariates in model 2, plus prevalent cardiovascular disease, body mass index, smoking status, years with diabetes mellitus, glycated hemoglobin, creatinine, and urinary albumin.

threshold amount of alcohol that increases the risk of hypertension is less clear.[22] In fact, some studies even suggest that light to moderate amounts of alcohol consumed may have salutary effects on blood pressure.[20,23–25] Our findings are at odds with a portion of prior research on this topic, as well as with a recent study in young women showing that moderate alcohol consumption is associated with a lower risk of hypertension.[26] It is important to delineate the comparison of this population with those in our studies, but it is similarly important to note that heavy alcohol consumption has a conserved association with hypertension across multiple populations and sexes.[19] Although heavy alcohol consumption has a clearly recognized association with hypertension, we add to this well-established body of knowledge by showing moderate alcohol consumption may also be implicated in its association with hypertension, specifically in patients with type 2 diabetes mellitus.[17–21,27,28]

Table 4. Association of Alcohol Intake With Stage 2 Hypertension

Alcohol Intake	Model 1 Unadjusted Odds Ratio (95% CI; *P* Value)	Model 2 Demographic-Adjusted Odds Ratio (95% CI; *P* Value)	Model 3 Fully Adjusted Odds Ratio (95% CI; *P* Value)
None	Reference	Reference	Reference
Light (1–7 drinks/wk)	0.94 (0.81–1.08) *P*=0.37	1.03 (0.89–1.20) *P*=0.68	1.02 (0.88–1.19) *P*=0.76
Moderate (8–14 drinks/wk)	1.39 (0.89–2.18) *P*=0.15	1.64 (1.05–2.58) *P*=0.03	1.62 (1.03–2.54) *P*=0.03
Heavy (≥15 drinks/wk)	2.31 (0.97–5.48) *P*=0.06	2.99 (1.25–7.12) *P*=0.01	3.04 (1.28–7.22) *P*=0.01

Demonstrates the association of the degree of alcohol consumption with stage 2 hypertension. Analysis was conducted by logistic regression performed with 3 models as above. Model 1 is unadjusted. Model 2 adjusts for age, sex, and race. Model 3 adjusts for the covariates in model 2, plus prevalent cardiovascular disease, body mass index, smoking status, years with diabetes mellitus, glycated hemoglobin, creatinine, and urinary albumin.

An important consideration, given our findings, is the recent ACC/AHA published guidelines for hypertension in 2017 which lowered the threshold defining hypertension and reduced the threshold which delineates stage 1 from stage 2 hypertension. Importantly, much of the previously published work describing the association of alcohol and hypertension used pre-2017 guidelines to classify hypertension. These threshold changes were made as recent data demonstrated those with blood pressures of 130 to 139 mmHg or 80 to 89 mmHg have an ≈2-fold increase cardiovascular disease risk compared with adults with a normal blood pressure.[29] The implications of this change may result in discovering associations of previously thought insignificant exposures with hypertension. Our findings may be one example of this as our study is predated by numerous epidemiologic studies that do not show an association of moderate alcohol consumption and hypertension.

Aside from the lack of association of moderate alcohol consumption with hypertension, epidemiological studies have also long established that light and moderate alcohol consumption have beneficial effects on cardiovascular health compared with those who abstain.[7–10,30–32] Some of the proposed and plausible mechanisms by which light and moderate alcohol consumption results in a cardioprotective effect are by the resultant increased levels of high-density lipoproteins, decreased levels of low-density lipoproteins, reduced platelet aggregation and clot formation, and lowered plasma apolipoprotein concentrations. These protective benefits summate in decreased atherosclerosis and thrombus formation.[33]

Interestingly, the abundance of literature also demonstrates worse cardiovascular outcomes in patients with hypertension. These findings, in those who consume moderate amounts of alcohol, combined with prior research demonstrating a reduced cardiovascular risk, both in the general population as well as patients with type 2 diabetes mellitus, should be considered together. The combination of the above

suggests the resultant risk of hypertension attributed to moderate alcohol consumption may eventuate in a modest to negligible impact on cardiovascular health overall.[34–36] Otherwise, we might be able to infer those who consume moderate amounts of alcohol would be at higher risk for hypertension and therefore cardiovascular disease. Notwithstanding, considerable difficulties prevent researchers from conducting randomized controlled trials in attempts to demonstrate the beneficial effects of light to moderate alcohol consumption. Further, the mechanism behind the cardioprotective effects of alcohol are complex and only hypothesized to be pathways to beneficial cardiovascular outcomes. Thus, caution should be used when broaching the subject as miscalculating the benefits of alcohol consumption on cardiovascular disease may prohibit simple and low risk interventions of an easily modifiable risk factor.

In light of our findings, low risk and simple lifestyle modifications to temper alcohol consumption may have the potential for clinical and public health benefits via decreased rates of hypertension. These benefits may well include, but are not limited to, decreased morbidity and mortality and lower healthcare costs.[1,37] The translational possibilities of these findings with respect to the low risk nature of intervention, such as alcohol cessation counseling, should be considered. Our findings diverge from previously published epidemiological studies lacking an association with hypertension in those who consume a moderate amount of alcohol; specifically, in a large population of patients with type 2 diabetes mellitus of which a paucity of literature exists. This report adds to a growing body of literature questioning the previously reported beneficial effects of alcohol on hypertension and cardiovascular health in patients with type 2 diabetes mellitus.[14,31,38]

Study Limitations and Strengths

Our study should be interpreted in the context of its limitations. We performed a cross-sectional analysis in a cohort sample of those participating in the ACCORD trial. As such, residual confounding bias may exist especially in the context of noting prior literature supporting a potential cardiovascular benefit with moderate alcohol consumption versus our findings that suggest a risk of hypertension, albeit in patients with type 2 diabetes mellitus. Although we adjusted for covariates in our analysis, with either known or suspected relationships with hypertension, some residual confounders that remain a possibility include, but are not limited to, family history, high salt intake, binge drinking, potential variabilities in the amount of alcohol consumed, masked hypertension, white-coat hypertension, and obstructive sleep apnea. Ideally, blood pressure should be measured in the most accurate fashion using ambulatory blood pressure monitoring. Although the ACCORD protocol for measuring blood pressure did not include ambulatory blood pressure monitoring, blood pressure measurements were recorded in a precise manner, in the seated position, using an automated device (the Omron 907), 3 times at each clinic visit. The blood pressure readings for ACCORD are the averages of the first, second, and third systolic and diastolic blood pressures. Although this precise and specific protocol seemed to minimize error with respect to blood pressure recordings, one could consider the lack of ambulatory blood pressure monitoring a residual confounder as masked hypertension and white-coat hypertension would not be diagnosed under these circumstances.

The change in alcohol percentage by volume over time should also be weighed as many of the older analyses studied alcohol consumption of patients that in some cases included beverages with a lower alcohol percentage by volume compared with alcoholic drinks today. It is possible that, in addition to the ACC/AHA hypertension guideline update, this may be a contributing factor as to why the association of moderate alcohol consumption with hypertension is now coming to light. Additionally, stratifying the level of alcohol consumption by sex is not uncommon. However, as in some national and international studies, we did not modify our model based on participant sex which may add to the residual confounders.[39–41]

Although diabetes mellitus is complex and results from an interaction between genes and environment, studies consistently support that genetic factors are implicated in individual risk for type 2 diabetes mellitus. The environmental risk factors that are well known include, but are not limited to, age, sex, obesity, ethnicity, family history, low physical activity, smoking, low amount of dietary fiber and high amount of saturated dietary fat, elevated blood pressure, dyslipidemia, and some drugs such as diuretics and non-selective β-blockers. The genetic influence appears to be a multifactorial transmission of genes of which few have the preponderance of effect.[42] Given the genetic component of diabetes mellitus, we cannot rule out a possible genetic association with alcohol consumption and hypertension in patients with type 2 diabetes mellitus. Unfortunately, collecting genetic data of genes known to have associated risk factors was not performed in the ACCORD study and therefore could not be added to our models. Because of this, the genetic disposition of our population also remains a possible confounder. While we effectively removed time with diabetes mellitus as a confounder by adding it to our fully-adjusted model as it admittedly increases risks of cardiovascular complications,

we do not know the specifics of long-term diabetes mellitus control of participants before enrollment in ACCORD—only their glycated hemoglobin at the time of enrollment. Moreover, though medications in use at the time of ACCORD enrollment were recorded, data on cardiovascular and diabetes mellitus medication that was used by participants in the years before trial enrollment was not recorded and therefore could not be adjusted for in our models, resulting in a possible residual confounder.

Response bias must be considered as these data were collected from our population who self-reported the amount of alcohol consumed. This is compounded by the stigma of alcohol consumption, which may lead to a more heavily weighted response bias and possibly result in an underestimated effect of alcohol consumption on hypertension. Similarly, as the detailed patterns of chronic alcohol consumption throughout each participants' life were not captured, we cannot account for time-varying alcohol intake in our analysis.

In addition, selection bias is important to consider as this population is a clinical trial cohort with patients selected based on their higher risk of cardiovascular disease and may not be representative of and comparable to the general population of patients with type 2 diabetes mellitus. Since the ACCORD trial started enrolling participants nearly 20 years ago, a cohort effect could also be present, as the tools with which patients with type 2 diabetes mellitus were managed likely differ from today's current practice. The strengths of the study include the large sample size in a unique population of patients with type 2 diabetes mellitus. However, a data set with more participants meeting the criteria for moderate and heavy alcohol consumption would have been ideal.

CONCLUSIONS

Though decades of literature and epidemiological studies have suggested that light and moderate alcohol consumption may have beneficial effects on cardiovascular health, our work supports recent analyses suggesting that consumption of >7 drinks per week may be associated with elevated blood pressure, stage 1 and stage 2 hypertension in those with type 2 diabetes mellitus and particularly those with elevated cardiovascular risk. Moreover, our data indicate a dose-risk relationship between alcohol consumption and the degree of hypertension.

ARTICLE INFORMATION

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