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Association Between Metabolic Syndrome and Its Individual Components with Viral Hepatitis B

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Abstract

Background—The association between hepatitis B and metabolic syndrome (MetS) has not been well described. Overall epidemiologic evidences for this association have suggested conflicting results. The aim of our study is to determine the association between hepatitis B infection and MetS using large U.S. population database, the Third National Health and Nutrition Examination Survey (NHANES III).

Methods—Individuals with age ≥ 18 years were included in this study. MetS was defined according to NCEP/ATP III guideline. The chronic hepatitis B was defined as presence of hepatitis B surface antigen. The presence of hepatitis B core antibody with/without surface antibody, in absence of surface antigen was considered as past exposure to hepatitis B. To represent national estimates, weighted frequencies for chronic hepatitis B and past exposure to hepatitis B are reported. Multivariate logistic regression analysis accounting for age, gender, race, smoking and alcohol status was conducted to identify the independent predictor(s) of MetS.

Results—Our study cohort consisted of population total of 593,594 with chronic hepatitis B and 7,280,620 with past exposure to hepatitis B. Prevalence of MetS among included study cohort was 25.7%. Inverse association was observed between MetS and chronic hepatitis B (aOR: 0.32, 95% CI 0.12–0.84). Among individual components of MetS, waist circumference was inversely associated with chronic hepatitis B (aOR: 0.31, 95% CI 0.14–0.71). No significant association noted between past exposure to hepatitis B and MetS or its individuals components.

Conclusion—In this study, we noted significant inverse association between MetS and chronic hepatitis B.

Keywords

Metabolic syndrome; NHANESIII; hepatitis B

INTRODUCTION

The epidemic of metabolic syndrome (MetS) has been on the rise in conjunction with increasing prevalence of obesity in the United States. The presence of MetS has also been shown to be associated with different types of chronic liver diseases, notably nonalcoholic

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fatty liver disease (NAFLD) and hepatitis C infection. The association between NAFLD and the MetS is well established. NAFLD is part of the spectrum of the MetS and its presence signifies advanced histology in these patients (1, 2). It is now widely recognized that chronic hepatitis C (CHC) is associated with insulin resistance and type 2 diabetes (3). Despite the strong association with MetS among NAFLD and hepatitis C patients, the correlation between hepatitis B infection and MetS is still elusive.

Some studies have reported association between individual components of MetS and hepatitis B but others reported the contrary (4, 5). Among individual components, triglyceride levels have consistently been inversely linked with hepatitis B but association of other metabolic abnormalities (such as increased waist circumference or diabetes) with hepatitis B has not been conclusive (6–9).

Considering significant public health burden of hepatitis B with estimated prevalence of 800,000 to 1.4 million along with rising epidemic of MetS in United States, we aim to study and systemically determine the association between hepatitis B infection, and MetS and its individual components using a large U.S. population database, the third National Health and Nutrition Survey (NHANES III).

METHODS

The NHANES III is a survey conducted in the United States from 1988 through 1994 by the National Center for Health Statistics. The survey consisted of complex, multistage, stratified, clustered samples of civilian from 2 months age and older to collect information about their health and nutrition. The NHANES III was approved by the Center for Disease Control and Prevention's Institutional Review board. The details of study design and sampling methods are described elsewhere (10).

Study cohort and definitions

For this study, subjects with age <18 years old, with missing value for hepatitis B core antibody (Anti-HBc)/hepatitis B surface antigen (HBsAg), with missing values for individual components of MetS, with chronic hepatitis C (defined as positivity to anti-HCV), excessive alcohol use with elevated liver enzymes (ALT more than 40 U/l in men and more than 31 U/l in women, or AST more than 37 U/l in men and more than 31 U/l in women) and with elevated transferrin level >50% were excluded. After applying these criteria, our study cohort consisted of population total of 146,158,119 subjects.

Demographic details including age, sex, race, and education level were recorded. Social history including smoking and alcohol use were included and participants were appropriately categorized according to their current and past use. Current smoker was defined as history of ongoing smoking with or without >100 cigarettes in lifetime. Excessive alcohol consumption was defined as more than 2 drinks per day in men and more than 1 drink per day for women (11). The average alcohol consumption was calculated based on the responses to 2 survey questions that queried about the number of days of drinking over the past 12 months and the number of drinks on a given drinking day.

During the physical examination, subject's body weight, height, and waist to hip ratio were measured. The body mass index (BMI) was calculated and subjects with BMI ≥30 kg/m^2 were considered to be obese. The presence of MetS was determined based on the guidelines proposed by Third Report of the National Cholesterol Education Program Adult Treatment Panel (ATP III) (12). The ATP III clinical definition of the MetS requires the presence of 3 or more of the following: (1) waist circumference > 102 cm in men and > 88 cm in women; (2) a triglyceride level ≥ 150 mg/dl; (3) a high-density lipoprotein (HDL) level < 40 mg/dl in

men and < 50 mg/dl in women, (4) systolic blood pressure ≥ 130 mm Hg or diastolic pressure ≥ 85 mm Hg; and (5) fasting plasma glucose ≥ 110 mg/dl. Subjects with MetS were further stratified into 3 categories depending on the presence of MetS components (3, 4 or 5 metabolic abnormalities).

Laboratory Measurements

The laboratory procedures followed in the NHANES III are described in detail elsewhere (13). All venous blood samples were immediately centrifuged and shipped weekly at −20 °C to a central laboratory. Antibodies to hepatitis B core antigen were measured using solid-phase competitive immunoassay (RIA) while determination of hepatitis B surface antigen was performed using sandwich radioimmunoassay. Cholesterol and triglycerides were measured quantitatively by a peroxidase-catalyzed reaction and HDL was measured following the precipitation of the other lipoproteins. Low-density lipoprotein (LDL) was calculated by using the formula: LDL = total cholesterol – (triglyceride/5) – HDL. LDL was not calculated and reported as a missing value if the triglyceride level was > 400 mg/dl.

Definition of chronic hepatitis B infection

Chronic hepatitis B infection was defined as the presence of hepatitis B surface antigen. Individuals with positive hepatitis B core antibody in absence of surface antigen were considered to have past exposure to hepatitis B.

Statistical Analysis

Basic descriptive statistics, including weighted frequencies and means, weighted percentages, and standard error were used to characterize the study population. Appropriate comparison tests including chi-square test and student t test were used for comparison between groups for categorical variables and continuous variables respectively.

To represent national estimates, all analyses were conducted using appropriate sample weight and weighted frequencies are reported to represent cases of chronic hepatitis B, past exposure to hepatitis B, and controls. Logistic regression including univariate and multivariate analyses were conducted to identify independent predictors of MetS and its individual components. We further performed subgroup analysis by ALT level to evaluate the effects of chronic liver inflammation. ALT level more than 40 U/l in men and more than 31 U/l in women was considered as elevated ALT. Strength of association is reported as adjusted odds ratio (adjusted for age, sex, race, smoking and alcohol use) with 95% confidence interval and *p* value. *P*-value of less than 0.05 was considered statistically significant. SAS version 9.2 (SAS institute, Cary, NC) was used for data management and all statistical analyses.

RESULTS

After inclusion criteria, our study cohort consisted of population total of 593,594 chronic hepatitis B, 7,280,620 with past exposure to hepatitis B and 138,283,905 controls. The demographics and characteristics are shown in table 1. When compared to controls, those with chronic hepatitis B infection were predominantly male (68.1% vs 47.5%, $p < 0.001$) and less obese (9.3% vs 21.7%, $p = 0.012$). They also had a lower non-Hispanic white population compared to controls (43.1% vs. 78.3%, $p < 0.001$). There were no differences in the education level, smoking status, and alcohol use. Similarly past exposure to hepatitis B cohort were largely male (54.1% vs 47.5%, p = 0.011) and had a lower non-Hispanic white population (44.4% vs. 78.3%, $p < 0.001$), when compared to controls. They also had lower education level but higher prevalence of smoking.

Comparison of chronic hepatitis B individuals with controls

The prevalence of MetS was significantly lower in those with chronic hepatitis B infection compared to controls. (10.4% vs 25.6%, p = 0.019). On multivariate analysis this difference was also observed to be statistically significant (aOR: 0.32, 95% CI 0.12–0.84). However, when we considered the relationship between chronic hepatitis B infection and each individual component of MetS, we found the inverse association between chronic hepatitis B infection and waist circumference (aOR: 0.31, 95% CI 0.14–0.71). There were also significant inverse associations noted for chronic hepatitis B with low HDL and impaired fasting glucose (low HDL - aOR: 0.38, 95% CI 0.15–0.98 and impaired fasting glucose – aOR: 0.17, 95% CI 0.03–0.97). The stratified analysis by gender showed significant inverse association between chronic hepatitis B and MetS among male population (aOR: 0.14, 95% CI 0.04–0.55). (Table 2)

Comparison of past exposure to hepatitis B individuals with controls

The prevalence of MetS in those with previous exposure to hepatitis B was 29.3%, and was not different than that of controls (25.6%, $p = 0.078$). We did not observe significant association in the multivariate analyses after controlling for other covariates (aOR: 0.87, 95% CI 0.69–1.08). There was no significant association noted between past exposure to hepatitis B status and individual component of MetS. No association noted between past exposure to hepatitis B, and MetS or its individual components when we analyzed the data stratified by genders (Table 3).

Subgroup analysis by ALT level

Among subgroup with elevated ALT level, chronic hepatitis B individuals had significantly low rate of MetS compared to controls (2.1% vs 49.8%, $p<0.001$). This effect was not observed for individuals with past exposure to hepatitis B. Prevalence of MetS was 42.4% among individuals with past exposure to hepatitis B compared to 49.8% in controls ($p=0.583$).

Though difference in prevalence of MetS was not statistically significant among individuals with chronic hepatitis B (12.5%) and controls (24.5%) with normal ALT levels (p=0.051), definite trend was noted towards lower rate in chronic hepatitis B group. Difference in rate of MetS was not significantly different for past exposure to hepatitis B and controls with normal ALT levels.

Additional comparison analyses between individuals with chronic hepatitis B and past exposure to hepatitis B were conducted. Individuals with chronic hepatitis B had lower prevalence of metabolic syndrome (aOR: 0.35, 95% CI 0.13–0.97). Among individual components, waist circumference and low HDL and impaired fasting glucose were inversely associated with chronic hepatitis B in reference to past exposure to hepatitis B (Table 4).

DISCUSSION

HBV is a hepatotrophic virus that causes acute and chronic infection. At the molecular level, HBV X protein (*HBx*), 1 of 4 open reading frames in the HBV genome, has been implicated in regulating apoptosis, inflammation, and tumorigenesis (14, 15). Recent studies demonstrated that HBx causes hepatic steatosis through the transcriptional activation of sterol regulatory element-binding protein 1 (SREBP1) and peroxisome proliferator-activated receptor (PPARγ) transcripts(16), suggesting the involvement of HBx in the transcriptional regulation of lipid and glucose metabolism-related genes. Based on the molecular mechanism, it is plausible to hypothesize the relationship between chronic hepatitis B infection and the presence of MetS. In this large population based study, we systemically

examined the association between metabolic syndrome, and chronic hepatitis B and past exposure to hepatitis B. Our study results showed inverse association between MetS and chronic hepatitis B. However, when each component of MetS was analyzed, chronic hepatitis B infectivity was inversely association with waist circumference, low HDL and impaired fasting glucose. Our study results are consistent with previous study by Jan CF et al, which also suggested inverse association between MetS and chronic hepatitis B (4).

The mechanism underlying the inverse association between low HDL levels and chronic hepatitis B infection is unclear. However, it is plausible that chronic inflammatory cytokines which were found to be increased in subjects with chronic hepatitis B infection might play a role. The evidence suggests that changes in the adipokines in chronic hepatitis B individuals might be responsible for such derangements in lipid levels (17, 18). Similar observations regarding association between chronic hepatitis B and low HDL was reported in previous study. Higher level of HBV DNA levels were associated with lower HDL level (19). Due to lack of HBV DNA levels in our database, we were not able to perform such subgroup analysis. Likewise, it is still unclear on why chronic hepatitis B is inversely associated with impaired fasting glucose. Some studies have suggested association between hepatitis B and hyperglycemia while others refute this association (7, 8, 20). Our subgroup analysis by ALT level suggested significantly low rate of MetS among individuals with chronic hepatitis B in presence of elevated ALT level. This may suggest possible role of chronic liver inflammation leading to derangements in glucose and lipid levels. Cirrhosis might be responsible for development of such metabolic derangements rather than virus itself among individuals with chronic hepatitis B (21). Unfortunately we were not able perform subgroup analysis by cirrhosis status as NHANES III database does not provide histological data. Mechanistic or prospective studies are needed to verify these findings.

The strength of our study is the large sample size in NHANES III dataset and the study design allows the results to be extrapolated to the entire U.S. population. By using weighted statistical analysis we were able to demonstrate association of MetS among estimated 593,594 chronic hepatitis B individuals in U.S. population. Sample weights also allowed us to adjust for selection probabilities. However, our study has some shortcomings. First, the cross sectional study design did not allow us to examine the temporal association between chronic hepatitis B infectivity, and MetS and its individual components. Second, we do not have the data on HBV DNA levels or adipokines to further explore the metabolic outcomes of interest in different subgroups. Third, lack of liver histology data did not allow us to perform subgroup analysis by cirrhosis status.

In this large U.S. population database, we found significant inverse association between MetS and chronic hepatitis B. Among individual components of MetS, waist circumference, low HDL and impaired fasting glucose were inversely associated with chronic hepatitis B. We did not find significant association between past exposure to hepatitis B and MetS. Further well designed, longitudinal follow-up studies are required to confirm this associations between viral hepatitis B, and MetS and its individual components.

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Abbreviations

MetS	Metabolic syndrome

NHANES III	Third National Health and Nutrition Examination Survey
NCEP/ATP III	Third Report of the National Cholesterol Education Program Adult Treatment Panel
BMI	Body mass index
HDL	High density lipoprotein
LDL	Low density lipoprotein
HBsAg	Hepatitis B surface antigen
Anti-HBc	Hepatitis B core antibody

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Table 1

Baseline characteristics of study cohort

	Chronic hepatitis B Weighted % (S.E.)	Past exposure to hepatitis B Weighted % (S.E.)	Controls Weighted % (S.E.)
Age (in years)	40.9 (2.2)	48.9 (1.1)	42.9 (0.4)
Sex			
Male	68.1 (3.8)	54.1 (2.5)	47.5 (0.5)
Female	31.9 (3.8)	45.9 (2.5)	52.5 (0.5)
Race			
Non-Hispanic white	43.1 (9.9)	44.4 (3.2)	78.3 (1.2)
Others	56.9 (9.9)	55.6 (3.2)	21.7 (1.2)
Education			
Less than high school	18.6 (4.4)	40.0 (3.0)	23.6 (1.1)
High School	35.2 (7.1)	27.2 (2.4)	34.3 (0.9)
More than high school	46.2 (9.9)	32.8 (2.8)	42.1 (1.4)
Current smoker			
Yes	19.8 (4.5)	31.3 (2.2)	26.6 (0.9)
No	80.2 (4.5)	68.7 (2.2)	73.4 (0.9)
Heavy alcohol use			
Yes	4.2 (1.1)	6.6 (1.2)	7.2 (0.5)
No	95.8 (1.1)	93.4 (1.2)	92.8 (0.5)
BMI			
≤ 24.9	68.0 (5.0)	46.6 (3.2)	46.6 (1.0)
25–29.9	22.7 (4.2)	32.4 (3.0)	31.7 (0.5)
≥30	9.3 (2.0)	21.0 (2.0)	21.7 (0.8)
AST level (U/L)	34.0 (5.7)	21.2 (0.4)	20.5 (0.1)
ALT level (U/L)	37.0 (10.1)	16.8 (0.7)	16.8 (0.4)

Table 2

Odds ratio of the metabolic syndrome and its individual components in chronic hepatitis B individuals compared to controls

	Total		Men		women	
	Crude OR (95% CI)	**Adjusted OR* (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR+ (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR+ (95% CI)**
Metabolic syndrome	0.34	0.32	0.13	0.14	0.89	0.73
	0.13–0.87	0.12–0.84	0.04–0.44	0.04–0.55	0.30–2.65	0.22–2.46
3 components	0.53	0.48	0.21	0.21	1.41	1.14
	0.20–1.44	0.18–1.33	0.06–0.73	0.05–0.82	0.44–4.51	0.34–3.84
4 components	0.07	0.08	0.03	0.04	0.18	0.14
	0.02–0.33	0.02–0.35	0.01–0.21	0.01–0.27	0.03–1.15	0.02–1.13
5 components$^{\delta}$	-	-	-	-	-	-
High BP	0.66	0.53	0.47	0.44	1.05	0.82
	0.29–1.47	0.20–1.36	0.16–1.39	0.13–1.50	0.39–2.81	0.22–3.02
Waist circumference	0.32	0.31	0.20	0.20	0.65	0.47
	0.14–0.75	0.14–0.71	0.05–0.76	0.04–0.93	0.28–1.55	0.21–1.08
High Triglyceride	0.44	0.43	0.36	0.40	0.55	0.52
	0.16–1.24	0.14–1.30	0.10–1.29	0.10–1.60	0.14–2.16	0.14–1.94
Low HDL	0.37	0.38	0.44	0.49	0.26	0.23
	0.15–0.91	0.15–0.98	0.14–1.38	0.14–1.70	0.09–0.73	0.08–0.66
Impaired fasting glucose	0.20	0.17	0.02	0.02	0.72	0.45
	0.03–1.48	0.03–0.97	0.01–0.14	0.01–0.14	0.07–7.38	0.06–3.33

*Adjusted for age, sex, race, smoking and alcohol status

+adjusted for age, race, smoking and alcohol status

$^{\delta}$none of the individual with chronic hepatitis B had all 5 components

Table 3

Odds ratio of the metabolic syndrome and its individual components in past hepatitis B exposure individuals compared to controls

	Total		Men		women	
	Crude OR (95% CI)	**Adjusted OR* (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR+ (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR+ (95% CI)**
Metabolic syndrome	1.20	0.87	1.07	0.86	1.37	0.88
	0.98–1.47	0.69–1.08	0.82–1.38	0.63–1.16	1.05–1.78	0.66–1.16
3 components	1.06	0.77	0.90	0.73	1.25	0.83
	0.80–1.39	0.57–1.04	0.64–1.28	0.49–1.09	0.87–1.80	0.57–1.19
4 components	1.35	1.08	1.19	1.09	1.55	1.05
	0.97–1.89	0.79–1.48	0.75–1.89	0.69–1.72	1.01–2.38	0.67–1.65
5 components	1.53	1.37	2.04	1.87	1.20	0.99
	0.96–2.42	0.86–2.17	1.09–3.85	0.98–3.57	0.59–2.44	0.46–2.14
High BP	1.43	0.87	1.21	0.81	1.69	1.03
	1.10–1.86	0.65–1.17	0.86–1.70	0.56–1.16	1.26–2.27	0.73–1.46
Waist circumference	1.02	0.78	0.87	0.73	1.31	0.83
	0.82–1.28	0.62–0.98	0.63–1.21	0.51–1.06	0.99–1.73	0.63–1.08
High Triglyceride	1.10	0.92	1.10	1.02	1.02	0.79
	0.87–1.38	0.71–1.18	0.80–1.52	0.72–1.44	0.77–1.35	0.59–1.06
Low HDL	1.04	0.98	1.03	1.04	1.07	0.90
	0.84–1.29	0.76–1.25	0.74–1.43	0.72–1.50	0.83–1.38	0.66–1.22
Impaired fasting glucose	1.83	1.30	1.88	1.50	1.72	1.06
	1.3–2.42	0.97–1.73	1.25–2.83	0.99–2.28	1.24–2.39	0.75–1.49

*Adjusted for age, sex, race, smoking and alcohol status

+adjusted for age, race, smoking and alcohol status

Table 4

Odds ratio of the metabolic syndrome and its individual components in chronic hepatitis B individuals compared to past exposure to hepatitis B

	Total	
	Crude OR (95% CI)	**Adjusted OR* (95% CI)**
Metabolic syndrome	0.28	0.35
	0.10–0.76	0.13–0.97
High BP	0.46	0.66
	0.22–0.95	0.29–1.54
Waist circumference	0.31	0.41
	0.13–0.78	0.17–0.96
High Triglyceride	0.40	0.45
	0.14–1.16	0.15–1.38
Low HDL	0.35	0.39
	0.15–0.85	0.16–0.97
Impaired fasting glucose	0.11	0.12
	0.01–0.87	0.02–0.80

*Adjusted for age, sex, race, smoking and alcohol status