Pergamon

Pharmacology Biochemistry and Behavior, Vol. 49, No. 3, pp. 629-638, 1994

0091-3057/94 $6.00 + .00

0091-3057(94)00190-1

Effect of Spontaneous Alcohol Intake on Heart Rate and Dietary Intake of Free-Living Women

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Received 31 August 1993

OROZCO, S. AND J. M. DE CASTRO. *Effects of spontaneous alcohol intake on heart rate and dietary intake of free-living women.* PHARMACOL BIOCHEM BEHAV **49**(3) 629-638, 1994.—Moderate alcohol consumers obtain excess calories from alcohol and these additional calories do not result in weight gain. This study examined the contribution of alcohol to the total caloric intakes and expenditures of light to moderate alcohol consumers and compared the data to soda drinkers. Physical activity levels were measured by employing continuous heart rate monitoring for a 6-day normal phase and a 6-day abstinence phase. The normal food intake of both groups was recorded in diet diaries. Subjects' overall intake of food energy during the alcohol week was significantly higher than during any of the other three phases (an excess of 241 kcal/day). This study suggests that excess alcohol calories are compensated by an increase in energy expenditure, as evidenced indirectly by increased heart rates occurring between the hours of 2300 and 0700 h, increased self-reported nightly restlessness, increased wake time, and exercise.

Feeding pattern Alcohol Physical activities Calories Heart rates Soda

A LARGE proportion of the population obtains a substantial amount of calories from alcohol. In nonalcoholic individuals, it has been observed that calories absorbed from alcohol are added to those from ingested foods; therefore, total energy intake is increased compared with that of individuals who do not drink (16). In studies investigating the relationship between dietary intake and alcohol consumption, calories derived from alcohol were added to the diet instead of replacing the calories derived from other nutrients (3,21,22), but nonalcohol energy intake was not significantly different; thus, alcohol calories were simply added to the food calories consumed (12,24). In addition, in the elderly, alcohol consumption did not displace food energy, but added to their diets instead (ages of 65 to 90) (15).

In a more recent study, the energy consumption of moderate alcohol consumers was observed during a 5-day period during which the subjects were allowed to drink as they do normally (alcohol week) and a 5-day period in which the subjects were to refrain from drinking any alcoholic beverages (no-alcohol week) (28). During the alcohol week, subjects consumed an additional 218 kcal a day in addition to the food calories consumed without altering any other macronutrient intake. In fact, when the alcohol calories were subtracted from the total energy intake, the intakes for the two conditions were almost identical. Although moderate alcohol consumers may be consuming excess energy, they do not store more calories than nondrinkers.

People tend to add alcohol to their diets rather than displacing food with alcohol, but those who drink alcohol are not the heaviest women and men, although they consume more calories a day than nondrinkers (3,16,19,22,24). In alcoholic subjects given ethanol under metabolic ward conditions, with 50% of the total caloric intake supplied by isocaloric substitution of ethanol for carbohydrates, there was a significant loss of body weight (29). An extra 2,000 kcal/day as chocolate for 14 days in one subject increased body weight, whereas 2,000 kcal/day as ethanol resulted in no significant increase in weight. Similarly, when alcohol calories were added to the food intake of overweight men, the use of alcohol was unrelated to the subjects' level of adiposity (7).

These results are compatible with other experiments done on healthy nonalcoholic men (26). Moderate alcohol consumers that were housed in a metabolic unit for four consecutive 18-day experimental periods and given alcohol between 22 and

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25% as total calories tended to lose weight even if all of the diets for a given individual were calculated to be isocaloric. In another study, the addition of alcohol calories to the baseline diet of moderate alcohol consumers did not cause weight gain in the lean individuals. The investigators noted that an extra 630 calories per day for 30 days should have produced an increment of 5.25 pounds. However, this was not observed (9). In another study, weight loss during the high ethanol (60% of total energy intake) feeding could not be attributed to excessive heat loss and negative energy balance (31). Other studies have also found a clear inverse relationship between alcohol intake and body mass index (8).

It is unclear what is the nature underlying mechanisms by which moderate alcohol consumers seem able to consume an additional amount of energy from alcohol, yet avoid having the excess calories be reflected in their body weight. In the energy balance equation, resting metabolic rate, energy input, the thermogenic effects of the food, and the activity level of the individual must be accounted for (30). The previous research has focused mainly on the first three variables and ignored the activity levels as a possible link to the missing calories.

Of the more than 30 studies examining the association between alcohol intake and adiposity levels in the general population, only six have looked at activity levels, and three of those studies did not even describe the relation between activity levels and alcohol intake (20). In one of the three studies that did examine the independent effect of alcohol intake on exercise, the investigators found that fewer moderately drinking men reported exercising regularly, and only 10% of women reported regular exercise, and this did not differ significantly with alcohol usage (22). Another study found the activity levels of men unaffected by alcohol intakes, whereas women drinkers had slightly higher activity levels than nondrinkers (19). And thirdly, an examination of the electrocardiogram of different social drinkers who ran on a treadmill at different levels of alcohol consumption found that only at high levels did alcohol consumption cause an irregular heart rhythm (32). Other studies have found greater intensity activity was associated with greater alcohol intake (17). Similarly, an investigation of the relationship of physical activity to alcohol consumption in youth (ages 15–16) found a significant positive association between physical activity and alcohol consumption in men, but not women (14).

In contrast, another study found that people at different levels of alcohol consumption are not more active necessarily (5). Other studies also have reported no relationship between alcohol consumption and physical activity (4). Although these studies all mentioned activity levels, there was not a clear relationship between activity levels and moderate alcohol consumption that might explain the disposition of the excess alcohol calories.

The present study used food intake diaries as a method of assessing the food and alcohol intakes of both the group of moderate alcohol consumers and the group of nonalcohol consumers. Each subject also recorded her physical activities and wore a heart rate monitor for the duration of the experiment. Although from this study the discrepancy is still not thoroughly explained, two findings did emerge. It was found that the most significant impacts of moderate alcohol consumption on humans were: a) its high caloric contribution without compensation and b) indirect evidence for higher energy expenditures including increased heart rates occurring between 2300 and 0700 h, self-reported decreased sleep duration, and increased wake time exercise.

METHOD

The details of the procedure are available in prior publications (10,11). Therefore, they will only be briefly summarized here. The study was conducted under the ethical guidelines of the National Institutes of Health and the American Psychological Association.

Subjects

Twenty-four women were recruited from Georgia State University. Participants received research participation credit towards satisfaction of an introductory psychology course requirement, a detailed nutritional analysis of their reported diets, and information about their metabolic rate. All subjects completed a Georgia State University Medical Health History form, were nonsmokers, nondieters, within an acceptable body weight as determined by the 1983 Metropolitan Life Insurance Co Height and Weight Table, not taking any medication likely to interfere with their dietary intake or metabolic rate, had no prior history of menstrual cycle complications or irregularities, and none were pregnant or nursing. Thirteen of the women recruited were light to moderate alcohol consumers as measured by the Michigan Alcoholism Screening Test (MAST) and 11 were soda drinkers, who rarely consume alcohol (0–2 times a year). The mean ages, height, weight, and other descriptive data for both groups are detailed in Table 1.

Apparatus

Food intake diary. The pocket-sized food intake diaries were approximately 8 × 18 cm and contained detailed instructions at the beginning on how to complete the diaries. Data collected in the diary for each meal/snack included seven-point Likert-scales that measured before and after each entry 1) the attractiveness of the food: bad–good, 2) their state of hunger: full–hungry, 3) and thirst: sated–thirsty, and 4) their moods: depressed–elated and calm–anxious. On the scales, for example, one indicated very full, whereas seven indicated very hungry, with four being a neutral response. The subjects also recorded the day of the week, the time the meal began and ended, whether it was a snack or a meal, whether it was eaten alone or in the presence of others, and the number. Subjects also recorded the number of men and women present, their relationship to the subject, and the number of people consuming any alcoholic beverages. The subjects also recorded their daily physical activities, the time the activity began and ended, and how strenuous this activity was for them on a seven-point Likert-scale, with 1 being not strenuous at all, 7 being extremely strenuous, and 4 being moderate. Finally, the subjects gave a detailed description of each meal including exactly what foods they ate, the amounts, and how they were prepared (the full ingredients and quantity). All subjects also kept a sleep log indicating the times they went to sleep and woke up, the number of times they woke up during the night, how alert they were when waking and how alert they were overall during the day on a 7-point Likert-scale, with one being very alert, 7 being cannot stay awake, and 4 being a little foggy.

Heart rate monitor. The subjects were equipped with the Polar Vantage XL Heart Rate Monitor (Polar Electro XL, Stamford, CT). The heart rate monitor has a sensor/transmitter attached onto an elastic band, which adjusts snugly on the subject's chest just below the pectoral muscle (breasts). The wrist monitor goes on just like an ordinary wrist watch. The monitor was programmed to record heart rates every minute and can record up to 33 consecutive h. Each monitor was then

TABLE 1

CHARACTERISTICS OF THE ALCOHOL AND SODA GROUPS

	Alcohol Group (n = 13)			Soda Group (n = 11)		
	Mean	Range	SEM	Mean	Range	SEM
Age*	30.23	18–50	2.55	21.27	18–29	1.05
Height (m)	1.63	1.57–1.72	0.34	1.65	1.49–1.77	1.02
Weight (kg)	59	47–86	7.26	57	47–75	5.26
% Body fat	25.67	19–30	0.83	26.06	21–30	0.89
Resting Metabolic Rate: (kcal/min)	0.96	0.85–1.07	0.080	0.967	0.85–1.05	0.07
Physical† Activity Level (Avg/minutes/per week)	166	0–600	On Phase 44.14	93	0–630	66.70
	109	0–423	Off Phase 29.89	27	0–260	25.88
Sleep‡ Duration/Avg/h/per night	7.14		On Phase 14.60	8.08		17.66
	7.36		Off Phase 10.31	8.06		18.68
Wake-up§ Number/times/night	1.68		On Phase 1.07	0.697		0.76
	1.34		Off Phase 0.62	0.633		0.37

*$F(1, 26) = 7.33, p < 0.05$.
†$Z = -2.06, p < 0.05$.
‡$F(1, 21) = 6.84, p < 0.05$.
§$F(1, 48) = 14.67, p < 0.001$.

downloaded into a computer file containing the subject's heart rates for each minute of the 12-day period.

Procedure

The subjects were asked to provide the names of two people with whom they most often ate to verify the diary reports. To promote adherence during the alcohol abstinence phase, the subjects also were told that the heart monitors that they were wearing would possibly detect alcohol intake. After the subjects had signed an informed consent form, they were given a food diary for their food/alcohol intake. After the completion of 1 day's diary entry, the subject and the experimenter reviewed the diary for proper recording and clarification of any difficulties.

The subject's baseline cardiac/exercise stress measures were obtained on the fifth day of their menstrual cycle, after having refrained from food and strenuous physical activity for at least 3–4 h. For the purpose of this study, testing was terminated when the subject reached 85% of the predicted maximal heart rate for age and level of fitness. An electrocardiogram (ECG) was conducted during the exercise stress using the Balke-Standard protocol (27). The subjects also wore the Polar Vantage XL Heart Rate Monitor during the ECG to examine the interrelationship between the ECG and the daily heart rate monitors to be worn for the duration of the experiment. Cardiac frequency is linearly related to VO_2 in most subjects during exercise and, therefore, oxygen consumption was measured during the exercise stress test using a breath-by-breath Med Graphics cart to empirically establish a linear prediction of energy expenditure based on cardiac frequency.

The subjects were weighed and skin-fold measurements were used to estimate body composition. The subjects then sat quietly in a comfortable chair and were instructed on the proper procedures of the Polar Vantage XL Heart Rate Monitor. The subjects were required to wear the heart rate monitors 24 h a day (with the exception of the shower time) for the entire experimental period.

The subjects underwent recording for two consecutive 6-day periods. The alcohol/soda phase consisted of 6 consecutive days during which the subjects were allowed to consume alcohol or soda as they would normally. The abstinence phase constituted 6 consecutive days in which the subjects refrained from consuming any sodas (soda group) or alcohol (alcohol group). The order of the phases was counterbalanced.

After the completion of the 12-day diaries, all subjects indicated compliance and honesty. Immediately after the completion of the 12-day diaries, the experimenter twice contacted the indicated family member, spouse, roommate, etc., to verify the entries in the diaries. The people contacted were given the date and location of the meal and were asked to name everything the subject ate. There were no instances of disagreement between the meal reported in the diary and the recall of the verifier.

Data Analysis

Food diary analysis. After the food diaries were checked and verified, the food and alcohol items were coded by a registered dietitian using a computer file of over 3500 food items created from the U.S. Department of Agriculture Handbooks numbers 8 and 456 of the Nutritive Value of American Foods. All food and liquid items were broken down into individual components, then given codes and entered into a computer for analysis.

The computer program then summed together the nutrient compositions of the food items recorded for each meal. Meals were defined based on two criteria, the amount of total food energy consumed in the meal, and the interval of time, in minutes, since the last meal. The computer took the entire set of codes defined as a meal and evaluated the nutritional composition of each individual item and summed them for each meal. Five meal definitions were used; in the first there had to be a minimum of 50 kcals ingested with a minimum interval since the last meal of at least 15 min. Four other definitions of 50 kcal and 45 min, 100 kcal and 45 min, 200 kcal and 45 min, and 50 kcal and 90 min were employed. Next, the computer program took the entire set of codes defined as a meal and evaluated the nutritional composition of each individual item and summed them for each meal. These meals were then characterized by their caloric content and composition of carbohydrates, fat, protein, vitamins, minerals, and alcohol. The composition of the meals was summed over the day to calculate the overall daily dietary intakes.

For the alcohol phase, those days on which drinking occurred was separated from those days without any alcohol intake and analyses were performed on the overall intakes and average meal sizes occurring on alcohol days and no-alcohol days within the alcohol phase. A 2 × 2 ANOVA was used to analyze the means of the alcohol days vs. the no-alcohol days during the alcohol phase for the drinkers and the soda vs. no-soda days for the nondrinkers.

The recordings of the heart rate monitors were calculated as daily means. The 24-h recording period constituted the hourly averages of the minute-by-minute heart rate data collected starting at 1900 h and ending at 0700 h. The 2 × 2 ANOVA was used to test for the differences between the four phases. The 2 × 2 ANOVA also was used to test for the differences in the mean expenditures obtained for the soda days and the no-soda days of the soda phase vs. the alcohol days and the no-alcohol days of the alcohol phase.

The data also were analyzed by time of day. Heart rates were broken down into hourly means and compared between all conditions. The heart rate data were further divided into three time periods consisting of 0700–1500 h, 1500–2300 h, and 2300–0700 h. The 2 × 2 × 3 ANOVA was used to test for the differences in the mean expenditures obtained between the four phases.

RESULTS

Thirty-five subjects began the study, two dropped out halfway through the study due to the discomfort of wearing the heart rate monitors, two others were eliminated because of substantial data loss due to faulty heart rate monitors, and one subject's food intake diary was never received. Another subject was dropped due to poor record keeping. Five subjects from the alcohol condition were dropped because they consumed a very low amount of alcohol during the alcohol condition (<10 g [70 kcal] of alcohol/day). The final count included 24 subjects, 13 alcohol and 11 soda consumers. In the soda group, three subjects drank mostly diet sodas, two drank both diet and nondiet, and the rest were strictly nondiet soda drinkers.

The mean ages, height, weight, and other descriptive data for both groups is detailed in Table 1. The alcohol group and the soda group were practically identical except for age, sleep duration, and physical activity, that is, the average minutes per day spent exercising. An analysis of variance (ANOVA) revealed a significant difference in age between the alcohol group and the soda group, with the alcohol group being significantly older than the soda group, $F(1, 21) = 8.85, p < 0.01$. The weight, height, body mass index, and resting metabolic rates were not significantly different between the groups. However, a Mann–Whitney U-test revealed a significant difference in the physical activity levels between the groups, with the alcohol group exercising a significantly larger amount ($Z = -2.06, p < 0.05$). Lastly, the alcohol group slept significantly less, $F(1, 21) = 6.84, p < 0.05$, and woke up significantly more times during the night than the soda group, $F(1, 48) = 14.66, p < 0.001$; $F(1, 50) = 12.14, p < 0.001$, respectively.

Overall Intake

Table 2 gives the mean amounts and the minimum and maximum values of the macronutrient composition of the overall intake for the normal alcohol consumption phase and the alcohol abstinence phase and the analogous data for the soda group. The results of a two-way ANOVA revealed a significant main effect for the subjects' overall intake of food energy for the subject's group (alcohol vs. soda), a significant main effect for the subject's phase (on vs. off), and a significant group × phase interaction, $F(1, 21) = 5.64, p < 0.05$; $F(1, 21) = 6.433, p < 0.05$; $F(1, 21) = 5.95, p < 0.05$, respectively. Subjects overall intake of food energy during the on phase was higher significantly than during the abstinence phase for the alcohol subjects, but not for the soda subjects, $F(1, 12) = 14.760, p < 0.01$. These differences were due to an additional of 241 kcal/day of alcohol that were ingested during the alcohol phase. For both groups, the amounts of the macronutrients, carbohydrates, proteins, or fats, did not differ significantly between phases. Therefore, energy consumption seems to be higher during the alcohol on phase than during any of the other conditions (alc-off, soda-on/off) due to the extra alcohol calories ingested.

Furthermore, for a clearer interpretation of the food intake data, only those days in which alcohol was consumed were compared to days on which alcohol was not consumed within the alcohol phase and to days in which soda was consumed and not consumed within the soda phase. Three subjects data in the alcohol group were not used in the comparison because they consumed alcohol on all days of the alcohol phase. Two subjects' data in the soda group were not used in the comparison because they consumed soda on all days of the soda phase.

Table 2 gives the mean amounts and the minimum and maximum values of the macronutrient composition of the overall intake for the alcohol days and the no-alcohol days and the analogous data for the soda group. The results of a two-way (ANOVA) revealed a significant main effect for the subjects' overall intake of food energy for the subject's group (alcohol vs. soda), a significant main effect for the subject's days (on vs. off), and a significant group × days interaction, $F(1, 16) = 7.44, p < 0.05$; $F(1, 16) = 38.96, p < 0.001$; $F(1, 16) = 6.05, p < 0.05$, respectively). On the days in which alcohol was consumed there was a significantly larger amount of calories being consumed as opposed to the days in which alcohol was not consumed, $F(1, 9) = 27.01, p < 0.01$. This additional energy intake during the on days also held true for the soda group, with a significantly larger amount of calories being consumed on soda days, $F(1, 8) = 16.26, p < 0.01$. Therefore, there seems to be a significantly larger amount of food being consumed during the on days for both groups, which was greater for the alcohol group.

It seems that during the on phases of both groups there is a significant elevation of intake in general, but the excess alcohol calories produces a larger total intake of calories in the alcohol group than the soda group during the on phase.

TABLE 2

MEAN AMOUNTS OF OVERALL INTAKES FOR THE TWO CONDITIONS

	On Phase			Off Phase	
Nutrients	Mean	SEM	*F*	Mean	SEM
Alcohol Group					
kCalories	1931	78.2	14.76*	1658	109.1
Carbohydrate (g)	216	14.7	–	210	20.2
Fat (g)	68	4.1	–	62	4.6
Protein (g)	71	3.2	–	65	4.3
Alcohol (g)	34	6.1	–	0.2	0.2
Soda Group					
kCalories	1494	154.1	–	1420	137.4
Carbohydrate (g)	170	21.7	–	165	22.6
Fat (g)	56	6.7	–	60	5.7
Protein (g)	54	5.5	–	55	5.3

MEAN AMOUNTS OF OVERALL INTAKES

	On Days			Off Days	
Nutrients	Mean	SEM	*F*	Mean	SEM
Alcohol Days vs. the No Alcohol Days of the Alcohol Phase					
kCalories	2429	195.1	27.01*	1477	123.6
Carbohydrate (g)	227	16.2	–	185	21.9
Fat (g)	84	9.0	12.4*	57	5.7
Protein (g)	91	13.8	7.1†	56	7.0
Soda Days vs. No Soda Days of the Soda Phase					
kCalories	1591	148.3	16.26*	1119	175.3
Carbohydrate (g)	197	22.3	34.66*	129	19.3
Fat (g)	63	7.3	–	47	8.2
Protein (g)	59	5.7	–	45	8.2

*$p < 0.01$.
†$p < 0.05$.

Meal Characteristics

Table 3 gives the mean amounts and the minimum and maximum values of the macronutrient composition of the overall meal intakes for the normal alcohol consumption phase and the alcohol abstinence phase and the analogous data for the soda group. The results of a two-way ANOVA revealed that the subjects' average meal intake of food energy during the on phase was significantly higher than during the abstinence phase for the alcohol subjects, but not for the soda subjects, $F(1, 21) = 5.72$, $p < 0.05$; $F(1, 12) = 12.83$, $p < 0.01$. Meals eaten during the soda phase did not contain significantly more food energy than meals eaten during the no-soda phase. For both groups, the amounts of the macronutrients, carbohydrates, proteins, or fats, did not differ significantly between phases. Therefore, as in the overall intake, energy consumption seems to be higher during meals consumed during the alcohol on phase than during any of the other conditions (alc-off, soda-on/off) due to the extra alcohol calories ingested.

For a clearer interpretation of the meal intake data, once again, only those days on which alcohol was consumed were compared to days on which alcohol was not consumed within the alcohol phase and to days on which soda was consumed and not consumed within the soda phase.

Table 3 gives the mean amounts and the minimum and maximum values of the macronutrient composition of the overall meal intakes for the alcohol days and the no-alcohol days of the alcohol phase and the analogous data for the soda group. The results of an ANOVA revealed that the subjects' overall intake of food energy between the on and off days differed significantly, with the on days having a significantly larger food energy intake than the off days, $F(1, 16) = 11.14$, $p < 0.01$. The meals did not differ significantly in their average amounts of carbohydrates, proteins, or fats between the groups or between the phases.

The sleep duration for the night prior to a drinking day and the night after a drinking day differed significantly between the groups, with the alcohol group sleeping a significantly less amount than the soda group, $F(1, 15) = 6.87$, $p < 0.05$; $F(1, 15) = 5.58$, $p < 0.05$. The duration of the meals during the on days were significantly longer lasting than meals during the off days, and specifically, for the alcohol group, $F(1, 16) = 7.13$, $p < 0.05$; $F(1, 16) = 6.46$, $p < 0.05$, respectively).

As in the overall intake analysis, alcohol days meals tend to be higher in food energy than meals consumed during the alcohol off phase and between the soda on and off meals. Once again, this higher energy consumption is probably due to the extra alcohol calories ingested. The longer duration of meals during the on days of the alcohol group may result from the fact that people who consume alcohol tend to consume alcohol in social settings and in the presence of other people, which is correlated with longer meal durations (12).

Heart Rate Analysis

For a clearer interpretation of the heart rate data, only those days in which alcohol was consumed were compared to those days in which alcohol was not consumed within the alcohol phase, and to those days in which alcohol was not consumed during the alcohol abstinence phase. Similar periods were used for the soda users. The heart rates were calculated in hourly means for each 24-h period. The 24-h period constituted the hourly averages of the minute-by-minute heart rate data collected starting at 0700–1900 h. The heart rate data were further divided into three 8-h time periods consisting of 0700–1500, 1500 to 2300, and 2300–0700 h.

Figure 1 shows the mean (+SEM) heart rates across the three 8-h time blocks for the on days and off days of the alcohol phase and the no alcohol days of the alcohol abstinence phase, as well as the on days and off days of the soda phase and the no soda days of the soda abstinence phase. Data were first compared on the overall on days of both the alcohol and soda group to the overall off days of the alcohol and soda group. The results of a two-way ANOVA revealed a significant group × phase interaction for the subjects' mean heart rate during the hours of 2300–0700, with the on days of the alcohol group having a significantly higher heart rate during the 2300–0700 h time block, $F(1, 20) = 8.36$, $p < 0.01$. There was not a significant increase in any of the three 8-h time blocks for the soda group. In addition, there were no instances in either group of significantly higher mean heart rates for the time blocks between 0700–1500 and 1500 to 2300 h.

Figure 2 shows the mean hourly heart rates for the 24-h period beginning at 0700 and ending at 0700 h for the alcohol on days and off days of the alcohol phase and the off days of the alcohol abstinence phase for the alcohol group compared to the analogous data for the 24-h period of the soda on days for the soda drinkers. A significant group × phase interaction occurred for the subjects' mean hourly heart rates with the on phase alcohol group having higher heart rates during the hours of 2000–2100, 2200–2300, 2300–2400, 0200–0300, and 0400–0500 h, $F(1, 19) = 8.38$, $p < 0.05$; $F(1, 19) = 6.79$, $p < 0.05$; $F(1, 20) = 5.3$, $p < 0.05$; $F(1, 16) = 4.88$, $p < 0.05$; and $F(1, 15) = 4.71$, respectively. No significant increases in the hourly heart rates occurred in any of the off phases for either group nor in the hourly heart rates of the on days for the soda group. During the on phase of the alcohol group there seem to be an elevated heart rate during

TABLE 3

SUMMARY OF AVERAGE MEAL INTAKES FOR THE TWO CONDITIONS

	On Phase			Off Phase	
Nutrients	Mean	SEM	*F*	Mean	SEM
Alcohol Group					
kCalories	538	34.0	12.83*	474	24.7
Carbohydrate (g)	59.3	15.3	–	58	16.3
Fat (g)	19.3	16.1	–	18.3	14.8
Protein (g)	19.6	5.5	–	19.5	6.6
Meal duration (min)	55	11.4	–	39	4.2
Soda Group					
kCalories	471	31.2	–	467	25.4
Carbohydrate (g)	56.5	14.7	–	53	14.7
Fat (g)	19.0	15.9	–	20.3	16.7
Protein (g)	18.5	5.7	–	18.0	4.4
Meal duration (min)	28	3.2	–	27	2.9

MEAN AMOUNTS OF OVERALL MEAL INTAKES

	On Days			Off Days	
Nutrients	Mean	SEM	*F*	Mean	SEM
Alcohol Days vs. the No Alcohol Days of the Alcohol Phase					
kCalories	647	63.4	16.91*	450	42.1
Carbohydrate (g)	59.7	19.1	–	55	22.8
Fat (g)	22.4	22.2	–	17.9	21.0
Protein (g)	24	14.0	–	17.3	9.5
Meal duration (min)	70	18.8	8.39†	43	10.3
Soda Days vs. No Soda Days of the Soda Phase					
kCalories	499	45.7	–	439	50.7
Carbohydrate (g)	59.8	19.6	–	51.3	22.4
Fat (g)	20.4	24.5	–	18.3	22.7
Protein (g)	19	8.0	–	17.3	9.6
Meal duration (min)	26	3.2	–	26	3.7

*$p < 0.01$.
†$p < 0.05$.

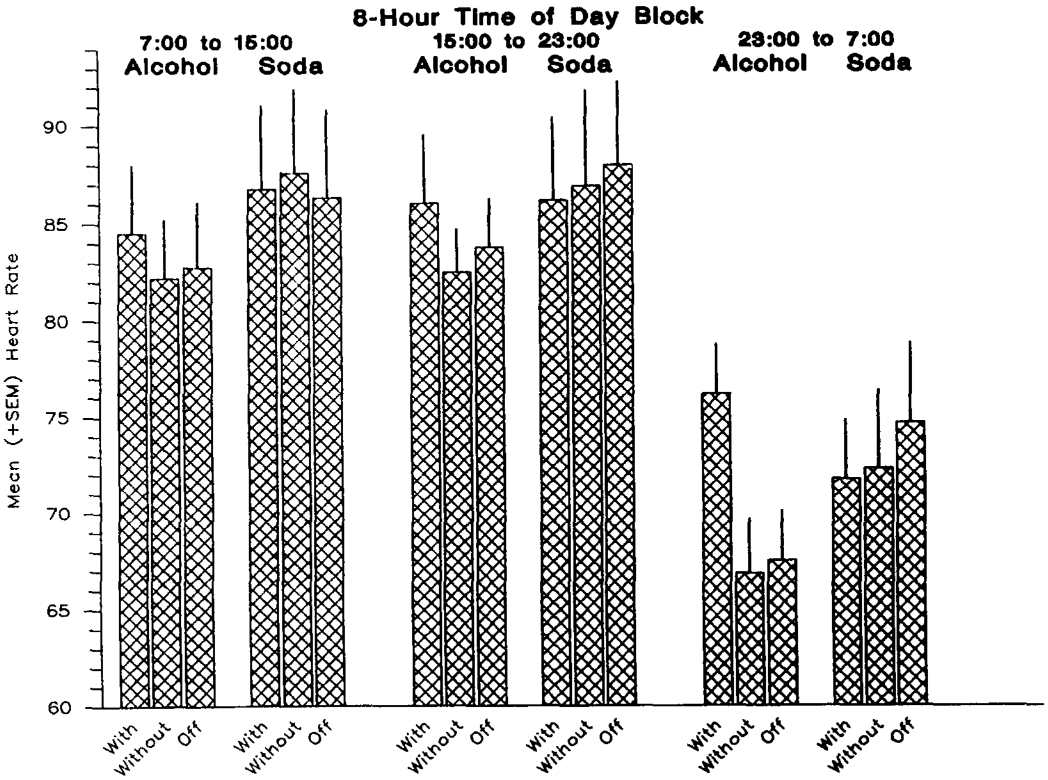

FIG. 1. Mean (+SEM) heart rates across the three 8-h time blocks of 0700–1500 h, 1500–2300 h, and 2300–0700 h for the alcohol on days (with) and off days (without) of the alcohol phase and the no alcohol days (off) of the alcohol abstinence phase, as well as the soda on days (with) and off days (without) of the soda phase and the no soda days (off) of the soda abstinence phase.

the overnight sleep period. This is not the case for the soda group.

DISCUSSION

The results of this experiment showed that moderate alcohol consumption led to: a) an increased caloric intake without compensation and b) higher energy expenditure between 2300 and 0700 h, as evidenced by increased heart rates in addition to self-reported sleep disruption, increased intake, and increased exercise.

During the alcohol phase the subjects consumed an additional 241 kcal a day over and above all other calories consumed, without altering significantly the intake of any other macronutrient. This was similar to a previous finding in which the subjects consumed an additional 218 kcal a day of alcohol during the alcohol week without altering the intake of any other macronutrient (28). The idea that moderate alcohol consumers tend to add alcohol to their caloric intake is not new (3,12,16,22,24,28).

In this study, not only did the alcohol subjects serve as their own controls, there was the unique feature of the addition of the soda control group. Asking subjects to abstain from drinking alcohol caused a substantial caloric reduction. On the other hand, asking subjects to refrain from drinking soda did not change the energy intake. Because the soda group's intake was unaffected by the abstinence manipulation, it is clear that the disruption and demand characteristics produced by the manipulation cannot account for the lower caloric intake in the alcohol abstinence phase.

Moderate alcohol consumers, on the average, consume an excess of 241 kcal a day of just alcohol compared to the no-alcohol phase and compared to the soda drinkers. However, even with this higher intake, in this study, both the alcohol group and the soda group were identical practically in all body size characteristics. This replicates previous studies that have found that moderate alcohol consumers are less obese or the same weight as nondrinkers (7,16,19,24).

In this study, the fact that three subjects reported drinking in their diaries during the alcohol abstinence phase is an indication of their compliance. All subjects, upon the completion of their diaries, were debriefed and asked whether they kept the diaries honestly. They were informed that they would receive experimental credit regardless of their response. All indicated compliance, honesty, and genuine enthusiasm for their nutritional and metabolic feedback.

Previous studies have shown alcohol intake to be associated with enlarged meals of long durations (12,28). In the present study, during the alcohol phase, meals with alcohol were significantly longer when compared to the alcohol abstinence phase and the soda on and off phases. Because subjects stay longer at the meals that contain alcohol, these results suggest that during the abstinence phase the subjects were, indeed, refraining from alcohol intake (12). Therefore, it seems that the subjects in this study kept their food and alcohol intakes accurately and honestly.

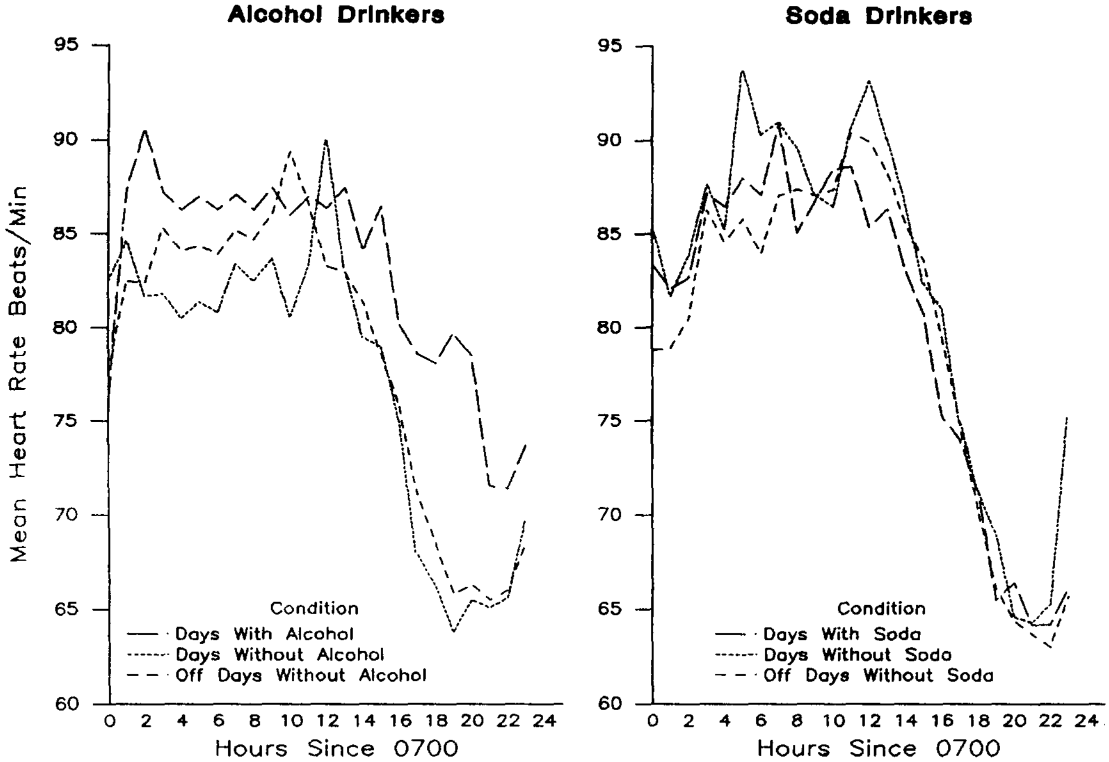

FIG. 2. Mean heart rates for the 24-h period beginning at 0700 h and ending at 0900 h for the alcohol on days and off days of the alcohol phase and the off days of the alcohol abstinence phase for the alcohol group compared to the 24-h mean heart rates of the soda on days and off days of the soda phase and the off days of the soda abstinence phase for the soda drinkers.

Similarly, during the on days vs. the off days of the on phase for both groups, there was a significant increase in caloric intake when either alcohol or soda was consumed (see Table 2). This dramatic acute effect of increased caloric intake on the on days vs. the off days for both groups could possibly be the result of an increasing reinforcing property of one reinforcer (i.e., alcohol) within a context of other available alternative reinforcers (i.e., salty snack items) (34). Subsequently, the elimination of that reinforcer also reduces the intake of the other reinforcers. Because this effect was seen only on the day-to-day comparisons and not on the overall averages during the on and off phases, it may be an indicator that humans are better at regulating caloric intake over longer periods of time.

Although there are significant differences in ages between the groups, the subjects in this study were well matched on several body characteristics (see Table 1). This also was true for their energy expenditure, as measured by their average resting metabolic rates. Both groups had similar resting metabolic rates overall, suggesting that alcohol consumers do not have a higher metabolic rates. The alcohol subjects must be expending the excess energy from alcohol in another way.

The alcohol group is more active by self-report than the soda group. The alcohol subjects remained active throughout the duration of the experiment, even during the alcohol abstinence phase. This lack of a difference in activity levels during the two phases of the alcohol group suggests that alcohol does not have an immediate effect of producing higher activity levels. Rather, these differences in activity levels between the groups could indicate that there is a chronic increase in activity associated with moderate alcohol intake or that people who consume alcohol tend to be more active. Regardless, at least part of the excess intake may be expended with the heightened activity.

The alcohol subjects slept less each night when compared to the soda subjects. As a result, the alcohol subjects were awake for a longer period of time. This increased the duration of their awake activity. This suggests that some of the alcohol calories may be expended during these extra periods of activity.

In addition, not only were the alcohol subjects sleeping less than the soda group, they woke up more often during the night after they drank alcohol than the soda group did after consuming sodas. During the alcohol nights, the subjects reporting waking up more during the night than on the nights of the alcohol abstinence phase. These results indicate that the alcohol subjects are experiencing a more restless sleep.

Several studies describing the effects of alcohol on the sleep of normal subjects have indicated that with the consumption of 1 g of ethanol per kg of body weight, rapid eye movement (REM) sleep is reduced in the first half of the night's sleep in approximately two-thirds of the subjects. This also is true in other subjects for the entire duration of the night and for the second half of the night (23,35). In one study of the effects of alcohol dose on the sleep of young men, the subjects had more disturbed sleep after alcohol consumption due to the wakefulness in the fifth hour of sleep, that increases substantially with higher doses (25). Other studies have found a strong relationship between alcohol intake and sleep disorders (2) and alcohol and insomnia in the elderly (13).

Another hypothesis to explain the nighttime restlessness is that perhaps the increased activity and restlessness associated with the alcohol group was a result of the diuretic effects of alcohol. In this study, the amount of fluid drank between 2000 h and midnight for both groups was correlated with nighttime heart rates to determine if there was an association between increased fluid intake (alcohol vs. soda) and nighttime increased heart rate. All correlations showed no association between nighttime fluid intake and increased heart rate for either the alcohol group or soda group. This suggests that the increased heart rate and activity during sleep is not the result of the diuretic effects of alcohol.

In this study, heart rate monitors were used to measure the subjects' heart rates during 24-h periods. The alcohol subjects' overall mean heart rates on the days they consumed alcohol were higher between the hours of 2300–0700 h when compared to the days in which they did not consume alcohol and when compared to both conditions of the soda group. In addition, the alcohol subjects overall mean heart rates on the days they consumed alcohol were also significantly higher for the individual hours of 2400 h, 0100 h, 0200 h, 0400 h, and 0500 h. These data suggest that alcohol intake may be increasing caloric expenditure during nighttime, possibly by disrupting sleep. Although alcohol is a depressant, the elevated heart rates were probably more of a reflection of the motor activity involved in restlessness than the actual direct effects of alcohol on the heart.

One of the purposes of this study was to investigate the metabolic aspects of moderate alcohol consumption by using the heart rate monitors to establish empirically a linear prediction of energy expenditure based on cardiac frequency. One of the problems in this kind of investigation is the lower predictability at the lower heart rates. Although the heart rates are elevated during the sleep hours on the nights they consume alcohol, this study cannot draw a conclusion that this represents an elevated energy expenditure due to the lower predictability of heart rate to energy expenditure at lower level heart rates, and even less predictability at the basal metabolic condition.

In this study, heart rate monitoring was used to estimate total energy expenditure (TEE). Although this use of heart rates as a measure of energy expenditure has been employed successfully by other investigators (6,18), the relationship of heart rate to energy expenditure has low predictability at the lower heart rates (33). It has been shown previously that the regression line of heart rate to energy expenditure seems to be curved in its lower part and linear in the higher ranges of energy expenditures (1). Unfortunately, most of the significant differences in the heart rates occurred during the night when most of the subjects were well below the resting metabolic rate. Further studies need to use more sensitive metabolic measures in an attempt to detect the minute increase in energy expenditure during the nights when alcohol is consumed.

The results of this study must be interpreted cautiously. This study used only females, who tend to be more concerned with their body weight than men. This may be advantageous because they are more likely to keep detailed food diaries and activity logs. Gender differences in the metabolism of alcohol must be considered because females may be more sensitive to the effects of alcohol than men. Hence, further studies should attempt to replicate the present findings using male subjects.

SUMMARY

In this experiment we found that one of the most significant impacts of moderate alcohol consumption on humans was its high caloric contribution without dietary compensation. Alcohol subjects consumed an additional 241 kcal a day over and above all other calories consumed, without significantly altering the intake of any other macronutrient. The present study demonstrated that this was not due to disruptive effects or demand characteristics produced by the manipulation, as subjects refraining from drinking soda did not change their energy intake.

The present results suggest that these excess alcohol calories are compensated by an increase in energy expenditure. This was evidenced by increased heart rates occurring between the hours of 2300–0700 h, increased nightly restlessness, increased wake time, and increased exercise found with moderate alcohol consumers. This increased caloric expenditure could account for the lack of weight gain seen in other studies even though there are excess alcohol calories being ingested by the alcohol group.

The present findings suggest that the mystery of the missing alcohol calories may really be a mystery of the effects of alcohol on activity. Whether people who consume alcohol are more active or whether alcohol is causing people to be more active remains a mystery and deserves further investigation.

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