Prevalence and clinical profile of metabolic syndrome in longevity: study from Guangxi Zhuang Autonomous Region, China

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Abstract

Background: Metabolic syndrome (MetS) was a risk factor for cardiovascular diseases, yet the prevalence of MetS among nonagenarians and centenarians was rarely reported. Here we investigated the prevalence of MetS and its components among nonagenarians and centenarians in our Zhuang population from Bama, Guangxi Zhuang Autonomous Region, China.

Method: In Bama area, there registered 881 individuals who lived more than 90 years old in 269,800 local residents and our study involved 307 long-lived participants and 486 local younger (35–68 years) persons, as controls. MetS was defined according to the revised National Cholesterol Education Program’s Adult Treatment Panel III (NCEP ATPIII) criteria.

Results: The overall prevalence estimates of MetS among longevity group were 28.0% based on NCEP ATPIII criteria. The most common metabolic component was elevated blood pressure (61.1%), followed by raised fasting glucose (39.1%) and low high-density lipoprotein cholesterol (low HDL-C) (28.0%). The prevalence of MetS and abdominal obesity in women (33.6% and 22.1% respectively) was higher than that of men (19.8% and 3.7% respectively) (P range < .001–0.019). Compared with controls, long-lived individuals were more likely to have two or more metabolic abnormalities (P range < 0.001), and less likely to have zero or one metabolic abnormality (P range < 0.001–0.020).

Conclusion: This study showed substantially the prevalence and clinical profile of MetS in longevity population in Guangxi Zhuang Autonomous Region, China.

Keywords: Longevity, Metabolic syndrome, Chinese
suggesting that nonagenarians and centenarians had lower prevalence of overweight, obesity and lower blood pressure [6]. Instead, centenarians from Poland showed that mildly elevated blood pressure is a marker for better health status [7]. Recent study of familial longevity from China revealed decreased diastolic blood pressure but increased systolic blood pressure in centenarians [8]. Similar discrepancy can also be found among studies of lipid profile and longevity. Biological study for longevity demonstrated that centenarians and their offspring have significantly larger high-density lipoprotein (HDL) levels and particle sizes and low-density lipoprotein (LDL) levels compared with controls [9, 10]. However, other studies did not find significant association of HDL-C levels with centenarians [11, 12].

All of these studies indicated that individuals with longevity might have different metabolic phenotypes from those general individuals under different ethnic background. But no reports on these metabolic items research integrated were seen now yet. Furthermore, the prevalence of MetS increased in Chinese population aged 60–95 [13]. Thus we perform the study to investigate the prevalence and clinical profile of MetS in longevity in Guangxi Zhuang Autonomous Region, China.

Methods

Study population

The project is a cross-sectional study within the framework of the “Longevity and Health of Aging Population in Guangxi China (LHAPGC)” [14]. In this study, “longevity” subjects were classified as participants who had survived to age 90 years or more, with “unrelated younger controls” aged 35–68 years. A random sample of 793 individuals belonged to the Zhuang population from Bama (total population: 269,800) was recruited, including 307 long-lived individuals (256 nonagenarians and 51 centenarians) and 486 local and unrelated younger controls. Zhuang population is one of the largest ethnic groups in mainland China, second only to the Han population. The individuals with longevity included 226 women and 81 men (mean age: 95.06 ± 4.91 years and 94.60 ± 4.09 years old for women and men, respectively; range: 90–111 years old). The control group comprised 185 women and 301 men (mean age: 47.98 ± 4.07 and 47.24 ± 3.70 years old for women and men, respectively; range: 35–68 years old).

The survey was conducted using a uniform standardized protocol. All participants were examined by a senior physician and underwent extensive neuropsychological test as well as taking instrumental examination such as electrocardiogram and ultrasound examination. Individuals with longevity as well as controls were excluded if they had chronic disease such as malnutrition, hepatic disease, kidney disease and cancer. All controls refer to local and unrelated younger participants in general population.

The study was conducted according to the principles expressed in the Declaration of Helsinki. The Ethics Committee of Beijing Hospital, Ministry of Health approved the study protocol. Written informed consent was obtained from each of the participants.

Measurements

MetS was diagnosed as three or more of the following five factors as defined by the revised National Cholesterol Education Program’s Adult Treatment Panel III (NCEP ATPIII) criteria for Asians (the American Heart Association and the National Heart, Lung, and Blood Institute (AHA/NHLBI) revised in 2005 [4], the same as the joint interim statement in 2009 [5]: (1) waist circumference ≥ 90 cm in males and ≥80 cm in females; (2) systolic blood pressure (SBP) ≥ 130 mmHg or diastolic blood pressure (DBP) ≥ 85 mmHg or taking antihypertensive drugs; (3) fasting blood glucose ≥ 5.6 mmol/L or taking drugs for diabetes; (4) triglycerides ≥ 1.7 mmol/L or taking antihyperlipidemic drugs; (5) HDL-C < 1.03 mmol/L in males and <1.29 mmol/L in females or taking antihyperlipidemic drugs.

Body mass index (BMI) was determined as weight (kg) divided by height (m) squared. Waist circumference was measured at the mid-point between the lowermost rib and the iliac crest.

Laboratory measurements

Blood samples were collected after at least eight hours overnight fast for serum biochemistry, lipid profile, and plasma glucose in all participants. Clinical biomarkers including fasting plasma glucose (FPG), triglyceride (TG), and high-density lipoprotein cholesterol (HDL-C) were determined following standard laboratory procedures. Blood pressure was measured using a standard mercury sphygmomanometer on the right arm after at least 10 min of rest.

Statistical analysis

All statistical analyses were conducted using the SPSS 18.0 software package. One-Way ANOVA and a chi-squared test were used to compare demographic and clinical data between longevity and controls. Age- and sex- adjusted were applied according to the 2010 population census of the people’s republic of China from National Bureau of Statistics [1]. A two-tailed $P < 0.05$ was considered statistically significant.
Results

Demographic and metabolic characteristics in two groups

Data for demographic characteristics were showed as numbers, and data for metabolic characteristics were presented as median and interquartile range (INR) in Table 1. Except for frequency of alcohol intake ($P = 0.772$), there were significant difference for frequency of cardiovascular disease, smoking status and sex ratio between the longevity group and the control one ($P_{\text{range}} < .001$). The study consisted of 793 participants with a female preponderance in the longevity group (Male: Female = 1:2.79). Generally, subjects in the long-lived individuals cohort had significantly lower levels of height, body mass index (BMI), weight, waist circumference (WC), and TG than controls ($P_{\text{range}} < .001$ – 0.002), except for systolic blood pressure (SBP), diastolic blood pressure (DBP), and FPG ($P_{\text{range}} < .001$) (see Table 1). There was no difference of HDL-C level between two groups ($P = 0.766$).

Overall prevalence of metabolic profile

Table 2 showed the prevalence of MetS among the longevity of Zhuang Population from Guangxi Zhuang Autonomous Region. The prevalence of MetS was significantly higher in the longevity group (28.0%) than it is in the local general control group (5.1%) (OR: 0.139, 95%CI: 0.087–0.224, $P < .001$) regardless of the used criteria ($P_{\text{range}} < .001$) (see Table 2). The most common metabolic component in longevity individuals was high blood pressure (61.1%), followed by raised fasting glucose (39.1%) and low HDL-C (28.0%). In addition, the prevalence of high blood pressure (HBP) (OR: 0.106,

| Variables                              | Longevity(N = 307) | Control(N = 486) | $P$   |
|----------------------------------------|--------------------|------------------|-------|
| Cardiovascular disease(N)              | 17                 | 0                | <.001 |
| Smoking status(N)                      |                    |                  |       |
| Never                                  | 295                | 420              | <.001 |
| Former                                 | 12                 | 15               |       |
| Current                                | 0                  | 51               |       |
| Cigarettes per day (current)(N)        |                    |                  |       |
| ≤ 10                                   | 0                  | 35               | -     |
| ≥ 11                                   | 0                  | 31               |       |
| Frequency of alcohol intake(N)         |                    |                  |       |
| 1–3 times/month                        | 6                  | 10               | 0.772 |
| 1–2 times/week                         | 23                 | 44               |       |
| 3–4 times/week                         | 8                  | 20               |       |
| Nearly 1 time/day                      | 5                  | 6                |       |
| Drugs(N)                               |                    |                  |       |
| Antidyslipidemic                       | 0                  | 0                | -     |
| Antihypertensive                       | 2                  | 0                |       |
| Antidiabetic                           | 0                  | 0                |       |
| Gender(M/F)(N)                         | 81/226             | 301/185          | <.001 |
| Age (Median(INR))                      | 94(91–98)          | 48(45–49)        | <.001 |
| Height (Median(INR))                   | 145.0(140.0–151.0) | 164.5(158.0–169.5) | <.001 |
| Weight (Median(INR))                   | 38(34–45)          | 66(58–72)        | <.001 |
| BMI (Median(INR))                      | 18.35(16.41–20.93) | 24.11(22.57–26.00) | <.001 |
| SBP (Median(INR))                      | 146(132–160)       | 120(110–130)     | <.001 |
| DBP (Median(INR))                      | 80(72–90)          | 76(70–84)        | <.001 |
| WC (Median(INR))                       | 71(65.0–78.0)      | 80.5(75.0–86.0)  | <.001 |
| FPG (Median(INR))                      | 5.08(4.30–6.16)    | 4.89(4.47–5.24)  | <.001 |
| TG (Median(INR))                       | 1.08(0.77–1.55)    | 1.52(1.22–1.86)  | 0.002 |
| HDL-C (Median(INR))                    | 1.40(1.10–1.81)    | 1.46(1.30–1.68)  | 0.766 |

INR interquartile range, BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure, WC waist circumference, FPG fasting plasma glucose, TG triglyceride, HDL-C high-density lipoprotein cholesterol
95% CI: 0.075–0.150, \( P < .001 \), raised fasting glucose (OR: 0.121, 95% CI: 0.080–0.183, \( P < .001 \)), and low HDL-C (OR: 0.241, 95% CI: 0.166–0.350, \( P < .001 \)) was significantly higher in long-lived individuals than it is in control subjects. On the contrary, the prevalence of high TG (OR: 1.980, 95% CI: 1.426–2.749, \( P < .001 \)) was much lower in people with longevity than the controls (see Table 2). There was no difference of the abdominal obesity between longevity individuals and controls (OR: 0.753, 95% CI: 0.508–1.116, \( P = 0.157 \)) (see Table 2).

### Prevalence of metabolic profile in longevity

Since numbers of male and female in longevity group are not equal, we compared the prevalence of clinical metabolic data among male and female participants. We did not find significant difference of age, height, weight, BMI, SBP, DBP, WC, FPG, TG and HDL-C among male and female long-lived individuals (\( P \) range > 0.05).

Compared to males, the estimated odds of having MetS were 2.057 times higher in female longevity subjects (OR: 2.057, 95% CI: 1.118–3.787, \( P = 0.019 \)) (see Table 3). At the same time, females were more likely to have abdominal obesity compared to males (\( P < .001 \)) (see Table 3). No significant difference of prevalence for elevated BP, raised fasting glucose, high TG, and low HDL-C among male and female individuals aged 90+ years were noted in this study (see Table 3).

### Trend for frequency of metabolic abnormalities in two groups

In this study, people aged 90+ have much higher prevalence of MetS than that of the controls (28.0% vs. 5.1%) (See Table 2). For further analyzing the trend of MetS, we researched the prevalence of having zero, one, two, three, four, and five MetS components in the two groups. Table 4 showed that Compared with controls, long-lived individuals were more likely to have two or more components of MetS (for longevity: 36.2% and 28.0% respectively; for controls: 21.2% and 5.1% respectively; \( P \) range < 0.001), and less likely to have zero or one components of MetS (for longevity: 6.2% and 29.6% respectively; for controls: 32.1% and 41.6% respectively; \( P \) range < 0.001–0.020).

### Discussion

The present study provided the information on the overall prevalence estimates of MetS in longevity group been 28.0% based on NCEP ATP III criteria. The most common metabolic component was high blood pressure, followed by raised fasting glucose and low HDL-C. The prevalence of MetS and abdominal obesity in women was higher than that of men. No significant difference of metabolic components among longevity participants were found after stratified by gender. The prevalence of MetS among longevity individuals was significantly

### Table 2 Clinical metabolic characteristics between longevity and controls

|                  | Longevity | Control   | \( \chi^2 \) | OR     | 95% CI      |
|------------------|-----------|-----------|--------------|--------|-------------|
|                  | \( n = 307(100\%) \) | \( n = 486(100\%) \) |              |        |             |
| AOB              | 17.3%     | 13.6%     | 2.002        | 0.753  | 0.508–1.116 |
| Elevated BP      | 61.1%     | 38.9%     | 183.15       | 0.106  | 0.075–0.183 |
| RFG              | 39.1%     | 7.2%      | 121.65       | 0.121  | 0.080–0.183 |
| high TG          | 21.8%     | 35.6%     | 16910        | 0.180  | 1.426–2.749 |
| low HDL-C        | 33.2%     | 10.7%     | 61005        | 0.241  | 0.166–0.350 |
| MetS             | 28.0%     | 5.1%      | 81740        | 0.139  | 0.087–0.224 |

95% CI 95% Confidence Interval, AOB abdominal obesity, Elevated BP elevated blood pressure, RFG raised fasting glucose, high TG high triglyceride, low HDL-C low high-density lipoprotein cholesterol, MetS metabolic syndrome

### Table 3 MetS and its components in longevity individuals stratified by gender

|                  | Male \( N = 81(100\%) \) | Female \( N = 226(100\%) \) | \( \chi^2 \) | OR     | 95% CI      |
|------------------|---------------------------|-----------------------------|--------------|--------|-------------|
| AOB              | 3.70                      | 22.10                       |              | 7.386  | 2.236–24.05 |
| Elevated BP      | 79.00                     | 83.60                       | 0.876        | 1.357  | 0.715–2.574 |
| RFG              | 43.20                     | 37.60                       | 0.785        | 0.792  | 0.473–1.327 |
| high TG          | 18.50                     | 23.00                       | 0.705        | 1.315  | 0.693–2.495 |
| low HDL-C        | 27.20                     | 35.00                       | 1.641        | 1.441  | 0.823–2.525 |
| MetS             | 19.80                     | 33.60                       | 5.507        | 2.057  | 1.118–3.787 |

\( *P \) value according to Fisher’s Exact Test

95% CI 95% Confidence Interval, AOB abdominal obesity, Elevated BP elevated blood pressure, RFG raised fasting glucose, high TG high triglyceride, low HDL-C low high-density lipoprotein cholesterol, MetS metabolic syndrome
higher than the local general control individuals. Interestingly, we found that compared with controls, longe-
vous individuals were more likely to have two or more
components of MetS, and less likely to have zero or one
components of MetS.

To the best of our knowledge, rare studies examined
the prevalence of MetS in longevity subjects. Studies
from Sichuan Province, China, reported a prevalence
rate of MetS with 9.3% to 10.8% in the total participants
among individuals aged 90+ years old [15, 16], which
was lower than ours. However, another Chinese cross-
sectional study reported the prevalence rate of MetS was
50.4% in 2001 and 58.1% in 2010 among subjects aged
60–95 years [13], which was much higher than ours.
The difference prevalence rate of MetS may be due to
different ethnics and different human age stages. Further
multicenter large-scale sample for longevity are needed
to address this problem.

The most common metabolic component among lon-
gevity subjects in our Zhuang population was inconsist-
ent with studies from other ethnic population [17, 18].
For example, studies performed in Korea found that the
most common component was high blood sugar levels,
followed by elevated triglyceride levels and high blood
pressure in males, and that elevated triglyceride levels,
followed by high blood sugar levels and high blood pres-
sure in females in a 66-year-old population [18]. In
China, it has been shown that the most common com-
ponent was elevated blood pressure, followed by central
obesity and raised fasting glucose among Chinese aged
60 years or older[19]. Since the age for the participants
in these studies were much younger than ours, it is pos-
sible that these inconsistent findings regarding different
prevalence of metabolic components could be age differ-
ces. Another possible explanation may be explained by
ethnic differences.

Females with longevity had higher prevalence of
MetS than the male participants, which were consist-
ent with several studies from different countries and
ethnic population [13, 17, 18]. It is interesting that
women had higher prevalence rates of MetS com-
pared with men. According to the National Bureau of
Statistics of China, the female/male ratio of longevity
population were 2.02:1 (648,588 male nonagenarians,
1,299,698 female nonagenarians, 8852 male centenar-
ians and 27,082 female centenarians in 2010) [1]. In
our study, females also occupied a larger proportion
(female/male: 2.79/1) in the longevity population.

\[
\begin{tabular}{lccccccc}
\hline
MetS components (N) & Longevity & Frequency & Percent & Mean ± Sd & Control & Frequency & Percent & Mean ± Sd & P & OR \\
\hline
0 & 19 & 6.2 & 95.21 ± 4.662 & 156 & 32.1 & 47.05 ± 4.030 & <.001 & 0.117–0.317 \\
1 & 91 & 29.6 & 95.21 ± 4.682 & 202 & 41.6 & 47.53 ± 3.341 & 0.02 & 0.536–0.949 \\
2 & 111 & 36.2 & 94.88 ± 4.810 & 103 & 21.2 & 47.79 ± 4.144 & 0.001 & 1.259–2.232 \\
3 & 63 & 20.5 & 94.63 ± 4.867 & 22 & 4.5 & 49.36 ± 5.141 & <.001 & 1.259–7.519 \\
4 & 19 & 6.2 & 94.68 ± 4.372 & 3 & 0.6 & 48.00 ± 4.359 & <.001* & 2.942–34.165 \\
5 & 4 & 1.3 & 95.25 ± 2.986 & 0 & 0 & - & - & - \\
Total & 307 & 100 & 94.94 ± 4.702 & 486 & 100 & 47.52 ± 3.859 & - & - \\
\hline
\end{tabular}
\]

*P value according to Fisher’s Exact Test

Std standard deviation

In this study, women were more likely to have abdom-
inal obesity than men in the longevity group. No signifi-
cant difference of prevalence for high BP, dysglycemia,
highTG, and lowHDL-C among male and female individ-
uals aged 90+ years were observed in this study. This re-
sult was inconsistent with other studies. For example,
studies performed in China shown that the prevalence of
TG, HDL-C, and WC among females is higher than the
prevalence in males among Chinese aged 60–95 years
[19]. In Turkey, researchers found that older adult
females had higher SBP, larger WC, and lowHDL-C than
older males [23]. In Korea, prevalence of abdominal
obesity and lowHDL-C in females were higher than
males, while prevalence of highTG, high BP, and dysgly-
cemia in males were higher than females [18]. The dif-
ference among different countries may be due to
different ethnics and sample size. Multicenter Collabora-
tion across different countries is needed to address this
question.
In our study, the high prevalence of MetS in longevity group could be linked to the observed higher prevalence of high BP, raised fasting glucose and low HDL-C and lower prevalence of high TG compared to the control group. These findings were supported by previous studies which demonstrated nonagenarians and centenarians had higher prevalence of confirmed hypertension, diabetes mellitus as well as dyslipidemia [6–8, 24]. Moreover, a study investigating frailty and metabolic syndrome in a Chinese community sample showed that, in those aged 90 years and older, frailty was a significant risk for near-term death, regardless of the metabolic syndrome [16]. Furthermore, another cross-sectional study implicated that metabolic syndrome may be associated with better cognitive function among nonagenarians and centenarians [15]. Thus, it seemed that MetS was not a risk factor for the oldest old. However, it is well established that MetS is strongly related to increased incidence of cardiovascular events in people aged 60–95 [13, 25]. One possible explanation of why MetS has a different effect among different stages of human beings might be because of “natural selection effect.” It is possible that those with more severe MetS have died of cardiovascular diseases before reaching an older age. Another possible explanation is that MetS components are associated with better health status among the oldest old [7, 9, 26]. Specifically, low prevalence of high TG might contribute a lot to longevity in our study, as low TG level has been identified as a marker for human longevity [26, 27]. Lastly, there was a possibility that traditional cardiovascular risk factors, such as an elevated cholesterol and hypertension, might not automatically apply to the very old.

Moreover, we found that long-lived individuals had higher frequency for having two or more metabolic abnormalities and lower frequency for having zero or one metabolic abnormality than the controls, which was consistent with previous studies that prevalence of MetS increased with age [13, 28]. More research is needed for the oldest old with MetS.

In our study, the control individuals had higher frequency of smoking than the longevity participants, which might explain the possibility for fewer controls having MetS, as smoking is a risk factor for younger people [29, 30]. However, our study has some limitations. Firstly, this was a cross-sectional study. Many variables were measured at a single time point and may be subject to conditions at the time of measurement. Since some of the study population had several risk factors including hyperlipidemia, we could not eliminate the possible effect of underlying diseases and medications used for these diseases. Secondly, the data came from a single region, which may limit generalizability. Thirdly, the sample size was not big enough in our study. Fourthly, the prevalence of various lipid and hematological parameters was based on a single assessment of blood, which may introduce a misclassification bias. Lastly, we have excluded individuals with chronic disease such as malnutrition, hepatic disease, kidney disease and cancer, which might underestimate the prevalence of MetS in our population, especially in long-lived individuals. Multicenter collaboration in prospective research of prevalence for MetS in longevity group is needed to address these questions.

Conclusions

In conclusion, our study analyzed the prevalence of MetS and its components distribution in longevity individuals in Zhuang population. We also reported that there existed the markedly differences of MetS rates by sex-specific groups in the population, and that long-lived individuals were more likely to have two or more metabolic abnormalities, and less likely to have zero or one metabolic abnormality than the controls.

Abbreviations

95% CI: 95% Confidence Interval; AHA/NHLBI: American Heart Association and the National Heart, Lung, and Blood Institute; AOB: Abdominal obesity; BMI: Body mass index; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; HDL-C: High-density lipoprotein cholesterol; INR: Interquartile range; LDL-C: Low-density lipoprotein cholesterol; MetS: Metabolic syndrome; NCEP ATP III: National Cholesterol Education Program’s Adult Treatment Panel III; SBP: Systolic blood pressure; SD: Standard deviation; TG: Triglyceride; WC: Waist circumference

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Availability of data and materials

The data for this research consists of in-person interview transcripts. Raw data cannot be publically released due to the risk the respondent confidentiality will be compromised.

Authors’ contributions

X.H.H., W.Z., G.F.P., Y.L., Z.Y. and C.Y.H. were responsible for the study conception and design. X.H.H. collected and analyzed the data and wrote the paper. Z.Y. and C.Y.H. supervised the study. W.Z., G.F.P., and Y.L. commented on drafts of the manuscript. All authors read and approved the final manuscript.
Ethics approval and consent to participate
The Ethics Committee of Beijing Hospital, Ministry of Health approved the study protocol. Written informed consent was obtained from each of the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References
1. National Bureau of Statistics of China. Tabulation on the 2010 population census of the people’s republic of China. 2011. http://www.stats.gov.cn/tjsj/pcsj/rkpdcw/indexch.htm. Accessed 15 Mar 2017.
2. Gaikuang: Bamadiqingwang 2011. http://www.gxdqw.com/preview/
3. BamaCounty: Baidu Baike 2013. http://baike.baidu.com/item/
4. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: An American Heart Association/ National Heart, Lung, and Blood Institute scientific statement. Executive summary. Cardiol Rev. 2005;13(6):322–7.
5. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; National Heart, Lung, and Blood Institute; American Heart Association; world heart federation; international atherosclerosis society; and International Association for the Study of obesity. Circulation. 2009;120(16):1640–5.
6. Masanovic M, Sogoric S, Kolici I, Curic J, Smoljanovic A, Ramic S, Cala M, Polasek O. The geographic patterns of the exceptional longevity in Croatia. Coll Antropol. 2009;33(Suppl 1):147–52.
7. Szwiecezek J, Dulawa J, Francuz T, Legierska K, Hornik B, Wlodarczyk-Sporek I, Janusz-Jenczen M, Bartko-Szwarzta A. Mildly elevated blood pressure is a marker for better health status in polish centenarians. Age (Dordr). 2015;37(1):9738.
8. He YH, Pu SY, Xiao FH, Chen XQ, Yan DJ, Liu WY, Lin R, Liao XP, Yu Q, Yang LQ, et al. Improved lipids, diastolic pressure and kidney function are potential contributors to familial longevity: a study on 60 Chinese centenarian families. Sci Rep. 2016;6:21926.
9. Milman S, Atzmon G, Candall J, Barzilai N. Phenotypes and genotypes of high density lipoprotein cholesterol in exceptional longevity. Curr Vasc Pharmacol. 2014;12(5):690–7.
10. Barzilai N, Atzmon G, Schechter C, Schafer EJ, Cupples AL, Lipton R, Cheng S, Shulkin AR. Unique lipoprotein phenotype and genotype associated with exceptional longevity. JAMA. 2003;290(15):1630–40.
11. Heijmans BT, Beekman M, Houwing-Duistermaat JJ, Cobain MR, Powell J, Blauw GJ, van der Ouderaa F, Westendorp RG, Slagboom PE. Lipoprotein particle profiles mark familial and sporadic human longevity. PLoS Med. 2003;1(2):e495.
12. Gong YY, Xie L, Zhou WP, Zhang YP, Gong YY, Xie L, Lian SQ, Yang J, Wang XY, Yang Z, et al. Glucose and lipid profile of a long-lived rural Han Chinese population and their families in southwest China. J Am Geriatr Soc 2009; 57(3):567–8.
13. Liu M, Wang J, Jiang B, Sun D, Wu L, Yang S, Wang Y, Li X, He Y. Increasing prevalence of metabolic syndrome in a Chinese elderly population: 2001–2010. PLoS One. 2013;8(6):e66233.
14. Feng J, Zhang J, Liu M, Wan G, Qi K, Zheng C, Lv Z, Hu C, Zeng Y, Gregory SG, et al. Association of mtDNA haplogroup F with healthy longevity in the female Chuang population, China. Exp Gerontol. 2011;46(12):987–93.