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Relationship between alcohol intake, body fat, and physical activity – a population-based study

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Abstract

Objectives—Aside from fat, ethanol is the macronutrient with the highest energy density. Whether the energy derived from ethanol affects the body composition and fat mass is debatable. We investigated the relationship between alcohol intake, body composition, and physical activity in the US population using the third National Health and Nutrition Examination Survey (NHANES III).

Methods—Ten thousand five hundred and fifty subjects met eligible criteria and constituted our study cohort. Estimated percent body fat and resting metabolic rate were calculated based on the sum of the skinfolds. Multivariate regression analyses were performed accounting for the study sampling weight.

Results—In both genders, moderate and hazardous alcohol drinkers were younger ($p<0.05$), had significantly lower BMI ($P<0.01$) and body weight ($p<0.01$) than controls, non drinkers. Those with hazardous alcohol consumption had significantly less physical activity compared to those with no alcohol use and moderate drinkers in both genders. Female had significantly higher percent body fat than males. In the multivariate linear regression analyses, the levels of alcohol consumption were found to be an independent predictor associated with lower percent body fat only in male subjects.

Conclusions—Our results showed that alcoholics are habitually less active and that alcohol drinking is an independent predictor of lower percent body fat especially in male alcoholics.

INTRODUCTION

In many parts of the world, drinking alcoholic beverages is a common feature of social gatherings. Once ingested, ethanol is immediately metabolized, yielding 7.1 kcal per each gram of ethanol (1). Aside from fat, ethanol is the macronutrient with the highest energy density and it affects the individual's total daily energy intake. Social drinkers tend to take alcohol with food thus ethanol seems to supplement food-derived energy (2). However, in heavy alcohol drinkers, energy derived from alcoholic beverages might replace, as opposed to supplement, the energy from other macronutrients such as carbohydrate and fat (2). The data available to support this notion are controversial, especially in social drinkers, where no

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positive correlation between the amount of alcohol intake and body weight has been observed (3). There is a paradoxical relationship, however, between the amount of alcohol consumed and body weight in chronic or heavy alcohol drinkers (4). In fact, weight loss, loss of temporal fat, peculiar body composition, and malnutrition are commonly observed in chronic drinkers (5). Studies of body composition of 34 male alcoholics vs. weight-matched controls showed that the alcoholics had significantly lower body fat mass (although a higher waist to hip ratio), suggesting that they were less capable of storing ethanol-derived calories as fat compared with controls (5). Another small study also found that alcoholics showed a lower body weight due to fat mass reduction (1). However, life style or physical activities which might interfere with body weight and fat have not been taken into the account in these studies. In order to study the relationship between alcohol intake, body composition, and physical activity in detail and expand the results of the previous studies to the population level, we explored such relationship using the data from third National Health and Nutrition Examination Survey (NHANES III). We hypothesized that the energy derived from alcohol intake has the influence on body weight and fat composition after adjusting for levels of daily physical activity.

METHODS

NHANES III was conducted in the United States from 1988 through 1994 by the National Center for Health Statistics of the Centers for Disease Control and Prevention. The NHANES III survey used complex, multi-stage, stratified, clustered samples of civilian, non-institutionalized populations of age 2 months and older to collect information about the health and diet of people residing in the United States. A detailed description of the survey and its sampling procedures are available on its website, http://www.cdc.gov/nchs/nhanes.htm. This study was approved by the CDC Institutional Review Board and all participants provided written informed consent.

Study cohorts and definition

During the survey period, 18,162 subjects underwent physical examination and laboratory assessment at a mobile examination center. We excluded subjects who were < 20 years old (n= 1,132) and those who were pregnant (n=280). In addition, those with missing values of the following variables were also excluded: hepatitis B (n=74) and C (n = 390) serologies, body mass index (n = 80), aspartate aminotransferase (AST) or alanine aminotransferase (ALT) (n=1,297), drinking history (n = 1,255), or anthropometric measurements (n=3,104). A total of 10,550 subjects constituted our study cohort.

We used the responses to two survey queries that questioned the number of days of drinking over the past 12 months and the number of drinks per day on a given drinking day to determine the average alcohol consumption. Moderate alcohol use was defined as up to two drinks per day for men and one drink per day for women. Hazardous alcohol consumption was defined based on the potential risk for alcohol-related problems, which is estimated to be men who drank > 2 drinks per day, and women who drank > 1 drink per day (6;7). The maximum drinking limits are equivalent to 28 and 14 grams of alcohol per day in men and women, respectively. The quantitative levels of alcohol drinking per day was calculated based on the standard drink of alcohol beverage in the United States contains about 14 grams of pure alcohol.

Anthropometric measurement and estimation of body fat mass

The detailed anthropometric measurements were described in detail in the NHANES Manual (8). In brief, weight and height were determined according to standardized procedures. Weight was recorded to the nearest 0.1 kg, while height was recorded to the nearest 0.1 cm.

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Body mass index (BMI) was calculated as weight (kg) divided by height (s) squared (m^2). The anthropometric measurements were taken on the right side of the body using standard procedures, except for a few measurements that were taken on the left side because of examinees' limitations. The measurements were recorded to the nearest 0.1 mm. All skinfolds were measured using Holtain skinfold calipers. The triceps skinfold was measured on the posterior surface at the midpoint of the right upper arm with the examinee standing erect and the arms hanging freely at the sides. The suprailiac skinfold was measured at a 45-degree angle at the marked iliac crest. The subscapular skinfold was measured in the standing position with the subject's shoulders and arms relaxed at the side. The measurement was made from a fold of skin and subcutaneous adipose tissue directly below (1.0 cm) and medial to the inferior angle of the scapular. Percent body fat was calculated based on the sum of the skinfolds as proposed by Durnin and Womersley (9).

Resting metabolic rate calculation

Resting metabolic rate (RMR) was estimated based on the measurement of subscapular skinfold using Kashiwazaki's equation (10).

Estimation of physical activity

Physical activity assessment was part of the comprehensive interview in NHANES III. In brief, subjects were asked to identify specified exercises in which they participated during their free time (jogging or running; riding a bicycle or exercise bicycle; swimming; aerobic dancing; other dancing; calisthenics or floor exercises; gardening or yard work; and weight lifting). They were inquired to specify the number of times they participated in an identified activity during the past month. Responses were standardized as 'times per week' using the conversion factors 4.3 weeks per month and 30.4 days per month, then rounded to the nearest whole number. The frequency of performance of other reported exercises, sports or physically active hobbies was also recorded. The physical activity was specified as the sum of intensity rating multiplied by times (of each activity) per month (11).

Laboratory Measurements

The laboratory procedures followed in the NHANES III are described in detail elsewhere (8). All venous blood samples were immediately centrifuged and shipped weekly at −20 °C to a central laboratory. In brief, serum biochemistries (such as ALT and AST) concentrations were assayed using a Hitachi 737 Analyzer (Boehringer-Mannheim Diagnostics, Indianapolis, IN).

Statistical analysis

Descriptive statistics such as means, standard deviations (SD), ranges, and percentages, were used to characterize the study patients. Comparisons among groups were made using Analysis of Variance for the continuous and chi-square (χ^2) test for the categorical variables. To avoid any arbitrariness in the choice of a cutoff point, we further stratified the amount of alcohol consumption in subjects who reported history of hazardous alcohol use into four groups using quartiles.

Physical activity data were not normally distributed. Log transformation for physical activity variable was performed to determine its association with alcohol consumption using linear regression.

Multivariate regression analyses were performed accounting for the study sampling weight. Variances were computed using the Taylor Linearization Method, assuming a with replacement (WR) design. Least square mean of the percent body fat were adjusted for age, race, smoking habits, poverty income ratio, and physical activity in the multivariate analysis.

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Because the cut-off for significant alcohol use was different between male and female, the analyses were performed separately based on sex. All statistical analyses and database management were performed using SUDANN software accounting for stratification, sample weight, and clustering. The analysis method also accounts for different sample weights and the effects of the complex sample design on variance estimation.

Results

Relationship between body composition and alcohol consumption in male

Among male participants (n= 5,529), 39% reported history of no alcohol use; whereas 51% were moderate drinkers and 10% had significant hazardous alcohol consumption (Table 1). Moderate and hazardous alcohol drinkers were younger than non-drinkers ($p < 0.05$). Body weight and BMI did not differ among each drinking group except that subjects who drank > 70 grams of alcohol/day had the lowest body weight and body mass index ($p < 0.01$). As expected, there was a significant correlation between body weight (Pearson Correlation Coefficients, $r = 0.64$, $p < 0.01$) and body mass index ($r = 0.72$, $p < 0.01$) with percent body fat. Significantly higher levels of AST and ALT were found in those with hazardous alcohol consumptions when compared to non-drinkers. Alcohol drinking had no effect on resting metabolic rate. Those with hazardous alcohol consumption had significantly less physical activity compared to those with no alcohol use and moderate social drinkers (Figure 1A). There were no differences in waist- to hip- ratio among groups. In the univariate analysis, percent body fat was significantly lower in those who drank any levels of alcohol when compared to non-drinker controls and the decrease in percent body fat was correlated with the amount of alcohol consumption. In the multivariate linear regression analyses adjusting for covariates (such as age, and physical activity), the levels of alcohol consumption were found to be an independent predictor associated with lower percent fat mass in these subjects (Table 3). The adjusted percent body fat stratified by alcohol consumption is shown in Table 4.

Relationship between body composition and alcohol consumption in females

As observed with male participants, women with a history of hazardous alcohol consumption were younger ($p < 0.05$), had significantly lower BMI ($P < 0.01$) and body weight ($p < 0.01$) than controls, non drinkers (Table 2). Again we found the significant correlations between body weight ($r = 0.70$, $p < 0.001$) and body mass index ($r = 0.77$, $p < 0.001$) with percent body fat. Again, no differences in waist-to- hip ratio were observed among groups, and as with their male counterparts, alcohol drinking had no effect on resting metabolic rate in female. Those with hazardous alcohol consumption were less physically active compared to non-drinkers (Figure 1B). Females had significantly higher percent body fat than males. In the univariate analysis, we found that percent body fat was significantly lower in female with a history of hazardous alcohol consumption when compared to non-drinkers. However, after controlling for other variables in the multivariate analysis, the levels of alcohol consumption were not associated with lower percent fat mass in female subjects (Table 3). The adjusted percent body fat stratified by alcohol consumption is shown in Table 4.

DISCUSSION

In this large population-based study, we found that: i) subjects having higher alcohol consumption were habitually less active, and ii) there was a gender difference in the effect of alcohol on body composition and percent body fat.

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The effect of alcohol consumption on body composition and body weight has been debatable. The conflicting results of several studies are likely related to variation in drinking behavior, physical activity, and food intake. When the energy derived from alcohol is added to that from food, it is conceivable that alcoholics should gain weight because of energy excess and inhibition of fat oxidation from alcohol (12). However, several epidemiological studies, including ours, show that alcohol intake does not systematically increase body weight, leading to the suggestion that higher physical activity (thus increasing energy expenditure) in heavy drinkers could explain this. In a study by Westerterp et al., alcohol intake as part of total food energy was measured with a 7-day dietary record in a 44 alcoholic subjects (22 female) and physical activity was monitored with a tri-axial accelerometer for movement registration (2). Mean alcohol intake ranged from 0 to 55 grams/day. This study found that the higher alcohol intake, the higher activity level. The dissimilarity between Westerterp's and our studies deserved further discussions. First, the mean alcohol intake in our report was significantly higher than that in Westerterp's study (2). Drinking alcohol at the high levels might interfere with cognitive function and impair physical health leading to sedentary/limited lifestyle. Second, the methods used to measure physical activity were different. While the accurate assessment of physical activity is possible especially in the laboratory, the measurement of physical activity in a free-living environment over a period of several days poses challenges. Tri-axial accelerometers allow assessment of physical activity over intervals that are long enough to be representative for normal daily life, and it has been shown to be an objective and reliable tool that can be used to distinguish activity levels between subjects (13). However, this assessment has shortcomings. Accelerometers are generally worn on the hip, which limits their ability to detect upper body movements and during walking they cannot detect grades or whether an individual is carrying a load (13). The measurement of physical activity in NHANES was based on questionnaire-based recall for estimating physical activity in a free-living environment over the past 30 days, and as such, it might suffer from errors associated with respondent recall and bias. Despite these differences, we observed the trend of decreasing physical activity even in those who reported drinking alcohol at the levels which is slightly above moderate drinks in both genders.

We also found the ethanol drinking is associated with lower percent body fat, but not waist-to- hip ratio, especially in male subjects, when controlling for covariates, such as physical activity and race. As pointed out by Addolorato et al., decreasing in body fat in male participants might be associated with the alteration in fuel use resulting in increased lipid peroxidation in chronic alcoholics (5). Such alterations could be due to the induction of the non-alcohol dehydrogenase pathway (which is seen in moderate drinkers), likely the microsomal ethanol oxidizing system (1;5). Moreover, ethanol might have the direct effects on human adipocytes. Our group has discovered that human adipocytes express the alcohol metabolizing enzymes such as alcohol dehydrogenase and aldehyde dehydrogenase, and thus can metabolize alcohol (personal communication). Ethanol may also interfere with fat metabolism in the adipose tissues because of its ability to metabolize ethanol leading to alteration in fat composition. The gender-difference on the ethanol effects on body fat is intriguing. It leads us to hypothesize that its effect might be related to ethanol metabolism which differs between genders. Further studies are needed to address this observation.

Several limitations in using NHANES datasets deserve discussion. First, the cross sectional design in NHANES does not enable us to truly address potential temporal associations between significant alcohol consumption and the variables of interest. Second, the accuracy of the alcohol consumption data, as with other retrospective study design, is unknown. Since the amount of alcohol consumption will be derived from self-report questionnaires, it is vulnerable to a recall bias in each participant.

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In summary, our results showed that alcoholics are habitually less active and that alcohol drinking is an independent predictor of lower percent body fat especially in male alcoholics when controlling for the levels of physical activity.

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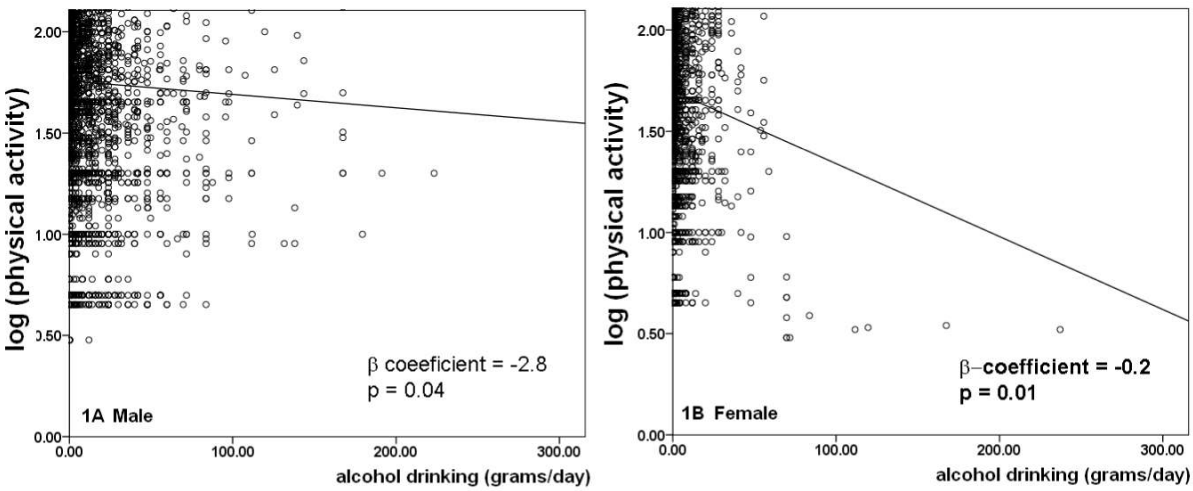

Figure 1.

Relationship between the levels of physical activity and alcohol consumption in male (1A) and female (1B) subjects. Physical activity was log-transformed to produce a normal distribution. The levels of physical activity were inversely related to the amount of alcohol consumption in both genders.

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TABLE 1

Clinical and anthropometric characteristics in male cohorts (n = 5,529)

	Non drinkers (n= 2145)	Moderate drinkers (≤ 28 grams/d) (n = 2797)	Significant alcohol consumptions				p-value
			29-40 grams/d (n=137)	41-48 grams/d (n=117)	49-70 grams/d (n=173)	>70 grams/d (n=160)	
Age (yrs)	55±19	44±18	41±14	42±15	40±15	42±17	< 0.05*
Race White Black others	71.2 25.4 3.4	73.1 23.4 3.5	69.3 28.5 2.2	72.7 24.8 2.5	75.7 21.4 2.9	72.5 23.1 4.4	< 0.01 ζ
Race-ethnicity Non-hispanic white Non-hispanic black Mexican American Others	46.1 24.7 25.5 3.7	43.8 22.7 29.9 3.6	40.9 27.0 28.5 3.6	34.2 24.8 37.6 3.4	36.4 20.8 40.5 2.3	38.7 23.1 34.4 3.8	< 0.05 ζ
Poverty Income Ratio	2.3 ± 1.6	2.8 ± 1.9	2.8 ± 2.0	2.5 ± 1.9	2.4 ± 1.5	2.2 ± 1.4	< 0.01 γ
Body mass index (kg/m^2)	26.4±4.2	26.0±3.8	26.3±3.9	26.1±4.2	26.5±4.2	25.4±4.6	< 0.01ζ
Body weight (kg)	78.9±14.6	79.1±13.5	80.2±13.8	78.9±13.7	80.5±14.3	76.6±16.0	< 0.01ζ
Waist to hip ratio	0.9±0.1	0.9±0.1	0.9±0.1	0.9±0.1	0.9±0.1	0.9±0.1	NS
AST (U/L)	22±9	23±14	26±15	27±20	28±17	35±16	< 0.05 ζ
ALT (U/L)	18±12	20±16	22±16	24±28	24±21	26±13	<0.05 ζ
%body fat	26.0±6.8	25.3±6.6	24.1±7.1	23.8±6.3	23.4±6.5	22.2±6.9	<0.05 *
Resting metabolic rate (Calories/day)	1872±272	1888±252	1916±261	1899±258	1931±270	1859±290	NS
Physical activity	148.4	163.5	84.1	77.9	64.2	61.4	<0.05 *

*Statistical significance was found when compared each hazardous drinking category to controls, non drinkers.

ζSignificant difference when compared those who drank > 70 grams/day compared to controls.

γSignificant difference when compared moderate drinkers and those who drank 29-40 grams/day compared to controls

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TABLE 2

Clinical and anthropometric characteristics in female cohorts (n= 5,021)

	Non drinkers (n=3302)	Moderate drinkers (≤ 14 grams/d) (n = 1446)	Significant alcohol consumptions				p-value
			14-18 grams/d (n=77)	19-24 grams/d (n=80)	24-28 grams/d (n=44)	>28 grams/d (n=72)	
Age (yrs)	52±20	43±16	39±14	38±14	38±15	39±14	< 0.05*
Race (%) White Black others	71.2 25.4 3.4	76.4 21.4 2.2	76.6 23.4 -	81.3 18.7 -	88.6 11.4 -	65.3 31.7 3.0	< 0.05 *,ζ
Race-ethnicity Non-hispanic white Non-hispanic black Mexican American Others	44.0 24.4 26.9 4.7	56.2 20.9 19.7 3.2	57.1 23.4 19.5 -	70 18.8 11.2 -	77.3 13.6 9.1 -	47.2 31.9 20.9 -	< 0.05 *,ζ
Poverty Income Ratio	2.2 ± 1.6	3.1 ± 2.0	−3.1 ± 2.1	−3.1 ± 2.1	−3.1 ± 2.1	−2.4 ± 1.8	< 0.01 γ
Body mass index (kg/m^2)	26.5±5.1	25.5±4.8	24.5±4.4	24.1±3.6	24.8±4.1	24.9±5.9	< 0.01*
Body weight (kg)	67.2±13.9	66.9±13.6	64.1±11.7	64.8±11.5	64.2±11.1	64.2±15.1	< 0.01*
Waist to hip ratio	0.8±0.1	0.8±0.1	0.8±0.1	0.8±0.1	0.9±0.1	0.8±0.1	NS
AST (U/L)	20±14	19±8	21±9	21±28	24±16	24±14	< 0.05 ζ
ALT (U/L)	15±14	14±10	14±10	14±15	15±13	19±16	<0.05 ζ
%body fat	36±6.3	34±6.6	33±6.5	33±5.9	34±6.1	33±6.6	<0.05 *
Resting metabolic rate (Calories/day)	1571±247	1579±234	1549±201	1562±214	1534±195	1568±270	NS
Physical activity	132.7	162.9	94.6	93.3	84.8	65.8	<0.05 *

*Statistical significance was found when compared each hazardous drinking category to controls, non drinkers.

ζSignificant difference when compared those who drank > 28 grams/day compared to controls.

γSignificant difference when compared each category of drinking (except for those who drank > 28 grams/day) compared to controls.

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Table 3

Associations between the variables of interest and percent body fat – multivariate analyses

	Male			Female		
Variables	**Parameter estimate**	**Standard error**	**p-value**	**Parameter estimate**	**Standard error**	**p-value**
Age	0.12	0.01	< 0.01	0.08	0.01	< 0.01
Physical activity	−0.0001	0.0001	0.27	−0.001	0.0001	0.72
Race	−0.34	0.09	0.004	0.16	0.10	0.12
Smoking	−0.04	0.05	0.42	−0.16	0.05	0.02
Poverty income ratio	0.36	0.03	<0.01	0.21	0.03	<0.01
Alcohol consumption	−0.20	0.05	<0.001	−0.07	0.06	0.25

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Table 4
Association between least square means of percent body fat and alcohol consumption

Male subjects	%body fat	Female subjects	%body fat
Non drinkers	25.1±0.1	Non drinkers	35.7±0.1
Moderate drinkers	24.8±0.1	Moderate drinkers	35.5±0.1
Alcohol consumption (grams/day)		Alcohol consumption (grams/day)	
29-40 41-48 49-70 >70	24.8±0.4 24.5±0.5 24.1±0.4* 23.7±0.2*	14-18 19-24 24-28 >29	35.1±0.6 35.6±0.5 35.9±0.4 34.8±0.5

Multivariate linear regression analysis was performed adjusting for age, race, smoking status, levels of physical activity, and poverty income ratio. Variances were computed using Taylor Linearization method accounting for the sampling weight.

* ($p < 0.01$, when compared to non and moderate drinkers).