The Effects of Consumption L-Arabinose on Metabolic Syndrome in Humans

Ziming Yang[1], Dianpeng Li[1,*], Haiying Jiang[1], Guiyun Qian[2], Weiguo Sui[3], Guimian Zou[3] and Hourui Zhang[1]

[1]*Guangxi Key Laboratory of Functional Phytochemicals Research and Utilization, Guangxi Institute of Botany, Chinese Academy of Sciences. No. 85 Yanshan Road, Yanshan District, Guilin, 541006, China*

[2]*The Second People's Hospital of Guangxi Zhuang Autonomous Rcglon. No. 1 Xinqioayuan Road, Guilin, 541006, China*

[3]*181st Hospital of Chinese People's Liberation Army, No. 46 Chongxin Road, Guilin, 541006, China*

Abstract: On the basis of results in rat, L-arabinose decreased total cholesterol (TC), triglycerides (TG), fasting glucose, systolic blood pressure, increased high-density lipoprotein cholesterol (HDLC), and enhanced the glucose tolerance. The primary purposes of the present study was to determine the effects of consumption L-arabinose on metabolic syndrome in humans. All volunteers received L-Arabinose by dissolving it in water. The volunteers didn't change the diet habits and lifestyles during the whole experiment. The trial lasted for 6 months, and experimental indicators were assayed every two months, which including weight, waist circumference, blood pressure, TG, TC, HDLC, low-density lipoprotein cholesterol (LDLC), fasting plasma glucose, erum uric acid, serum creatinine (Scr), blood urea nitrogen (BUN), alanine aminotransferase (ALT) and aspartate aminotransferase (AST). Our results showed that the L-arabinose decreased waist circumference, TC, fasting glucose, serum uric acid, ALT and slightly increased HDLC and slightly decreased diastolic blood pressure after 6 months. A tendency for decreased waist circumference, TC, fasting glucose, serum uric acid, ALT after 2, 4 and 6 months of treatment with L-arabinose was observed. In addition, L-arabinose decreased TC, LDLC and body weight. No effects on Scr, BUN, AST. In conclusions**,** L-arabinose would reduce most the metabolic syndrome risk factors(decreased circumference, TC, fasting glucose, and so on), and treat the metabolic syndrome as a whole. The present study would provides strong evidence that long-term received L-arabinose would be manage metabolic syndrome.

Keywords: L-arabinose, metabolic syndrome, triglycerides, ALT, waist circumference.

INTRODUCTION

Metabolic syndrome is a complex disorder with high socioeconomic cost that is considered as a worldwide epidemic. Metabolic syndrome is defined as a cluster of interconnected factors that directly increase the risk of coronary heart disease, other forms of cardiovascular atherosclerotic diseases, and diabetes mellitus type 2. Its main components are dyslipidemia (elevated TG and apolipoprotein B (apoB)-containing lipoproteins, and LDLC), elevation of arterial blood pressure and dysregulated glucose homeostasis, while abdominal obesity and/or insulin resistancehave gained increasing attention as the core manifestations of the syndrome [1~3]. This clustering of abnormalities is frequently seen and attributed to people's dietary habits. The incidence of this syndrome has been estimated to increase with age for individuals over 50 years of ages [4]. Metabolic syndrome typically is characterized by any 3 of the following 5 risk factors: 1) waist circumference≥102 cm in males and≥88 cm in females; 2) TG≥150 mg/dL or under treatment for elevated TG; 3) HDLC < 40mg/dL in males and < 50 mg/dL in females or under treatment for reduced HDLC; 4) SBP≥140 mmHg or DBP≥90 mmHg or under treatment for hypertension; and 5) fasting glucose≥110 mg/dL or under treatment for elevated glucose [1]. Metabolic syndrome affects 14%-16% of the population in china [5], 27% of the population in India [4], nearly 30% of the population in Europe [6], and more than 40% of the population in the US [7]. The metabolic syndrome has received increasing attention in the past few years.

The monosaccharide L-arabinose is an aldopentose and the second most abundant pentose beside D-xylose in plants. Although most monosaccharides are normally present in nature in their D-form, L-arabinose is a rare exception to this rule and found mainly in its furanose form as a component of the plant biopolymers hemicellulose and pectin [8]. L-arabinose, as a low calorie sweetener (401.3kcal/mol), was approved to be used as a safe food additive by US FDA and Japan. US Medical Association approved to use L-arabinose as the nutritional supplements or nonprescription drugs for anti-obesity. Japan approved L-arabinose to be the

*Address correspondence to this author at the Guangxi Key Laboratory of Functional Phytochemicals Research and Utilization, Guangxi Institute of Botany, Chinese Academy of Sciences, No. 85 Yanshan Road, Yanshan District, Guilin, 541006, China; Tel: 86-13635187786; Fax: 86-773-3550067; E-mail: ldp@gxib.cn

#Co-Authors E-mail: yangziming198310@126.com, 376878251@qq.com, qgy_410@yahoo.cn, suiwg@163.com, zougm2004@126.com, zh-hr@hotmail.com

special health-care food additive for adjusting blood sugar. Animal studies previously reported that the occurrence of microbial degradation of L-arabinose in the small intestine and a portion of the ingested L-Arabinose was excreted in the urine, suggesting the metabolizable energy of L-arabinose was significantly less than that of D-glucose [9]. A study reported that when C^{14}-labelled L-arabinose is intravenously infused in man only 0.8 % was recovered in expired carbon dioxide, suggesting the L-arabinose lower-efficiency of utilization in humans [10]. Their findings indicated that L-arabinose could be used as an energy source only after microbial fermentation. Although widely present in nature, L-Arabinose is rarely used, and its physiological effects *in vivo* have received little attention. L-Arabinose selectively inhibits intestinal sucrase activity in a noncompetitive manner and suppresses the plasma glucose increase due to sucrose ingestion [11~14]. Because the intestinal absorption of sucrose is inhibited in the presence of L-Arabinose, the absorption of sucrose should be reduced by arabinose ingestion. L-arabinose feeding prevents increased due to dietary sucrose in TG levels in rats [14]. Furthermore, a subchronic study investigated L-Arabinose can enhance the glucose tolerance significantly in rats with Normal Feeding and High-Sucrose and High-Fat Feeding, it also can decrease TG and increase HDLC and reduce body fat and slow the trend of weight gain in rats with High-Sucrose and High-Fat Feeding [15]. Most of the studies reported so far on the absorption and utilization of L-Arabinose relate to omnivore animal species other than humans. A humans study showed that 4% L-arabinose in sucrose beverages reduced postprandial glucose, insulin, and C-peptide responses and enhances the GLP-1 response without gastrointestinal adverse effects [12]. A nutrition study reported that as compared to a placebo control, consumption of a L-arabinose and trivalent chromium formula after a 70-gram sucrose challenge was effective in safely lowering both circulating glucose and insulin levels which was tested for insulin, and no adverse effects were found after acute sucrose challenge or in those who consumed LA-Cr daily for four weeks [16]. Possible digestive implications as increased flatulence, diarrhea, or stomach pain were not reported [12]. The primary purposes of the present study were to determine the effects of consumption L-arabinose on metabolic syndrome in humans.

SUBJECTS AND METHODS

Subjects

The study subjects were recruited from the Second people's Hospital of Guangxi Zhuang Autonomous Region and nearby communities. The inclusion criteria were as follows: Co morbids, no chronic diseases, no autoimmune disease, no gastrointestinal disease, no pregnancy, no blood donation within the past 6 mo before entering the study, no use of dietary supplements, no drinking, no smoking, no regular use of medicine but have metabolic syndrome. The metabolic syndrome definition was based on the National Cholesterol Education Program Adult Treatment Panel III Criteria with modification on waist circumference cut-off to be more appropriate for an Asian population. Thus, metabolic syndrome was defined as the presence of three or more of the following five criteria: 1) waist circumference≥90 cm in males and≥80 cm in females; 2) TG≥150 mg/dL or under treatment for elevated triglycerides; 3) HDLC < 40mg/dL in males and < 50 mg/dL in females or under treatment for reduced HDLC; 4) SBP≥130 mmHg or DBP≥85 mmHg or under treatment for hypertension; and 5) fasting glucose≥100 mg/dL or under treatment for elevated glucose. 43 volunteers were recruited who met the criteria and the volunteers at the age of 30-76. All the participants provided written consent. Volunteers were informed of about the potential benefits (e.g. may decrease fasting glucose), and potential risks (e.g. may produce gastrointestinal reactions). The baseline characteristics of the 43 subjects are given in Table **1**.

Experimental Design

All volunteers received L-Arabinose by dissolving it in water. The volunteers weighing more than 60 kg received the dose of L-Arabinose 20g twice daily and the volunteers weighing less than 60 kg received the dose of L-Arabinose 15g thrice daily. Volunteers were asked if they experienced any side effects related to the use of L-Arabinose. If they experienced caused diarrhea related to the use of L-Arabinose, we would modification the criteria to these people: the volunteers weighing more than 60 kg received the dose of L-Arabinose 15g thrice daily and the volunteers weighing less than 60 kg received the dose of L-Arabinose 10g twice daily. When they still had an attack of diarrhoea after eating L-Arabinose in modification criteria, we suggested them to stop this experiment. The volunteers don't change the diet habits and lifestyles during the whole experiment. The trial lasted for 6 months. On the test day, the fasting subjects traveled to the department by car or bus (the least strenuous means of transportation). On arrival, they were weighed, waist circumference was measured, and after 10 min of rest, blood pressure was measured and

Table 1: Subject Characteristics (Values are means ± SD, *n*=30)

Variable	Value
Age (y)	49.9 ±9.9
Male (*n* (%))	63.3
total cholesterol (mg/dL)	210.0±26.9
triglycerides (mg/dL)	253.3±189.5
High-density lipoprotein cholesterol (mg/dL)	43.7±9.3
Low-density lipoprotein cholesterol (mg/dL)	136.2±33.7
fasting plasma glucose (mg/dL)	113.4±26.1
serum uric acid (mg/dL)	7.12±1.67
serum creatinine (mg/dL)	1.07±0.27
blood urea nitrogen (mg/dL)	16.49±3.95
alanine aminotransferase (IU/L)	37±28
aspartate aminotransferase (IU/L)	26±12
Body weight (kg)	72.2±13.0
Waist circumference (cm)	93.0±8.6
systolic blood pressure (mmHg)	135±23
diastolic blood pressure (mmHg)	83±12

blood samples were collected. TG, TC, HDLC, LDLC, fasting plasma glucose, erum uric acid, Scr, BUN, ALT and AST were measured. Clinical examination and TC, TG, HDLC, LDLC, fasting plasma glucose, serum uric acid, Scr, BUN, ALT, AST were routinely performed at each clinical visit.The above experimental indicators measured every two months. Gastrointestinal symptoms (heartburn, distension, nausea, vomiting, stomachache, rumbling in the gut, flatulence, and diarrhea) were registered during the experiment by asking the volunteers. During the experiment, Four people could not continued the experiment due to job transfers, 1 fainted during the first test day and dropped out, 2 declined to participate due to ineffectualness, 1 could not continued the experiment due to weight dropped many, but health examination was everything is normal, 3 could not continued the experiment due to diarrhea, 2 participants were excluded because their received L-Arabinose didn't according to criteria. A final total of 30 participants completed this experiment. In planning the study, it was estimated that 30 subjects would be sufficient to detect significant differences in TC, TG, HDLC, LDLC, fasting plasma glucose, serum uric acid, Scr, BUN, ALT, AST.

Measuring Study Variables

Trained personnel measured the anthropometric variables according to the written protocol. Body weight was measured using a electronic scale; Waist circumference was measured on a horizontal plane midway between the inferior margin of the ribs and the superior border of the iliac crest using a tape measure; Resting blood pressure was measured twice with at least 5 minute intervals using an automatic sphygmomanometer if the difference between the first and second measurement was more than 10 mmHg, then repeated measurements were performed. The average of the last two measurements was used for the analysis. Blood samples were collected from the antecubital vein after at least an 8 hour fast and collected into plain tubes; within 30 min of collection, the samples were centrifuged for 15 min at 2800×g and 4℃, and the serum was stored at -20℃until analyzed. TG assay by GOD-PAP method, TC assay by COD-CE-PAP method, HDLC assay by PTA-Mg^{2+} method, LDLC assay by Polyvinyl sulfate (PVS) precipitation method, fasting plasma glucose assay by GOD-PAP method, erum uric acid assay by URO-PAP method, serum Scr assay by Folin method, BUN assay by Diacetyl monoxime method, and ALT, AST assay by Reitman-Frankel method.

Statistical Analysis

Descriptive data were reported as means± SDs, and the results were reported as means ± SEMs. Statistically significant differences between pre treatment and post treatment means of variables were analyzed by Paired-Samples *T* -Test for data normally distributed and by the Mann-Whitney test for data not normally distributed, using SPSS 11.5 for windows (SPSS Inc., IL, USA). *P* value of less than 0.05 was considered to be significant. Volunteers were not stratified according to their ages and sex in order to analyze treatment outcomes. ALT and AST was then

additionally adjusted as a markers of liver function, Scr and BUN was then additionally adjusted as a markers of kidney function.

RESULTS

Gastrointestinal Symptoms

Thirteen of 30 subjects reported symptoms (mild diarrhea) after treatments with L-arabinose and 1 of 30 subjects reported symptoms (mild nausea) after treatment with L-arabinose.

Body Weight

The Volunteers received L-arabinose after 2, 4 and 6 months of treatment decreased the mean body weight. In comparing with the Pre-treatment mean body weight (72.2±13.0kg), the 2 months Post-treatment (71.5±13.3kg) decreased and had statistically significance (P<0.05), the 4 months Post-treatment (71.3±13.0cm) decreased and had statistically significance (P<0.05), the 6 months Post-treatment (70.8±13.6cm) decreased and had statistically significance (P<0.05)**,** a tendency for decreased mean body weight after 2, 4 and 6 months of treatment with L-arabinose was observed (Figure **1**).

Waist Circumference

The Volunteers received L-arabinose after 2, 4 and 6 months of treatment decreased the mean waist circumference. In comparing with the Pre-treatment mean waist circumference (93.0±8.6cm), the 2 months Post-treatment (92.1±8.5cm) decreased but was not statistically significant (P>0.05), the 4 months Post-treatment (90.6±8.7cm) decreased and was statistically significant (P<0.01), the 6 months Post-treatment (89.9±8.5cm) decreased and was statistically significant (P<0.01)**,** a tendency for decreased mean waist circumference after 2, 4, 6 months of treatment with L-arabinose was observed (Figure **1**).

Triglycerides

The Volunteers received L-arabinose after 2, 4 and 6 months of treatments decreased the mean serum concentrations of TG. In comparing with the Pre-treatment mean serum concentrations of TG (253.3±189.5 mg/dL), the 2 months Post-treatment (239.1±190.4mg/dL) decreased but was not statistically significant (P>0.05), the 4 months Post-treatment (203.7±154.5 mg/dL) decreased and was statistically significant (P<0.01), the 6 months Post-treatment (186.0±130.2 mg/dL) decreased and was statistically significant (P<0.01), a tendency for decreased mean

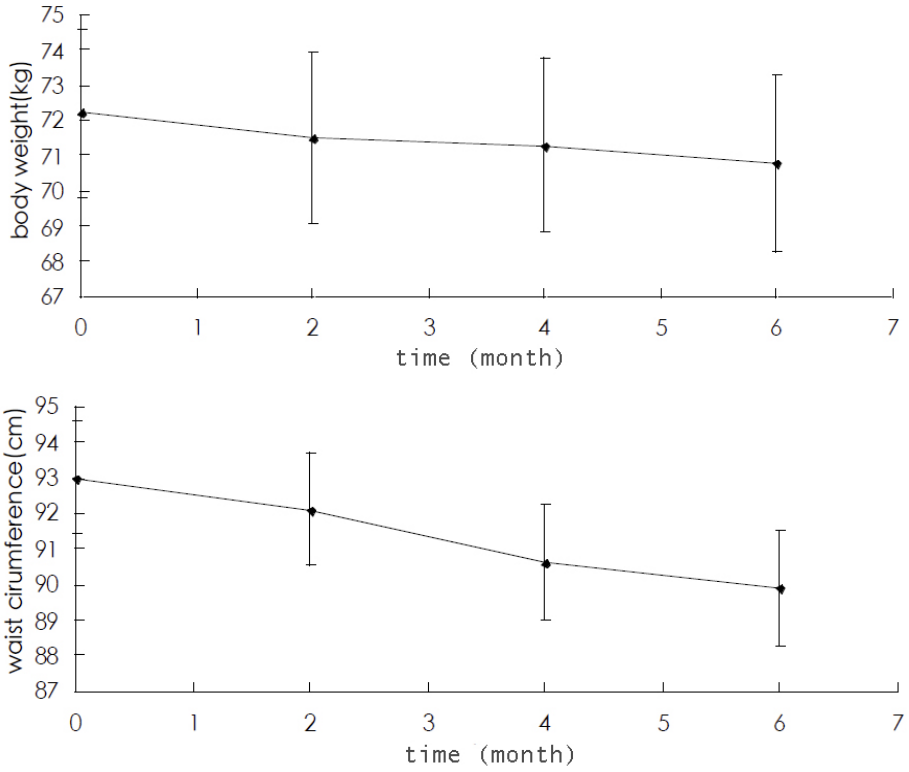

Figure 1: Mean (±SEM) body weight, waist circumference in 30 volunteers after 2, 4 and 6 months of treatments with L-arabinose.

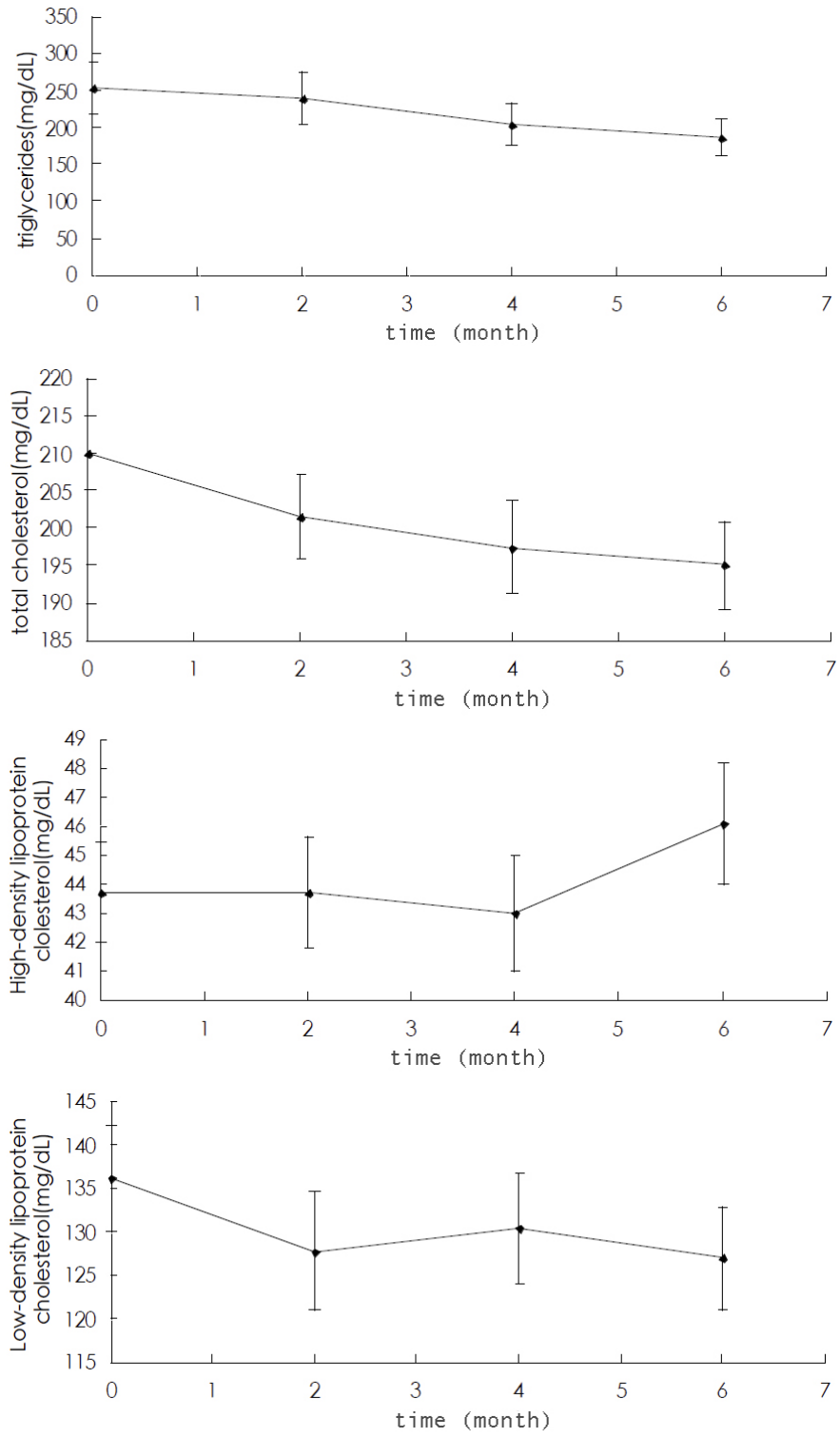

Figure 2: Mean (±SEM) serum concentrations of TG, TC, HDLC, and LDLC in 30 volunteers after 2, 4 and 6 months of treatments with L-arabinose.

serum concentrations of TG after 2, 4 and 6 months of treatment with L-arabinose was observed (Figure **2**).

Total Cholesterol

The Volunteers received L-arabinose after 2, 4 and 6 months of treatment decreased the mean serum concentrations of TC. In comparing with the Pre-treatment mean serum concentrations of TC (210.0±26.9 mg/dL), the 2 months Post-treatment (201.5±31.5mg/dL) decreased but was not statistically significant (P>0.05), the 4 months Post-treatment (197.3±33.1 mg/dL) decreased and had statistically

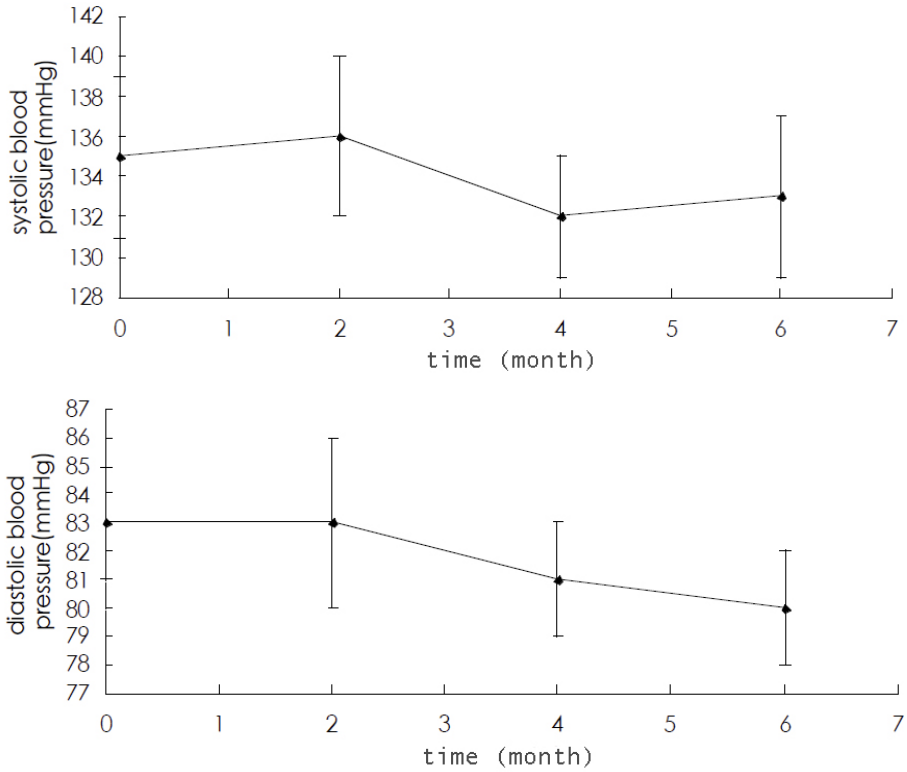

Figure 3: Mean (±SEM) systolic blood pressure and diastolic blood pressure in 30 Volunteers after 2, 4 and 6 months of treatments with L-arabinose.

significance (P<0.05), the 6 months Post-treatment (195.0±31.2 mg/dL) decreased and had statistically significance (P<0.05), a tendency for decreased mean serum concentrations of TC after 2, 4 and 6 months of treatments with L-arabinose was observed (Figure **2**).

High-Density Lipoprotein Cholesterol

In comparing with the Pre-treatment mean serum concentrations of HDLC (43.7±9.3 mg/dL), the 2 months Post-treatment (43.7±10.4 mg/dL) didn't change, the 4 months Post-treatment (43.0±9.3 mg/dL) slightly decreased but was not statistically significant (P>0.05), the 6 months Post-treatment (46.1±11.6 mg/dL) increased but was not statistically significant (P>0.05). Mean serum concentrations of HDLC stayed at a relatively constant level for 4 months after intake of L-arabinose, at the end of the sixth month, the mean serum concentrations of HDLC increased (Figure **2**).

Low-Density Lipoprotein Cholesterol

In comparing with the Pre-treatment mean serum concentrations of LDLC (136.2±33.7 mg/dL), the 2 months Post-treatment (127.7±37.2 mg/dL) decreased but was not statistically significant (P>0.05), the 4 months Post-treatment (130.4±35.2 mg/dL) slightly decreased but was not statistically significant (P>0.05), the 6 months Post-treatment (126.9±31.7 mg/dL) decreased but was not statistically significant (P>0.05).

Systolic Blood Pressure

Repeated-measures analysis showed no significant effects.

Diastolic Blood Pressure

In comparing with the Pre-treatment mean diastolic blood pressure (83±12 mmHg), the 2 months Post-treatment (83±14 mmHg) didn't change, the 4 months Post-treatment (81±10 mmHg) decreased but was not statistically significant (P>0.05), the 6 months Post-treatment (80±9 mmHg) decreased and was statistically significant (P<0.01). Mean diastolic blood pressure stayed at a relatively constant level for 2 months after intake of L-arabinose, at the end of the sixth month, the mean diastolic blood pressure decreased (Figure **3**).

Fasting Plasma Glucose

In comparing with the Pre-treatment mean fasting plasma glucose (113.4±26.1 mg/dL), the 2 months Post-treatment (108.3±18.4 mg/dL) decreased but was not statistically significant (P>0.05), the 4 months Post-treatment (106.2±18.2 mg/dL) decreased but was not

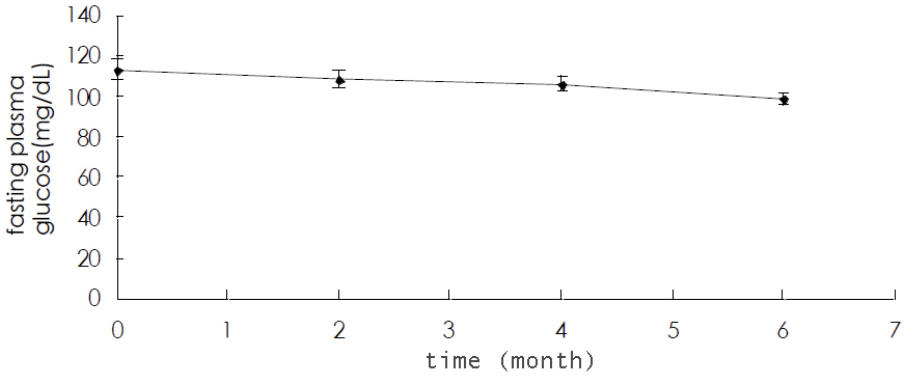

Figure 4: Mean (±SEM) fasting plasma glucose in 30 Volunteers after 2, 4 and 6 months of treatment with L-arabinose.

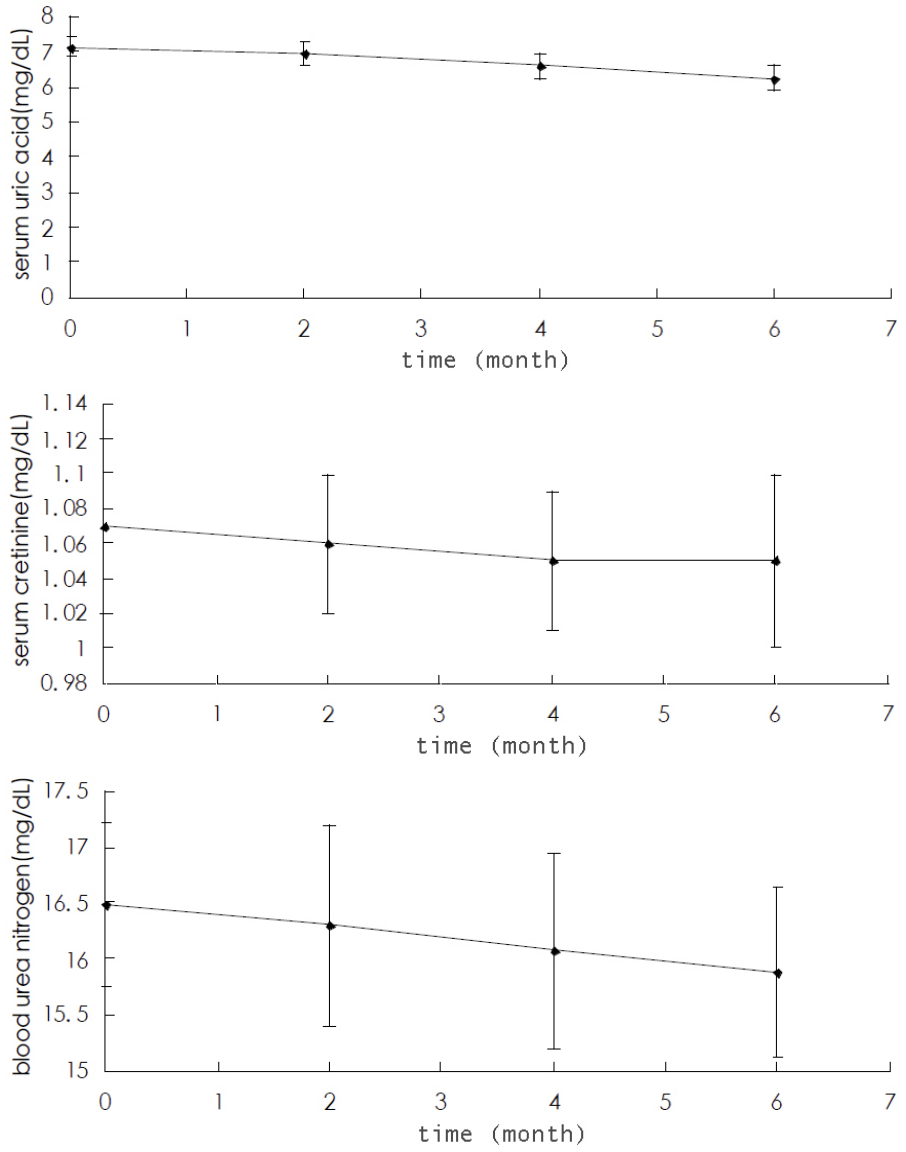

Figure 5: Mean (±SEM) serum uric acid, Scr, BUN in 30 Volunteers after 2, 4 and 6 months of treatments with L-arabinose.

statistically significant (P>0.05), the 6 months Post-treatment mean fasting plasma glucose (98.8±15.3 mg/dL) decreased and had statistically significance (P<0.01). A tendency for decreased mean fasting plasma glucose after 2, 4 and 6 months of treatments with L-arabinose was observed (Figure **4**).

Serum Uric Acid

In comparing with the Pre-treatment mean serum uric acid (7.12±1.67 mg/dL), the 2 months Post-treatment (6.93±1.75 mg/dL) decreased but was not statistically significant (P>0.05), the 4 months Post-treatment (6.57±1.87 mg/dL) decreased but was not statistically significant (P>0.05), the 6 months Post-treatment (6.23±1.87 mg/dL) decreased and was statistically significant (P<0.01). A tendency for decreased mean serum uric acid after 2, 4 and 6 months of treatments with L-arabinose was observed (Figure **5**).

Serum Creatinine

Repeated-measures analysis showed no significant effects.

Blood Urea Nitrogen

Repeated-measures analysis showed no significant effects.

Alanine Aminotransferase

In comparing with the Pre-treatment mean serum concentrations of alanine aminotransferase (37±28 IU/L), the 2 months Post-treatment (30±16 IU/L) decreased and had statistically significance (P<0.05), the 4 months Post-treatment (29±21 IU/L) decreased and had statistically significance (P<0.05), the 6 months Post-treatment (26±13 IU/L) decreased and had statistically significance (P<0.01). A tendency for decreased mean serum concentrations of alanine aminotransferase after 2, 4 and 6 months of treatments with L-arabinose was observed (Figure **6**).

Aspartate Aminotransferase

Repeated-measures analysis showed no significant effects.

DISCUSSION

The primary purposes of the present study was to determine the effects of consumption L-arabinose on metabolic syndrome in humans. Waist circumference, TG, fasting glucose, HDLC, and blood pressure were metabolic syndrome definition was based on the National Cholesterol Education Program Adult Treatment Panel III Criteria. This study clearly showed that L-arabinose could decreased waist circumference, TG, fasting plasma glucose, diastolic blood pressure, and slightly increased HDLC after 6 months of treatment with L-arabinose. The key findings of this study were as follows: L-arabinose could therapy

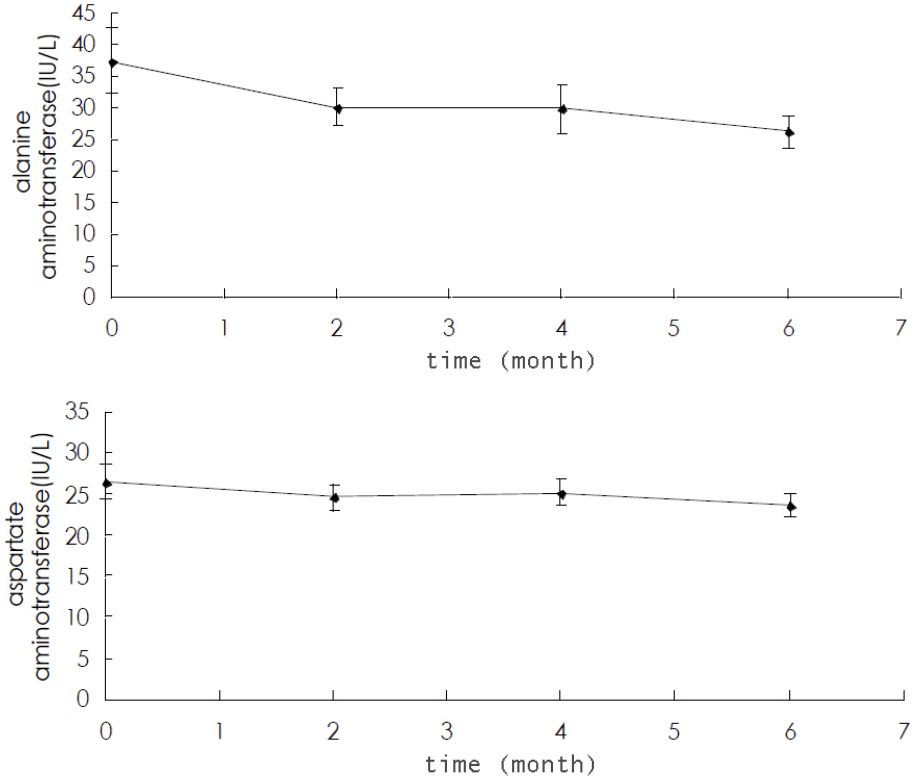

Figure 6: Mean (±SEM) serum concentrations of alanine aminotransferase in 30 Volunteers after 2, 4 and 6 months of treatments with L-arabinose.

metabolic syndrome in humans through decreasing TG, fasting glucose, waist circumference, blood pressure, and increasing HDLC.

As mentioned in the introduction, L-arabinose prevents increases due to dietary sucrose in TG levels in rats [7], increase HDLC and reduce body fat and slow the trend of weight gain in rats with high-sucrose and high-fat feeding [8], and reduces postprandial glucose in both healthy and type 2 diabetic subjects [5,9]. These results agree with the results obtained in the current study: decreasing TG and increasing HDLC in rats are in agreement with the results of human study, and reduceing postprandial glucose in healthy subjects is supported in the present study. Previous studies have shown that rats were gavaged a formulation(the formulation was composed of w/w: dry bean extract (seed–Phaseolus vulgaris) 19%, hibiscus extract (flower-Hibiscus sabdariffa) 31%, L-arabinose 31%, gymnema extract ((leaf-Gymnema sylvestre) 12%, green tea extract leaf- (Camellia sinensis) 6%, and apple extract (fruit-Malus sylvestris) 1% plus the addition of Lactobacillus acidophilus and Bifidobacterium bifidum) for nine weeks lowered systolic blood pressure, but systolic blood pressure began to drop in the test rats after the fifth week [17]. In the current study, it was found that L-arabinose did not affect the systolic blood pressure and mean diastolic blood pressure stayed at a relatively constant level for 2 months after intake of L-arabinose, at the end of the sixth month, the mean diastolic blood pressure decreased and have statistically significant. This finding is not in agreement with the results of a previous study.

Metabolic syndrome is a complex disorder, which is a cluster of various cardiometabolic disorders including hypertension, obesity, dyslipidemia and glucose intolerance [18]. Serum uric acid levels and ALT levels have been reported to be associated with metabolic syndrome [18~25]. Uric acid is the final product of purine metabolism and is excreted *via* the urine in higher primates, particularly in humans, over half of the antioxidant capacity of blood plasma comes from uric acid [26]. Serum uric acid levels is strongly and positively associated with metabolic syndrome risks, one of the possible biological mechanisms is related to insulin-stimulated endothelial nitric oxide synthesis [27], another possible mechanism is related to inflammation and oxidative stress, uric acid in adipocytes of obese mice induced inflammatory oxidative changes: hence the resulting development of metabolic syndrome [28, 29]. Reports have shown that serum uric acid levels have been increasing since 1960s in the US population. Non-alcoholic fatty liver disease, which is caused by excess deposition of fat in the liver, is now regarded as the hepatic manifestation of metabolic syndrome [30]. Non-alcoholic fatty liver disease, diagnosed on the basis of a raised ALT (ALT; >40 IU/ L) after exclusion of other known causes of elevated liver enzymes, was reported to be predictive of developing metabolic syndrome. Moreover, an elevated ALT level within its reference range, which is also known as a ‘‘high-normal’’ ALT level, is also associated with increased risks of metabolic syndrome, high-normal serum ALT is associated with increased risk of developing metabolic syndrome [18]. The present study found L-arabinose decreased serum uric acid levels and ALT levels, a tendency for decreased mean serum concentrations of serum uric acid levels and ALT after 2, 4 and 6 months of treatments with L-arabinose was observed. To our knowledge, this is the first study to find L-arabinose decreased serum uric acid and ALT levels.

The incidence and prevalence of gout and hyperuricemia are increasing worldwide secondary to a multitude of factors, especially changes in dietary intake and lifestyle, in both developed and developing countries [31]. Gout progresses through four clinical phases: asymptomatic hyperuricemia, acute gouty arthritis, intercritical gout (intervals between acute attacks) and chronic tophaceous gout [32]. Gout is characterized by hyperuricemia exceeding 6.8 mg/dl, the upper limit of urate solubility [31]. Management aims to reduce serum uric acid below 6.0 mg/dl (357mmol/l), according to several consensus reports and recommendations, decreases the risk of recurrent attacks and tophus formation [31]. The present study found L-arabinose decreased serum uric acid levels, according to this result, L-arabinose could prevent the occurrence of gout.

In addition, we measured TC, LDLC, body weight, Scr, BUN, AST. A TC reading can be used to assess your risk for heart disease [33], according to the National Cholesterol Education Program, your TC level should be lower than 200 mg/dL, if your total cholesterol level is 200 mg/dL or above, your total cholesterol level is considered to be high, in this case, your healthcare provider may recommend lifestyle changes to lower it -- especially if it is discovered that your LDL and/or TG are also high. This finding that L-arabinose can decreased mean serum concentrations of TC lower than 200 mg/dL which is near optimal TC, corresponding to lower rates for heart disease. Low-density lipoprotein transports cholesterol from the liver

to the tissues of the body. LDLC is therefore considered the "bad" cholesterol. Low-density lipoprotein levels between 25 and 100 mg/dL are considered optimal LDLC, corresponding to lower, but not zero, rates for symptomatic cardiovascular disease events; Low-density lipoprotein levels between 100 and 129 mg/dL are considered near optimal LDLC level, corresponding to higher rates for developing symptomatic cardiovascular disease events; Low-density lipoprotein levels between 130 and 159 mg/dL are considered borderline high LDLC level, corresponding to even higher rates for developing symptomatic cardiovascular disease events [34]. This finding that L-arabinose can decreased mean serum concentrations of LDLC lower than 130 mg/dL which is near optimal LDLC, corresponding to lower rates for developing symptomatic cardiovascular disease events. The present study showed that L-arabinose decreased mean body weight, and did not affect the mean serum concentrations of Scr, BUN, AST. As previously mentioned, L-arabinose decreased mean serum concentrations of ALT. ALT and AST was then additionally adjusted as a marker of liver function; Scr and BUN was then additionally adjusted as a marker of kidney function. L-arabinose did not affect the liver and kidney function.

The clinical management of metabolic syndrome is difficult because there is no recognized method to prevent or improve the whole syndrome, the background of which is essentially insulin resistance [36]. The prime emphasis in management of the metabolic syndrome per se is to mitigate the modifiable, underlying risk factors (obesity, physical inactivity, and atherogenic diet) through lifestyle changes (dietary counseling and encouragement to exercise). Effective lifestyle change will reduce all of the metabolic risk factors. Then, if absolute risk is high enough, consideration can be given to incorporating drug therapy to the regimen. Many physicians treat the individual characteristics of metabolic syndrome (high blood pressure, high triglycerides, and so on) instead of the syndrome as a whole, placing particular emphasis on those components that are easily amenable to drug treatment [35]. Many people might be unwilling to further change their unhealthy lifestyle in modern society, and prescribe drugs used to correct individual aspects of metabolic syndrome, many patients inevitably develop the many adverse effects of these drugs, in particular increased insulin resistance, so the prevalence of the metabolic syndrome is high. We found L-arabinose will reduce most the metabolic syndrome risk factors (decreased circumference, triglycerides, fasting glucose, and so on), and treat the metabolic syndrome as a whole. The present study provides strong evidence that long-term received L-arabinose would be manage metabolic syndrome.

ACKNOWLDGEMENTS

We thank a total of 43 volunteers in the Second people's Hospital of Guangxi Zhuang Autonomous Rcglon and nearby communities participated in the study. L-Arabinose(Thomson Biotech, Xiamen) funded the research but had no influence on the protocols, design, calculations, or publishing of the manuscript.

CONFLICT OF INTEREST

The authors' responsibilities were as follows—All authors contributed to the development of the final study design and interpretation of the results. DL: principal investigator; ZY: conducted the literature search and data analyses; ZY and DL: participated in the preparation and revision of the manuscript; and ZY, DL, HJ, GQ, WM, MZ, and HZ: contributed to the execution of this study at various stages. None of the authors declared a conflict of interest.

REFERENCES

[1] Eva K, Panagiota P, Gregory K, George C. Metabolic syndrome: definitions and controversies. BMC Med 2011; 9: 48-60. http://dx.doi.org/10.1186/1741-7015-9-48

[2] Apridonidze T, Essah PA, Iuorno MJ, Nestler JE. Prevalence and characteristics of the metabolic syndrome in women with polycystic ovary syndrome. J Clin Endocrinol Metab 2004; 90: 1929-35. http://dx.doi.org/10.1210/jc.2004-1045

[3] McLaughlin T, Allison G, Abbasi F, Lamendola C, Reaven G. Prevalence of insulin resistance and associated cardiovascular disease risk factors among normal weight, overweight, and obese individuals. Metabolism 2004; 53: 495-9. http://dx.doi.org/10.1016/j.metabol.2003.10.032

[4] Abhishek G, Vani G. Metabolic syndrome: What are the risks for humans. Biosci Trends 2010; 4(5): 204-12.

[5] Diabetes Society of the Chinese Medical Association Metabolic Syndrome Study Group. Diabetes Society of the Chinese Medical Association on the recommendations of the metabolic syndrome. Chin J Diabetes 2004; 12(3): 156-200 (in chinese).

[6] Cameron AJ, Shaw JE, Zimmet PZ. The metabolic syndrome: Prevalence in worldwide populations. Endocrinol Metab Clin North Am 2004; 33: 351-75. http://dx.doi.org/10.1016/j.ecl.2004.03.005

[7] Ford ES, Giles WH, Mokdad AH. Increasing prevalence of the metabolic syndrome among U.S. adults. Diabetes Care 2004; 27: 2444-9. http://dx.doi.org/10.2337/diacare.27.10.2444

[8] Bernhard S, Benjamin M. Fungal arabinan and L-arabinose metabolism. Appl Microbiol Biotechnol 2011; 89: 1665-73. http://dx.doi.org/10.1007/s00253-010-3071-8

[9] Schutte JB, De-Jong J, Van-Weerden EJ, Tamminga S. Nutritional implications of L-arabinose in pigs. Br J Nutr 1992; 68: 195-207. http://dx.doi.org/10.1079/BJN19920077

[10] Segal S, Foley JB. The metabolic fate of C^{14} labeled pentoses in man. J Clin Invest 1959; 38: 407-13. http://dx.doi.org/10.1172/JCI103815

[11] Seri K, Sanai K, Matsuo N, Kawakubo K, Xue C, Inoue S. L-arabinose selectively inhibits intestinal sucrase in an uncompetitive manner and suppresses glycemic response after sucrose ingestion in animals. Metabolism 1996; 45: 1368-74. http://dx.doi.org/10.1016/S0026-0495(96)90117-1

[12] Inger KM, Ole H, Inge T, Jens JH, Jens RA, Klaus B. The effects of L-arabinose on intestinal sucrase activity: dose-response studies *in vitro* and in humans. Am J Clin Nutr 2011; 94: 472-78. http://dx.doi.org/10.3945/ajcn.111.014225

[13] Gilbert RK, Samuel CK, Patti LK, Robert BL, Nicholas VP, Harry GP. A combination of l-arabinose and chromiumlowers circulating glucose and insulin levels after an acute oral sucrose challenge. Nutr J 2011; 10: 42-7. http://dx.doi.org/10.1186/1475-2891-10-42

[14] Osaki S, Kimura T, Sugimoto T, Hizukuri S, Iritani N. L-arabinose feeding prevents increases due to dietary sucrose in lipogenic enzymes and triacylglycerol levels in rats. J Nutr 2001; 131(3): 796-9.

[15] HE L, Man QQ, Qiu ZL, Fu P, Wang XG. Effects of L-Arabinose on Growth and Carbohydrate, Lipid Metabolism in Wistar Rats with Normal Feeding and High-Sucrose and High-Fat Feeding. Chinese Journal of Food Hygiene 2009; 21: 406-9 (in chinese).

[16] Gilbert RK, Samuel CK, Patti LK, Robert BL, Nicholas VP, Harry GP. A combination of l-arabinose and chromium lowers circulating glucose and insulin levels after an acute oral sucrose challenge. Nutr J 2011; 10: 42-7. http://dx.doi.org/10.1186/1475-2891-10-42

[17] Harry GP, Bobby E, Debasis B, Sidney S. Inhibition by Natural Dietary Substances of Gastrointestinal Absorption of Starch and Sucrose in Rats. Subchronic Studies. Int J Med Sci 2007; 4(4): 209-15.

[18] Yu X, Yu-fang B, Min X, *et al*. Cross-sectional and longitudinal association of serum alanine aminotransaminase and c-glutamyltransferase with metabolic syndrome in middle-aged and elderly Chinese people. J Diabetes 2011; 3: 38-47. http://dx.doi.org/10.1111/j.1753-0407.2010.00111.x

[19] Ju-Mi L, Hyeon CK, Hye MC, Sun MO, Dong PC, Il S. Association Between Serum Uric Acid Level and Metabolic Syndrome. J Prev Med Public Health 2012; 45(3): 181-7. http://dx.doi.org/10.3961/jpmph.2012.45.3.181

[20] Eiji O, Ryu K, Kenichi W, Vijayakumar S. Prevalence of Metabolic Syndrome Increases with the Increase in Blood Levels of Gamma Glutamyltransferase and Alanine Aminotransferase in Japanese Men and Women. Inter Med 2009; 48: 1343-50. http://dx.doi.org/10.2169/internalmedicine.48.2094

[21] Ishizaka N, Ishizaka Y, Toda E, Nagai R, Yamakado M. Association between serum uric acid, metabolic syndrome, and carotid atherosclerosis in Japanese individuals. Arterioscler Thromb Vasc Biol 2005; 25(5): 1038-44. http://dx.doi.org/10.1161/01.ATV.0000161274.87407.26

[22] Lin SD, Tsai DH, Hsu SR. Association between serum uric acid level and components of the metabolic syndrome. J Chin Med Assoc 2006; 69(11): 512-6. http://dx.doi.org/10.1016/S1726-4901(09)70320-X

[23] Goessling W, Massaro JM, Vasan RS, D Agostino RB Sr, Ellison RC, Fox CS. Aminotransferase levels and 20-year risk of metabolic syndrome, diabetes, and cardiovascular disease. Gastroenterology 2008; 135(6): 1935-44. http://dx.doi.org/10.1053/j.gastro.2008.09.018

[24] Wang JY, Chen YL, Hsu CH, Tang SH, Wu CZ, Pei D. Predictive value of serum uric Acid levels for the diagnosis of metabolic syndrome in adolescents. J Pediatr 2012; 161(4): 753-6. http://dx.doi.org/10.1016/j.jpeds.2012.03.036

[25] Chiou WK, Huang DH, Wang MH, Lee YJ, Lin JD. Significance and association of serum uric acid (UA) levels with components of metabolic syndrome (MS) in the elderly. Arch Gerontol Geriatr 2012; 55(3): 724-8. http://dx.doi.org/10.1016/j.archger.2012.03.004

[26] Kang DH. Potential role of uric Acid as a risk factor for cardiovascular disease. Korean J Intern Med 2010; 25(1): 18-20. http://dx.doi.org/10.3904/kjim.2010.25.1.18

[27] Feig DI, Kang DH, Johnson RJ. Uric acid and cardiovascular risk. N Engl J Med 2008; 359(17): 1811-21. http://dx.doi.org/10.1056/NEJMra0800885

[28] Sautin YY, Nakagawa T, Zharikov S, Johnson RJ. Adverse effects of the classic antioxidant uric acid in adipocytes: NADPH oxidase-mediated oxidative/nitrosative stress. Am J Physiol Cell Physiol 2007; 293(2): 584-96. http://dx.doi.org/10.1152/ajpcell.00600.2006

[29] Furukawa S, Fujita T, Shimabukuro M, Iwaki M, Yamada Y, Nakajima Y. Increased oxidative stress in obesity and its impact on metabolic syndrome. J Clin Invest 2004; 114(12): 1752-61.

[30] Marchesini G, Brizi M, Bianchi G, *et al*. Nonalcoholic fatty liver disease: a feature of the metabolic syndrome. Diabetes 2001; 50(8): 1844-50. http://dx.doi.org/10.2337/diabetes.50.8.1844

[31] Ignacio GV, Tahir K, Luis R. Espinoza. Efficacy and safety of febuxostat in patients with hyperuricemia and gout. Ther Adv Musculoskel Dis 2011; 3(5): 245-53. http://dx.doi.org/10.1177/1759720X11416405

[32] Mark D, Harris, Lori B, Siegel, Jeffrey A, Alloway. Gout and Hyperuricemia. Am Fam Physician 1999; 59(4): 925-34.

[33] Simon C, Earl SF. Why have total cholesterol levels declined in most developed countries. BMC Public Health 2011; 11: 641-5. http://dx.doi.org/10.1186/1471-2458-11-641

[34] Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive Summary of The Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). JAMA 2001; 285(19): 2486-97. http://dx.doi.org/10.1001/jama.285.19.2486

[35] Michel DL. Commentary on the clinical management of metabolic syndrome: why a healthy lifestyle is important. BMC Med 2012; 10: 139-48. http://dx.doi.org/10.1186/1741-7015-10-139

Received on 09-04-2013 Accepted on 29-04-2013 Published on 30-04-2013

DOI: http://dx.doi.org/10.6000/1927-5951.2013.03.02.2