Nutritional Sciences 9(2), May, 2006, pp.124-130

Effects of Alcohol Intake on Body Fluid Balance and Fat Mobilization After Exercise Induced Dehydration

Hyun Jeong Park, Yoon Jung Bae[1], Joohyung Lee[2] and Dae Taek Lee[2§]
Graduate School of Sports Industry, Kookmin University, Seoul 136-702, Korea
[1]Graduate School of Obesity Science, Dongduk Women's University, Seoul 136-714, Korea
[2]Kim Chang Kew Exercise Physiology Laboratory, Kookmin University, Seoul 136-702, Korea

To examine the effects of alcohol consumption on body fluid restoration and fat mobilization following exercise induced dehydration, nine healthy collegiate men (24±2 yrs, 177±5 cm, 72±8 kg, 10.5±2.3% body fat) underwent three experiments. In each experiment, subjects ran on a treadmill to reduce individual body mass to 2.2±0.1% and consumed one of three beverages containing 0, 4, or 8% alcohol over 60 min followed by 4 hr of resting recovery. They consumed approximately 150% of weight loss (2053±204, 2091±149, and 1943±295 mL) and content of alcohol was 9.9±1.0 (0%), 71.9±5.1 (4%), and 132.2±20.1 g (8% trial). Body weight, urine volume and samples, blood samples, and thirst sensation were measured five times; at baseline, immediately after exercise, and 0, 1st, and 4th hr of recovery. Blood alcohol concentration after ingestion was 0.0±0.0 (0%), 0.1±0.02 (4%), and 0.2±0.03% (8% trial). No differences in blood sodium and potassium concentrations, and urine specific gravity were noticed over time periods and trials. Thirst sensation tended to be elevated in all trials immediately after exercises and urine output was elevated during the recovery. The magnitude of changes in these variables was proportional to the alcohol concentrations, but not statistically significant. While serum osmolality was not different among trials and time periods in 0 and 4% trials, it was higher during recovery than the baseline in the 8% trial ($P<0.01$). Triglycerides did not change throughout the time period and among trials. Free fatty acids were elevated after exercise in all trials and 4th hr of recovery in 0% ($P<0.05$). Subjects' net body fluid balance at 4th hr of recovery was negatively maintained and proportional to alcohol concentrations. Only 8% trials showed a significant reduction at 1st and 4th hr of recovery compared to 0 hr. The results suggested that diuretic effect of alcohol after moderate level of dehydration appeared dose dependent, but beverage containing alcohol up to 4% did not induce impaired rehydration than alcohol free drinks. Alcohol effects on fat mobilization during recovery appeared to be minimal and the mechanism is unclear.

Key words: Ethanol, Serum osmolality, Urine output, Rehydration, Free fatty acid

Received February 21, 2006; Revised March 14, 2006; Accepted March 19, 2006

INTRODUCTION

When a physical exertion initiates and continues, metabolic and thermoregulatory adjustments play a role to meet the body's requirements. In this process, exercise induces energy store depletion and body heat accumulation. As exercise continues, sweat excretion has to be delivered for successful physical efforts, and progressive dehydration can not be avoided. Hence, adequate intake of fluid and subsequent restoration of body fluid should be accomplished during and/or after an exercise. For establishing an effective rehydration strategy after body fluid loss by exercise, many authorities examined various types of drinks from water to common beverages.[1-4)]

It has been proposed that many factors influence water restoration after exercise-induced dehydration including, but not limited to, age,[5)] composition of drink and gastric emptying,[2,6,7)] renal reabsorption capacity,[8)] acclimation status,[9)] and voluntary fluid intake.[9,10)] Maintenance of fluid balance after a bout of exercise is a major concern, in particular when urine forms after ingestion of a drink, which counteracts rehydration process. Ingestion of large volume of plain water may inhibit thirst and will also promote a diuretic response.[3)] Carbohydrate and electrolytes containing drinks may be beneficial for body fluid restoration as well as optimal exercise capacity regain than plain water, but high concentration of carbohydrate will cause fluid hyperosmolality reducing the net rate

§ To whom correspondence should be addressed.
(E-mail : dtlee@kookmin.ac.kr)

of water absorption.[11)]

In our society, alcohol beverage, preferably beer, is one of the commonly consumed drink by many people, and in many cases, it is consumed in a water-depleted state as a means of rehydration and relaxation such as following exhaustive exercises. Since volume replacement is important after dehydration and palatability of fluid has a major impact on the volume consumed, large amount of beer is consumed over a relatively short period of time. One concern with beer drinking is the adverse effects of alcohol on the restoration of body fluid because of known diuretic effects of alcohol[12)] and the low electrolyte content of beer.[13)] This issue has been discussed since early years and up to date.[14-16)] However, a question remains as to whether there is a different response of body fluid restoration after consuming different alcohol concentrations at a given volume. Also, it is not clear in what concentration of alcohol the restoration of body fluid would be impaired.

Despite available studies provided valuable information on health effects of alcohol on blood lipid profiles,[17-19)] many epidemiological and clinical studies only defined some associations between cardiovascular and liver diseases and the volume of alcohol consumption.[20,21)] Previous studies also showed that fat oxidation was substantially suppressed after alcohol consumption probably due to the fate of acetate, the major metabolic by-product of ethanol in the liver.[22)] Also, released acetates into blood stream are known to inhibit lipolysis.[20,23)] But, systemic studies testing the effect of alcohol intake on blood lipid variables following exhaustive exercise with moderate dehydration are sparse.

Therefore, the purpose of this study was to examine the effect of beverage intake containing different concentrations of alcohol on body fluid restoration during recovery following exercise-induced dehydration and to explore alcohol effects on fat mobilization in healthy young men.

METHODS

1. Subjects

Nine healthy collegiate male volunteers were recruited. They reported no metabolic, hepatic, and alcohol related diseases and were accustomed to consuming 2,000~3,000 mL of beer on an average occasion. They were nonsmokers and exercised on a regular basis but not necessarily elite athletes. The purpose and the nature of study were thoroughly explained before their participation and they signed an informed consent form. The physical characteristics of the subjects were age of 24.1±2.3 yrs, height of 176.8±5.2 cm, weight of 72.2±7.9 kg, body mass index of 23.0±1.7 kg/m^2, waist-to-hip ratio of 0.81±0.19, body fat content of 10.5±2.3 %, systolic and diastolic blood pressure of 117.1±10.2 and 72.8±9.5 mmHg, respectively, and resting heart rate of 77.2±8.5 of beat · min^{-1}.

2. Experimental Design

Subjects visited the laboratory four occasions. For the first visit, their physical characteristics were measured, and during subsequent three visits they underwent experimental testings. Each experiment consisted of three phases; 1) exercise-induced dehydration, 2) beverage intake, and 3) volume recovery. In each experiment, subjects consumed one of three different beverages: 1) alcohol free beer; 0% trial (actual concentration; 0.6%, OB Sound, Oriental Brewery Co., Korea), 2) 4% alcohol added beer; 4% trial (4.3%, Cass, Oriental Brewery Co., Korea), and 3) 8% alcohol added beer; 8% trial (8.5%, Duvel, Belgium). The composition of beverages were identical in all respects except the alcohol concentration. Each experiment was separated by seven days, thus conducted at the same day of the week. The order of beverage intake was randomly selected and balanced for avoiding trial order bias for each subject. The characteristics of beverages were not informed to the subjects.

3. Procedures and Measurements

At the first visit, subjects' height, weight, waist and hip circumferences, body fat content by bioelectrical impedance (GIF-891DH, Gilwoo, Korea), blood pressure, and resting heart rate were measured.

On the day of experiments, subjects reported to the laboratory after at least 10 hours of overnight fasting. They were asked to abstain from strenuous exercise and alcohol consumption for the last two days before experiments. High protein and/or high fat diets were prohibited for one day prior to each experiment. After their arrival, subjects rested comfortably in a seated position at 24 ℃ room temperature for 10 min. Approximately 10 mL of blood samples from antecubital veins were taken and subjects were asked to empty their bladder as completely as possible in a measuring container. Subjects' naked body weight was then measured. The subjective thirst rating was assessed with a visual linear analog scale.[24)]

After the baseline data were collected, subjects began exercise-induced dehydration phase by running on a treadmill wearing long pants and shirts at 28 ℃ room temperature for 50~90 min to reach a state of weight loss by 2% of each subject's baseline body weight. When the target weight loss was assumed to achieve, they dried themselves and naked body weight was measured again.

If their target weight loss was not achieved, then they exercised further. After completion of the dehydration phase, they were allowed to take shower and their blood samples and urine volumes were taken. Before next experimental phase, their thirst sensation was also assessed. Time spent from the cessation of exercise to the beverage intake phase was approximately 30 min.

During the beverage intake phase, subjects consumed one of three beverages at 25 ℃ room temperature. The volume of beverage provided was equal to 150% of the measured body weight loss. The rate of consumption was controlled by each subject but they were encouraged to consume within 60 min (48±12 min in 0% trial, 57±7 min in 4% trial, and 60±11 min in 8% trial). Immediately following completion of beverage intake, blood samples were taken which was considered as 0 hour of volume recovery phase. Blood samples were taken again at 1st and 4th hour of volume recovery phase. Urine volume and thirst sensation were also taken at 0, 1st, and 4th hour of recovery. During recovery, subjects maintained comfortable positions but were not allowed any vigorous activities.

The collected blood samples were divided and transferred into clot activator and EDTA contained tubes. Blood ethanol concentration was measured spectrophotometrically by an enzymatic method using EDTA treated samples with an alcohol dehydrogenase-based reaction (COBAS INTEGRA systems, Roche Diagnostics, Germany). Serum osmolality was measured by freezing-point depression (Fiske Osmometer, Germany). Serum samples were used for analyzing triglycerides (Ektachem DT60II, Johnson & Johnson, USA) and free fatty acids by colorimetry method (Hitachi 7180, Japan). Serum sodium and potassium concentrations were analyzed (Ektachem DTEII, Johnson & Johnson, USA). Urine volume and urine specific gravity were also measured.

Whole body net fluid balance was calculated from the weight loss by exercise, the volume of beverage consumed, and the urine volume. It was expressed as a relative term to the initial body weight as described previously.[16] The total amount of alcohol consumed in gram was calculated as total volume of beverage (mL)×alcohol concentration (%)×0.8÷100, where 0.8 is specific gravity of alcohol for converting milliliter to gram.

4. Statistical Analyses

The values of measured variables were expressed as the means and standard deviations. One way ANOVA with repeated measures were employed for comparison between trials throughout the time periods. Statistical significance was considered when $P<0.05$.

RESULTS

1. Weight Change, Volume Retention, and Blood Ethanol Concentration

The baseline body weight (71.4±6.7 kg in 0%, 71.5±8.0 kg in 4%, and 71.5±7.0 kg in 8% trials) and the amount of weight reduction at the end of exercise (70.0±6.7 kg in 0%, 70.1±7.9 kg in 4%, and 70.0±7.0 kg in 8% trials) were similar in all experiments. The total volume of beverage subjects consumed during beverage intake phase was 2053.3±204.0, 2091.4±148.5, and 1943.4±295.0 mL for 0, 4, and 8% trials, respectively ($P>0.05$). The average volume of alcohol consumed was 12.3±1.2, 89.9±6.4, and 165.2±25.1 mL, and the average amount of alcohol consumed was 9.9±1.0, 71.9±5.1, and 132.2±20.1 g, in 0, 4, and 8% trials, respectively. The average amount of alcohol consumed per body weight was 0.14, 1.03, and 1.89 g/kg, in 0, 4, and 8% trials, respectively. The blood ethanol concentration in 0% trial was not detected during all volume recovery phases. But it was maintained at 0.1±0.02% in 4% trial throughout the recovery. In 8% trial, blood ethanol was 0.2±0.04, 0.2±0.03, and 0.2±0.02% at 0, 1, and 4 hr of recovery, respectively ($P<0.001$).

2. Changes of Blood Measurements

Serum sodium and potassium concentrations were shown in Table 1. These variables maintained their normal biological ranges throughout the experiments regardless the beverage types.

The serum osmolality during the experiments was shown in Fig. 1. While no difference was found in each measuring time period, values of serum osmolality in 8% trial throughout the recovery period was higher than the corresponding baseline value and 0% trial values in each time period ($P<0.01$).

Table 1. Serum Sodium and Potassium Concentrations During Experiments

	Trial	Baseline	Post Exercise	Recovery		
				0 hr	1 hr	4 hr
Sodium	0%	138.6±3.2	139.7±2.8	137.8±3.3	138.6±5.3	136.0±4.3
(mmol/L)	4%	140.1±2.0	141.2±3.0	138.8±3.1	139.7±3.0	139.9±3.7
	8%	140.1±4.5	141.3±3.3	140.9±5.9	142.2±4.9	141.0±3.5
Potassium	0%	3.9±0.3	4.1±0.4	4.1±0.4	4.0±0.3	3.9±0.4
(mmol/L)	4%	4.1±0.2	4.2±0.2	4.2±0.4	3.8±0.3	3.9±0.3
	8%	4.1±0.4	4.3±0.3	4.0±0.3	4.0±0.4	4.0±0.4

no statistical difference was found between trials and times

The changes of triglycerides and free fatty acids during the experiments were shown in Fig. 2. No statistical differences between trials and among time periods were found in triglycerides. The post-exercise values of the free fatty acids were elevated in all three trials. However, the values returned to the baseline level at 0 hr of volume recovery phase and remained at the level during the rest of time period except 4 th hour of the 0% trial, during which the value was elevated up to the post-exercise level again (P<0.001).

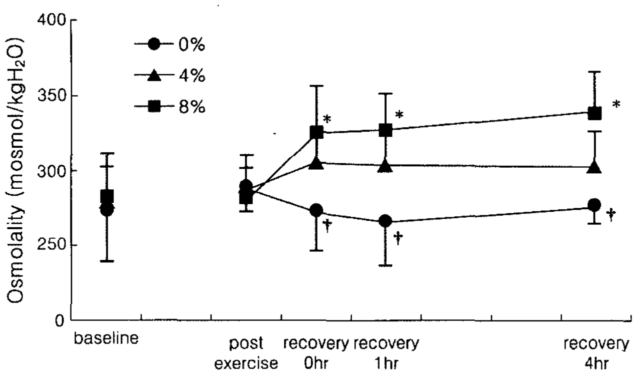

Fig. 1. Serum Osmolality Changes during Experiments
* significantly different compared to the baseline (P<0.05)
† significantly different compared to corresponding time of 8% trial (P<0.05)

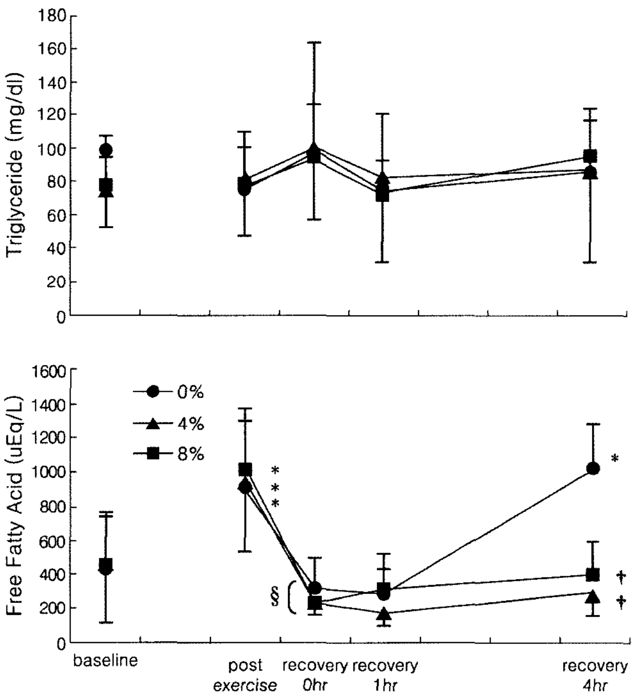

Fig. 2. Triglycerides and Free Fatty Acid Responses during Experiments
* significantly different compared to the baseline (P<0.05)
† significantly different compared to corresponding time of 0% trial (P<0.05)
§ significantly different compared to post exercise value of the corresponding trial (P<0.05)

3. Urine Output and Body Fluid Balance

The volume of urine excreted in each time period, accumulative urine volume during volume recovery phase, and urine specific gravity during the experiments were shown in Table 2. The volume of urine was elevated as soon as beverages were consumed and the volume reached its peak level at 1 hr of recovery followed by a slight suppression. But it remained above the baseline level at 4 hr of recovery in all trials. However, the tendency was not statistically significant (P>0.05). The urine specific gravity was reduced during the recovery periods compared to the baseline in all trials, but was not different between trials and among time periods (P>0.05).

The whole body net fluid balance during the experiment was shown in Fig. 3. Upon completion of exercise, the whole body net fluid balance was reduced as much as weight loss and the same extent in all trials. At the end of beverage intake phase, subjects were positively hydrated, but it was reduced continuously throughout the experiments. At 0 hr of volume recovery phase, subjects for 0% and 4% trials showed hyperhydrated states (P<0.05), but their hydration states returned to the baseline level during the rest of the volume recovery phase. During 8% trials, subjects maintained euhydrated at 0 hr of recovery, but at the end of 4 hr of recovery, their net body fluid was negatively balanced (P<0.05).

Table 2. Urine Output and Urine Specific Gravity During Experiments

	Trial	Baseline	Post Exercise	Recovery 0 hr	Recovery 1 hr[a]	Recovery 4 hr[b]
Volume (mL)	0%	28±29	28±29	147±129	267±123	202±113
	accumulative				415±194	617±285
	4%	37±17	37±17	208±190	321±176	272±124
	accumulative				528±345	800±430
	8%	36±32	36±32	216±150	414±167	248± 81
	accumulative				630±240	878±256
Specific Gravity	0%	1.023±0.004	1.020±0.005	1.011±0.009	1.005±0.004	1.010±0.005
	4%	1.023±0.003	1.021±0.004	1.015±0.005	1.004±0.004	1.007±0.007
	8%	1.020±0.009	1.023±0.008	1.012±0.010	1.004±0.001	1.006±0.004

[a] accumulative value was calculated as sum of urine volume at 0 and 1 hr.
[b] accumulative value was calculated as sum of urine volume at 0, 1, and 4 hr.
no statistical difference was found between trials and times

4. Thirst Sensation

The thirst sensation was shown in Fig. 3. The subjective thirst sensation tended to be suppressed after drinking beverages in all trials and remained below of the resting level although not statistically different (P>0.05). In general, there was a tendency of a stronger thirst sensation proportional to the alcohol concentration during recovery (P>0.05).

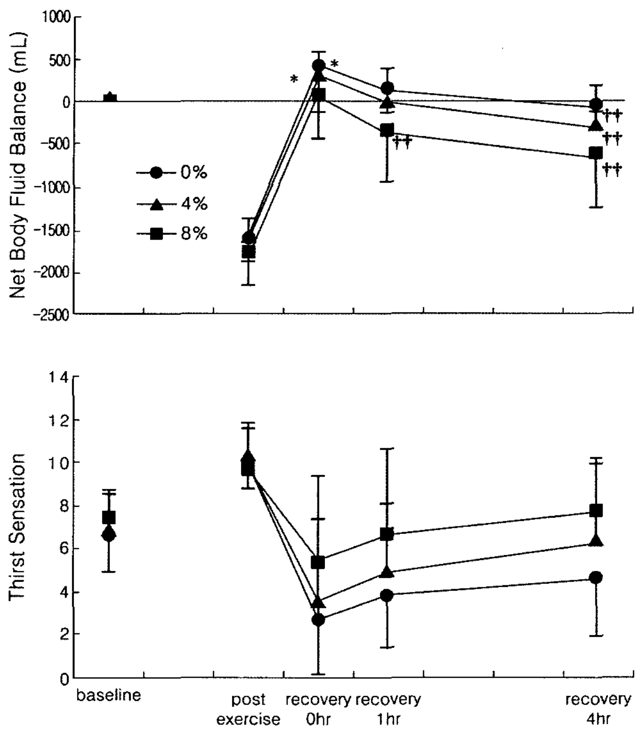

Fig. 3. Net Body Fluid Balance and Thirst Sensation during Experiment
* significantly different compared to the baseline (P<0.05)
†† significantly different compared to 0 hr recovery period of the corresponding trial (P<0.05)

DISCUSSION

It has been well recognized for many years that alcohol has a potent diuretic effect. The present study confirmed this notion and suggested that higher alcohol concentration in drinking beverage produced substantial negative balance of body fluid even after hypohydration induced by exercise. In the present study, about 4% of alcohol contents in beverage did not induce marginal reduction of body fluid relative to alcohol free beverage. On the other hand, 8% of alcohol contents did impair restoration of body fluid volume probably due to increased urine production although the body water content was lower than the baseline level. When subjects consumed 8% alcohol beverage, their serum osmolality was higher than the baseline level and their net body water was remained negative to the baseline. However, their subjective thirst sensation was still remained blunted below the baseline for four hours after 8% alcohol beverage consumption.

It has been reported in early years that small quantity of alcohol consumption may not seriously impair the effectiveness of rehydration after a state of body water depletion.[14] More recently, Shirreffs and Maughan[16] concluded that consumption of beverages containing alcohol up to 2% did not interfere rehydration from water depletion, and was observed to be similar to alcohol free drinks. Also, drinks containing 4% alcohol tended to delay the fluid restoration. The results of present study clearly demonstrated and extended the status of current knowledge as such 8% of alcohol drinks further impaired the restoration of body fluid.

The volume of water replenishment after water deficit has been of concern. If one might intend to complete the restoration of fluid balance, it was necessary to consume a volume of fluid greater than the volume lost during exercise.[25] In the present study, when alcohol-free and 4% alcohol containing beverages were consumed, subjects were positively hydrated at the end of rehydration period and maintained the baseline level throughout. However, although the equal amount of beverage was consumed, beverages containing 8% alcohol reduced body fluid content below the normal level due to urine formation. A previous study[16] showed no substantial body fluid volume changes during recovery period after consuming up to 4% alcohol drinks. Collectively, these data indicate that an obvious diuretic effect can result in negative fluid balance when drinks contains more than 4% of alcohol regardless volume supplied over the volume lost during dehydration.

The volume of urine formation is mainly determined by circulating levels of vasopressin. One of the factors known to reduce vasopressin release is an increased serum osmolality. It has been reported that alcohol causes dehydration by inhibiting the release of vasopressin even during a hypohydration state,[12] and that alcohol plays the osmotic effect independently by inhibiting vasopressin secretion.[26] Since the present study did not measure circulating vasopressin levels, any interactions between fluid balance and hormonal control mechanism could not be evaluated. However, there was a consistent pattern in volume related variables such that beverages of higher contents of alcohol induced larger urine output, higher serum osmolality, and subjective thrist sensation indicating close interactions between alcohol contents and body fluid regulation. One observation in which majority of urine volume was excreted during the first hour of recovery after beverage intake following dehydration supported the previous study.[16]

It may be difficult to define an alcohol concentration under which, the body fluid volume could be reasonably restored after exercise-induced mild dehydration. The present study demonstrated that beverage containing alcohol up to 4% did not induce any obvious impaired rehydration compared to alcohol free beverage. In contrast, Shirreffs and her colleague,[25] when employed 0, 1, and 4%, alcohol containing beverages after dehydration, concluded that up to 2% alcohol did not influence in recovery from dehydration while 4% alcohol tended to delay the recovery process. However, they only showed a tendency, not for the significant differences in many parameters. The amount of alcohol consumed in the previous study[16] and the present study was compatible (68.0 g vs. 71 g), but the estimated net body fluid balance in their subjects at 4th hour of recovery was over -500 mL while -270 mL in this study. The discrepancies between two studies were not clearly interpreted but one candidate may be individual sensitivities since there were large standard deviation in urine output.

Studies on alcohol effects on lipid mobilization are few. The triglyceride in this study was not affected by alcohol. Previous studies reported no changes in type 2 diabetes patients[27-29] while others showed higher elevation after alcohol ingestion in healthy population.[18,30,31] Whether alcohol intake either influences on triglyceride catabolism or augments its secretion by the liver and intestines is not completely understood.[18] But it may be a consequence of the balance between an impaired removal of triglyceride rich particles from the blood[32] and an acute inhibitory effect on lipoprotein lipase.[32,33] During fluid volume recovery period, the free fatty acid level tended to decrease by alcohol supporting previous studies[28,34] but not all.[35] Suppression may be due to the fate of acetate, the major product of ethanol oxidation, which is released to the blood stream and primarily oxidized over other substrates.[36] One interesting observation was that free fatty acids were reduced slightly immediately after rehydration and remained suppressed except 0% trial, during which it rebounded at 4 th hour of recovery to the level of post-exercise. For now, this reponses could not be explained.

The changes of blood lipid level after acute bout of exercise and during subsequent rehydration may be interpreted carefully, since uncorrected values of these variables can not solely be explained by actual changes. Potential variation by fluid volume shifts among intra - and inter - vascular spaces should be accounted.[18,37] Also, subjects in this study were young and healthy. Individual differences between normal subjects and those of dislipidemic, diabetic, or other patient groups need to be considered.

CONCLUSION

Based on the above results, it can be concluded that diuretic effect of alcohol after moderate level of dehydration appeared dose dependent, but beverage containing alcohol up to 4% did not induce impaired rehydration than alcohol free drinks. Alcohol effects on fat mobilization during recovery appeared to be minimal and the mechanism is unclear.

Acknowledgement

The authors would like to express sincere thanks to all the subjects who voluntarily and enthusiastically participated in this study.

Literature Cited

1) Gonzales-Alonso J, Heaps CL, Coyle EF. Rehydration after exercise with common beverages and water. *Int J Sports Med* 13:399-406, 1992
2) Maughan RJ, Leiper JB. Sodium intake and post-exercise rehydration in man. *Eur J Appl Physiol* 75:311-319, 1995
3) Maughan RJ, Leiper JB, Shirreffs SM. Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. *Br J Sports Med* 31:175-182, 1997
4) Nose H, Mack GW, Shi X, Nadel ER. Role of osmolality and plasma volume during rehydration in humans. *J Appl Physiol* 65:325-331, 1988
5) Mack GW, Weseman CA, Langhans GW, Scherzer H, Gillen CM, Nadel ER. Body fluid balance in dehydrated healthy older men: thirst and renal osmoregulation. *J Appl Physiol* 76:1615-1623, 1994
6) Maughan RJ, Owen JH, Shirreffs SM, Leiper JB. Post-exercise rehydration in man: effects of electolyte addition to ingested fluids. Eur *J Appl Physiol* 69:209-215, 1994
7) Ryan AJ, Lambert GP, Shi X, Chang RT, Summers RW, Gisolfi CV. Effect of hypohydration on gastric emptying and intestinal absorption during exercise. *J Appl Physio*l 84: 1581-1588, 1998
8) Lindeman RD. Renal and urinary tract function. In: Fregly MJ, Blatteis CM, eds. Handbook of Physiology, Aging. sect. 11, chapt. 19, pp.485-504, American Physiological Society, Bethesda, MD, 1995
9) Greenleaf JE, Brock PJ, Keil LC, Morse JT. Drinking and water balance during exercise and heat acclimation. *J Appl Physiol* 54:414-419, 1983
10) Zappe DH, Bell GW, Swartzentruber H, Wideman RF, Kenny WL. Age and regulation of fluid and electrolyte balance during repeated exercise sessions. *Am J Physiol* 270:R71-R79, 1996
11) Rehrer NJ. Fluid and electrolyte balance in ultra-endurance sport. *Sports Med* 31:701-715, 2001
12) Roberts KE. Mechanism of dehydration following alcohol ingestion. *Arch Intern Med* 112:154-157, 1963

13) Farthing MJG. Oral rehydration therapy. *Pharmacol Ther* 64:477-492, 1994
14) Eggleton MG. The diuretic action of alcohol in man. *J Physiol* 101:172-191, 1942
15) Kleeman CR, Rubini ME, Lamdin E, Epstein FH. Studies on alcohol diuresis. II. The evaluation of ethyl alcohol as an inhibitor of the neurohypophysis. *J Clin Invest* 34:448-455, 1955
16) Shirreffs SM, Maughan RJ. Restoration of fluid balance after exercise-induced dehydration: effects of alcohol consumption. *J Appl Physiol* 83:1152-1158, 1997
17) Crouse JR, Grundy SM. Effects of alcohol on plasma lipoproteins and cholesterol and triglyceride metabolism in men. *J Lipid Res* 25:486-496, 1984
18) El-Sayed MS, AL-Bayatti MF. Effects of alcohol ingestion following exercise on postprandial lipemia. *Alcohol* 23:15-21, 2001
19) Veenstra J, Okhuizen T, Van de Pol H, Wedel M, Schaafsma G. Effects of moderate dose of alcohol on blood lipids and lipoproteins postprandially and in the fasting state. *Alcohol* 25:371-377, 1990
20) Bunout D. Nutritional and metabolic effects of alcoholism: their relationship with alcoholic liver disease. *Nutrition* 15: 583-589, 1999
21) Marmot M, Brunner E. Alcohol and cardiovascular disease: the status of U-shaped curve. *Br Med J* 303:565-568, 1991
22) Suter PM, Schutz Y, Jequier E. The effect of ethanol on fat storage in healthy subjects. *N Engl J Med* 326:983-987, 1992
23) Siler SQ, Neese RA, Hellerstein MK. De novo lipogenesis, lipid kinetics, and whole-body lipid balances in humans after acute alcohol consumption. *Am J Clin Nutr* 70:928-936, 1999
24) Takamata A, Ito T, Yaegashi K, Takamiya H, Maegawa Y, Itoh T, Greenleaf JE, Morimoto T. Effect of an exercise-heat acclimation program on body fluid regulatory responses to dehydration in older men. *Am J Physiol* 277:R1041-R1050, 1999
25) Shirreffs SM, Taylor AJ, Leiper JB, Maughan RJ. Post-exercise rehydration in man: effects of volume consumed and dodium content of ingested fluids. *Med Sci Sports Exerc* 28: 1260-1271, 1996
26) Rubini ME, Kleeman CR, Lamdin E. Studies on alcohol diuresis. I. The effect of ethyl alcohol ingestion on water, electrolyte and acid-base metabolism. *J Clin Invest* 34:439- 447, 1955
27) Christiansen C, Thomsen C, Rasmussen O, Hauerslev C, Balle M, Hansen C, Hermansen K. Effect of alcohol on glucose, insulin, free fatty acid and triacylglycerol responses to a light meal in non-insulin-dependent diabetic subjects. *Br J Nutr* 71:449-454, 1994
28) Christiansen C, Thomsen C, Rasmussen O, Hansen C, Hermansen K. The acute impact of ethanol on glucose, insulin, triacylglycerol, and free fatty acid responses and insulin sensitivity in type 2 diabetes. *Br J Nutr* 76:669-675, 1996
29) Rasmussen BM, Christiansen C, Rasmussen OW, Hansen C, Hermansen K. Alcohol and post-exercise metabolic responses in type 2 diabetes. *Metabolism* 48:597-602, 1999
30) Mishra L, Le NA, Brown WV, Mezey E. Effect of acute intravenous alcohol on plasma lipoproteins in man. *Metabolism* 40:1128-1130, 1991
31) Verdy M, Gattereau A. Ethanol, lipase activity, and serum-lipid level. *Am J Clin Nutr* 20:997-1003, 1967
32) Nilsson-Ehle P. Alcohol-induced alterations in lipoprotein lipase activity and plasma lipoproteins. In: Avogaro P, Sirtori CR, Tremoli E, eds. Metabolic Effects of alcohol. pp.175-186, Elsevier/North-Holland Biomedical Press, Amsterdam, 1979
33) Schneider J, Panne E, Braun H, Mordasini R, Kaffarnik H. Ethanol-induced hyperlipoproteinemia. Crucial Role preceding ethanol intake in the removal of chylomicrons. *J Lab Clin Med* 101:114-121, 1983
34) Raben A, Agerholm-Larsen L, Flint A, Holst JJ, Astrup A. Meals with similar energy densities but rich in protein, fat, carbohydrate, or alcohol have different effects on energy expenditure and substrate metabolism but not on appetite and energy intake. *Am J Clin Nutr* 77:91-100, 2003
35) Suter PM, Jequier E, Schutz Y. Effect of ethanol on energy expenditure. *Am J Physiol* 266:R1204-R1212, 1994
36) Crouse JR, Gerson CD, DeCarli LM, Lieber CS. Role of acetate in the reduction of plasma free fatty acids produced by ethanol in man. *J Lipid Res* 9:509-512, 1968
37) El-Sayed MS, Rattu AJM. Changes in lipid profile variables in response to submaximal and maximal exercise in trained cyclists. Eur *J Appl Physiol* 73:88-92, 1996