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# Serum levels of polyunsaturated fatty acids are low in Chinese men with metabolic syndrome, whereas serum levels of saturated fatty acids, zinc, and magnesium are high

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**Abstract**

The purpose of this study was to examine the hypothesis that serum levels of phospholipid (PL) fatty acids (FA) and minerals are associated with the components of metabolic syndrome (MetS) in the Chinese population and the profiles of changes may differ from patients with MetS from Western countries. The levels of serum PL, FA, and minerals were examined in 201 subjects (52 with MetS and 149 healthy controls without any MetS components) in China. The saturated FA proportion in serum was significantly higher, whereas the proportion of total polyunsaturated FA (PUFA), n-3 and n-6 PUFA (22:6n-3: −16%, $P = .006$; 20:4n-6: −36%, $P < .001$), and estimated δ-5 desaturase were significantly lower in the MetS group compared with those that are not MetS. Subjects with MetS had higher levels of serum Zn ($P = .037$) and Mg ($P < .001$) than subjects without MetS. The proportion of n-3 PUFA was significantly negatively correlated with body mass index and waist circumference. In conclusion, serum PL FA composition and serum minerals in Chinese men with MetS differed significantly from that of healthy individuals, reflecting a decrease in n-3 and n-6 PUFA, especially 22:6n-3 and 20:4n-6, and an increase in saturated FA, magnesium, and zinc. These changes may reflect improper dietary intake in subjects with MetS, and dietary modification could be useful to prevent MetS and as an adjunctive therapy.


*Keywords:* Metabolic syndrome; Fatty acids; Minerals; Desaturase; Chinese men

*Abbreviations:* BMI, body mass index; Ca, calcium; Cu, copper; D5D, δ-5 desaturase; D6D, δ-6 desaturase; FA, fatty acids; Fe, iron; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; MetS, metabolic syndrome; Mg, magnesium; PG, prostaglandin; PL, phospholipids; PUFA, polyunsaturated FA; SFA, saturated FA; Zn, zinc.

## 1. Introduction

Metabolic syndrome (MetS) is a clustering of abnormalities including obesity, dyslipidemia, hyperglycemia, and hypertension [1]. The major components of MetS are associated with genetic predisposition and lifestyle factors. In the last 2 decades with rapid economic growth and change in diet and lifestyle, MetS has become one of the most widespread health challenges in China, with a prevalence of 9.8% and 17.8% in men and women, respectively [2].

The fatty acid (FA) composition of serum phospholipids (PLs) can be used to track dietary intake of FA for a period of a few weeks and also reflects endogenous FA metabolism

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[3], regulated by different enzymes, such as desaturases and elongases [4]. The FA composition in serum can be used as an indicator for the risks of some metabolic and cardiovascular diseases [4]. High proportions of palmitic acid (16:0) and dihomo-γ-linolenic acid (20:3n-6) and low concentrations of linoleic acid (18:2n-6) in serum cholesteryl esters are characteristic of these populations in Western countries [5]. Furthermore, several enzymes, including δ-5 desaturase (D5D), δ-9 desaturase (D9D), δ-6 desaturase (D6D), and elongase, are involved in the endogenous synthesis of polyunsaturated FAs (PUFA), and thus, their activities can be estimated by the product precursor ratios of individual FAs in human tissues [4].

The serum minerals, zinc (Zn), copper (Cu), calcium (Ca), magnesium (Mg), and iron (Fe), are associated with MetS [6,7]. Hypomagnesemia has been demonstrated in various experimental models of hypertension [8]. Zinc has been positively correlated with total cholesterol and low-density lipoprotein cholesterol (LDL-C) [9]. Furthermore, trace elements, such as Zn and Mg, are important cofactors for normal activities of desaturases and elongases in endogenous FA synthesis [10,11]. Therefore, the alteration of serum mineral levels in individuals with MetS may influence the activities of these enzymes and, hence, the regulation of FA metabolism and production of PUFA.

Alterations of serum FA composition or minerals of subjects with MetS have been reported in Western countries [12-14]. Serum FA composition predicts the long-term development of MetS [12,13] and is related to components of MetS. Low serum Mg levels are related to MetS and its components [14]. The research of FA and minerals in Chinese population is sparse. Our hypothesis is that altered PL FA composition and minerals in serum are correlated with the components of MetS. The changes may differ from that in subjects with MetS in Western countries. The lifestyle factors and genetic phenotype differ dramatically between Chinese and Western populations, which may influence the intake of FAs and minerals and their metabolism in the blood. We performed a cross-sectional study to compare the serum FA composition and mineral levels of male subjects with MetS in the eastern coastal area of China. The levels of FAs in serum PLs were determined by gas-liquid chromatography, whereas the levels of serum minerals were detected by a Perkin-Elmer Flame Atomic Absorption Spectroscopy (Perkin Elmer AAnalyst 800; Perkin-Elmer, Beaconsfield, United Kingdom).

## 2. Methods and materials

### 2.1. Definition of the MetS

We used the Chinese Diabetes Society's definition of MetS [15]. Metabolic syndrome was considered present when 3 or more of the following components were met: (1) overweight or obesity: body mass index (BMI) 25 or more; (2) Hyperglycemia: fasting blood glucose 6.1 mmol/L or more and/or 2-hour postprandial blood glucose 7.8 mmol/L or more, and/or diabetic patient under treatment; (3) hypertension: systolic/diastolic blood pressure 140/90 mm Hg or greater and/or patients with hypertension under treatment; and (4) dyslipidemia: fasting blood triacylglycerol (TG) 1.7 mmol/L or more and/or blood high-density lipoprotein cholesterol (HDL-C) (fasting) less than 0.9 mmol/L (male) and less than 1.0 mmol/L (female).

### 2.2. Subjects

Subjects provided informed consent. The study protocol was approved by the Ethics Committee, Zhejiang University, China. There were 379 male participants aged 24 to 57 years in the study, recruited through a health check program in 2 sanatoriums of Hangzhou, China. In the 2 months before the study, the participants did not smoke and had no acute diseases, operations, or chronic medication. Of the 379 participants, there were (1) 120 subjects with 1 component of MetS (31.7%), (2) 58 subjects with 2 components of MetS (15.3%), (3) 43 subjects with 3 components of MetS (11.3%), and (4) 9 subjects with 4 components of MetS (2.4%). The subjects with 3 or 4 components of MetS were selected as MetS group (52 subjects, 13.7%). The 149 subjects who did not have any components of MetS were selected as the control group.

### 2.3. Blood sampling and blood biochemical parameters analysis

Blood samples were taken from the antecubital vein after the subjects fasted overnight (>12 hours). All samples were processed within 3 hours of sampling, and serum samples were divided into aliquots for immediate analysis or for long-term storage at −80 °C. Serum biochemical parameters were measured by Olympus AU2700 chemistry-immuno analyzer (Olympus America Inc, Melville, NY).

### 2.4. Serum PLs FA and serum minerals

The total lipid of serum was extracted with chloroform: methanol 1:1 (C:M, vol/vol) containing 10 mg/L of butylated hydroxytoluene and 10 mg/L of C17:0 PL (diheptadecanoyl) (Nu-Chek-Prep, Inc, Minn) as the internal standard [16,17]. The serum PL fractions were separated by thin-layer chromatography. The methyl esters of the FA were prepared by saponification using potassium hydroxide (KOH) (0.68 mol/L in methanol), followed by transesterification with 20% boron trifluoride (BF3) in methanol. The FA compositions of serum PL were determined by gas-liquid chromatography as described previously [16,17]. Levels of serum minerals were quantified using a Perkin-Elmer Flame Atomic Absorption Spectroscopy according to the standard method [18].

### 2.5. Estimation of desaturase activity

The desaturase activity was estimated as the product-precursor ratio of individual FAs in serum PL according to