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ENVIRONMENTAL MECHANISM OF REGIONAL LONGEVITY IN CHINA

ABSTRACT. The integrated study on environment of typical China's longevity areas was conducted by using comprehensive methods of health geography. It was found that Chinese longevity areas mainly located in the south China and clustered in Sichuan-Chongqing, Central plain and Southeast region, the Yangtze River Delta and Pearl River Delta; in which drinking water was of weakly alkaline, Se, Fe, K content was moderate, higher content of Ca, Co, Mn, and low Cr, Cd, Pb; the concentration of trace elements benefit for health in soils and food staples was higher; hair of centenarians had higher Li, Mg, Mn, Ca, Zn content, lower concentration in Cd, Cr, Cu, Ni; healthy centenarians were also benefited from a favorable social environment factors, such as physiological health, psychological state, light meals and higher proportion of vegetables. The study was the first time to reveal quantitatively the relationship between longevity and the natural and human environment, and provided a scientific basis for the promotion of development of China's longevity area, to achieve the construction of ecological civilization.

KEY WORDS: regional longevity, environment, centenarians, chemical elements.

INTRODUCTION

China has entered into the aging society, and it is in the rapid aging period. According to the sixth national census data in 2010, the population of aged over 60 years old is 177,648,705 people, accounting for 13.26 % of the total population of China, and the population aged 65 and over is 118,831,709 people, accounting for 8.87 % of the total population. Compared with last national census in 2000, the proportion of the population aged 60 and over has increased by 2.93 %, the proportion of the population aged 65 and over has increased by 1.91 %. These data suggest that the construction of healthy aging society has become an important issue, but also an important task to cope with rapid aging. The so-called healthy aging refers to a healthy state of complete physical, mental and social functions to the most of elderly in the aging society, but also means that the social development would not be excessively influenced by fast population aging. Therefore, it is necessary to reveal the mechanism of the formation for longevity, especially carrying on a comprehensive analysis on aspects of physiology, psychology, socio-economy with natural environment.

For a long time, we observed the problem of aging in China and found the phenomenon of regional longevity, in another words, the distribution of longevity people has been of the geographic clustering in China [Wang et al., 2008; Lv et al., 2011; Wang et al., 2014]. Centenarians have been a symbol of health and longevity, and it can be considered as the outcome of interactions between lifestyle, heredity, environmental, health care level and psychological factors. Among

these, environment could play an extremely important rule resulted in the regional distribution of longevity in China. The reason we study regional longevity in China will be as the follows:

First, the regional longevity in China is an objective phenomenon, which requires a multiple study to reveal the factors on longevity for scientific understanding and better explanation. Forming of region longevity is the result from the integration of many factors. As a typical case, the longevity area, in which centenarians gathering live, more influenced by the geographical environment. The so-called geographical environment refers to the earth's surface in which mankind depends on, survival and development, is the unity of two parts as the nature environment and human environment. Natural environment is consisted of rock, soil, water, air, biological and other components (elements), all these integrate to form the natural complex. According to the perspective of the earth's sphere, the natural environment could be divided into the lithosphere, hydrosphere, atmosphere and biosphere. Human environment is the regional combination of social, cultural and production activities, including various components such as population, ethnic, settlement, politics, society, economy, transportation, military, social behavior, and others (elements). They constitute the spheres of the earth's surface, called the humanities sphere, also known as social sphere. Geographical environment consisted of natural environment and human environment plays a decisive role on human health. Until now there are many studies on the factors of longevity, but no satisfied explanation to longevity of regional aggregation has been reached; some studies just made simple comparison on the different factors of the longevity environment; the study on the relationship between longevity and the chemical elements only present single correlation analysis, lack of research on the multi-chemical elements from environmental transfer to human, and

lack of a comprehensive study to find out the common characteristics of the different regions.

Second, it is the needs to summarize the comprehensive features of natural environment and human environment for building healthy aging society. The mechanism of longevity environment could provide a scientific basis for the government, institutions, and public to promote environmental protection, social development and economic growth, and will be benefit for actively respond to the challenge of aging.

Third, learning from the different experiences of innovative measures to protect the local elderly in the typical longevity areas could provide economic and effective way to be implemented for the construction of healthy aging society, and these would be suitable to diversity of natural environment, varying degrees of aging, and different economic regions.

Therefore, we did a comprehensive study on environmental factors of longevity region. This article briefly described the distribution feature of aging and longevity population. Contrary to the defects of the former studies on longevity with natural environmental factors and social factors, five typical "longevity county", Xiayi in Henan province, Mayang in Hunan province, Zhongxiang in Hubei province, Yongfu in Guangxi Autonomous region, Sanshui in Guangdong province were chosen to study. By sampling of water, soil, food and hair of centenarians, and macro and trace elements of analysis, the relationship between trace elements and longevity could be established, and the chemical elements spectrum impacting longevity could be identified. Therefore the common regular pattern of the natural environment to health and longevity could be initially revealed. Simultaneously, the human geographical environmental characteristics of typical of longevity areas were also analyzes, and preliminary

discussion to build up China's "longevity county" was present.

METHODOLOGY

Human health refers to the structure and functions of the human body systems continuing in a relatively stable state, and maintains dynamic equilibrium with the external environment. Health and longevity are the important indicators of earth's environmental quality. Based on the close relationship between human health and the geographical environment, the main academic idea of this study is focused on the environmental characteristics of longevity area in China, and revealing the factors of longevity with the environment.

The technical approach is that with geography's ideas and methods, we study the distribution features of longevity areas and their environmental characteristics; at the same time, using comparison on the environment to find out the differences and similarities between longevity and non-longevity areas; and then propose suggestion for promoting health and longevity.

The demographic database of the sixth census of China in 2010 was utilized mainly and the statistical yearbooks in recent years for our studies. With the support of ArcGIS software, we constructed the spatial and attribute database of the centenarians using the map of China and the sixth census population data. Before that, field survey and sampling in different counties, and chemical analysis were carried on. The water, soil, food, hair samples were prepared according to the methods of national standard for quality control, and using ICP-OES to analyze for the content of Al, Ba, Ca, Fe, K, Mg, Mn, Mo, Na, P, Sr, V, Zn and others, the concentration of Cd, Co, Cr, Cu, Li, Ni, Pb and Se were determined by ICP-MS. All the statistical analysis was done with different modeling methods.

RESULTS

The spatial distribution of centenarians in China

According to China's sixth census, the geographical distribution of longevity population is of significant regional characteristics. Figure 1 shows those sub-provincial administrative units with the centenarian rate 2.7 per 100,000 people, which is the current average level of the centenarian rate in China. The gathering areas of centenarians in China are distributed mainly in the south of the country, located substantially on the south boundary of the North-South climate stripe of China; more in Sichuan-Chongqing region, the Central Plains region of China; most along the river watershed distribution such as the Yangtze River, Pearl River; and more gathered in the Yangtze River Delta, Pearl River Delta region; the areas distributed in the hilly and alluvial flood plains; non endemic areas. These show that the distribution of longevity areas relates to natural and human environment factors.

In provinces, autonomous regions and municipalities as the administrative unit, the proportion of centenarians in Hainan province is 18.75/100,000 as the highest in the China. Guangxi autonomous region (7.80/100,000), Sichuan province (4.21/100,000) and Guangdong province (3.65/100,000) respectively ranked as second to four. The longevity index referred to the ratio of population over 65 years old to 90 years and above in Hainan province is 2.89 % ranking the first in China, Shanghai (2.63), Guangdong province (2.41) and Guangxi autonomous region (2.31), respectively ranked as second to four.

Making comparison analysis on meteorological data with the longevity areas, it was found that China's longevity areas mostly located in warm climate type zone, average temperatures were between 8.6–24.9 °C, relatively abundant rainfall, relative humidity more than 68 %, and average annual sunshine hours higher than 821.5 hours in the most longevity areas.
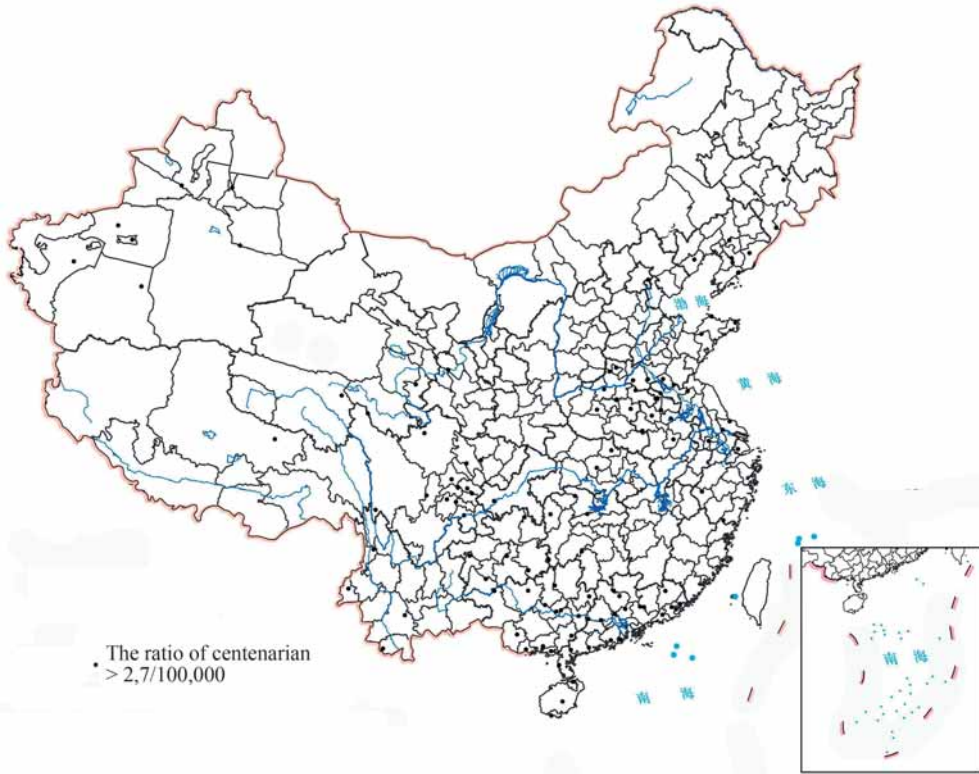
The ratio of centenarian
> 2,7/100,000

Fig. 1. The distribution map of centenarians in China.

The correlation analysis on chemical elements in the centenarian and the environment

Selected five typical "longevity county" of China, Xiayi county in Henan province, Mayang county in Hunan province, Zhongxiang city in Hubei province, Yongfu county in Guangxi autonomous region, Sanshui district in Guangdong province as the study areas, the chemical environment where centenarians live in was studied. The samples of drinking water, soils, staple grains and hairs of centenarians were collected and the contents of chemical elements were analyzed to find the impact of chemical elements on health and longevity.

Characteristics of chemical elements content in drinking water

Drinking water may make an important contribution to total dietary intake of required macro- and trace elements essential for human health and affect the desirable balance of these elements. In this study, the pH and Na, Fe, Ba, Cd, Cr, Cu, Mn, Mo, Ni, Pb, Se, Zn, F concentrations of the collected 182 drinking water samples from longevity areas were compared with the national standards for drinking water quality GB 5749–2006 and World Health Organization guidelines. The results show the quality of drinking water samples could meet these standards and had pH > 7, these were classed as weakly alkaline, which is beneficial to health and longevity according to some studies. All these results show as well that the drinking waters of longevity areas are clean and free from pollution, and with enough contents of Se, Fe and Ca, this is the important factor to local longevity.

Characteristics of chemical elements content in soil

Soil quality is not only the indicator of local environmental quality also affects the levels

Table 1. The content of chemical elements in rice(μg/g)

Element	Ca	Cu	Fe	K	Mg	Mn	P	Zn	Se*
Minimum		0.369	0.259	197.1	39.54	2.024	196.9		18.35
Maximum	6272.	7.558	291.3	4993.	1749.	45.65	4127.	45.90	199.6
Mean	233.0	2.895	24.15	2234.	751.2	14.42	1951.	20.26	56.69
Standard deviation	38.54	0.125	2.464	107.1	39.13	0.878	81.60	0.679	2.445
Median	81.64	2.332	15.74	1485.	629.5	9.2	1724.	16.64	49.44

* μg/kg

of nutrients in food crops. By analyzing the collected 325 soil samples, the results shown that content of Cd, Cr, Cu, Pb, Zn, Ni and other heavy metals could meet well the national soil environmental quality standard as the grade II which means no pollution of heavy metals in the soils of longevity areas. Nevertheless, Fe, Se, Zn are relatively affluent, and these would be benefit for health [Liu et al., 2013].

By the multiple regression analysis on the background values of chemical elements in soils of China according to the national survey, with the centenarian index (number of centenarians/per 100,000 people) and the longevity index (number of centenarians/the population of 65 years old and above) it was found:

$\tilde{Y}$ (centenarian index) =

1.679 – 0.205 Ni + 0.413 Co +

+ 0.006Se (R^2 = 0.402, p < 0.01);

$\tilde{Y}$ (longevity index) =

= 3.425 – 0.262Ni + 0.435 Co +

0.006 Se (R^2 = 0.369, p < 0.01).

The regression equation shows that the trace elements, cobalt and selenium which are benefit for health are positively correlated with centenarian index and longevity index, and nickel is negatively correlated with these two indicators. These imply that longevity could be result from the good soil environmental quality.

Characteristics of chemical elements content in rice as the staple grain

The grains could directly affect human health. Table 1 presents the concentration of chemical elements in 235 staple grain samples collected from longevity areas. The data shows that sufficient supply of essential chemical elements from food is beneficial to health and longevity. For example, selenium content in the grain level from the national perspective, less than 25 μg/kg is the level of selenium deficiency, 40–70 μg/kg selenium is middle level, greater than 1000 μg/kg is excess selenium levels [Tan 1989]. The selenium content in rice of longevity areas is the averaged 56.69 μg/kg, the median is 49.44 μg/kg, which means moderate selenium content good for health.

Characteristics of chemical elements content in the hair of centenarians

Collected 153 samples of hair from longevity people, the results of chemical element level of hair are shown in Table 2 with reference values. Compared with the reference value [Miekeley et al. 1998], centenarian's hair is significantly enriched for Ca, Li, Mg, Mn with low level of Cr, Cd, Cu, K, Ni, and Fe, P, Pb, Sr, Zn, Se are within the normal reference range.

Due to the presence of extreme values, a simple average value of the chemical element could not reflect the true distribution feature of the elements, so we further calculated the probability inside and outside of the reference range of the element content in hair. Table 3 shows the probability of element content

Table 2. The content of chemical elements in the hair of centenarians (µg/g)

Element	Reference	Mayang	Sanshui	Xiayi	Zhongxiang	Yongfu
Ca	350-860	1743	993	1049	1252	630
Cd	<1.0	0.112	0.214	0.047	0.039	0.046
Cr	0.78-1.0	0.020	0.860	0.046	0.016	0.038
Cu	13-35	5.15	7.33	6.50	6.54	7.07
Fe	6.0-15	12.95	31.44	10.33	12.79	10.22
K	17-140	16.83	12.25	13.29	11.37	12.42
Li	0.05-0.3	1.651	0.083	0.660	0.963	0.643
Mg	40-110	180	93.76	147.36	134.49	65.76
Mn	0.26-0.75	1.91	1.04	2.97	1.14	3.50
Ni	<1.6	0.037	0.653	0.035	0.020	0.034
P	120-180	137	152.38	107.34	112.98	106.67
Pb	<6.0	3.47	6.95	2.66	1.67	2.77
Sr	1.0-7.6	4.85	3.27	5.17	3.82	2.07
Zn	125-165	170.78	176.03	135.15	151.08	140
Se	0.38-0.7	0.39	0.58	0.24	0.39	0.31

Table 3. Probability inside and outside of the reference range of the element content in hair of centenarians (RVs, %)

< RVs	Cr	Cd	Cu	Ni	Ca	Li	Mg	Mn	Zn
Mayang	100	99.9	100	100	3.1	4.3	2.6	2.24	8.0
Sanshui	100	96	99.5	100	19.8	15.2	2.62	1.73	18.6
Xiayi	100	100	99.8	100	6.8	0.2	0.58	11.2	33.2
Zhongxiang	100	100	99.9	100	18.3	0.46	22.6	17.9	25.6
Yongfu	100	99.2	100	100	2.7	18.4	4.1	23.2	23.9
≈RVs	Cr	Cd	Cu	Ni	Ca	Li	Mg	Mn	Zn
Mayang	0	0	0	0	0.73	2.6	11.6	4.2	31.7
Sanshui	0	0	0.5	0	2.32	4.2	31.4	10.7	23.8
Xiayi	0	0	0.2	0	1.97	4.0	16.8	3.2	44.6
Zhongxiang	0	0	0.1	0	20	9.7	44	2.1	55.1
Yongfu	0	0	0	0	14.4	4.5	22.2	5.2	32.8
> RVs	Cr	Cd	Cu	Ni	Ca	Li	Mg	Mn	Zn
Mayang	0	0.1	0	0	89.6	93.1	85.9	73.4	60.4
Sanshui	0	4.0	0	0	57.0	80.6	42.4	72.0	57.7
Xiayi	0	0	0	0	73.5	95.8	77.4	85.6	22.3
Zhongxiang	0	0	0	0	61.8	85.7	33.4	80.0	19.4
Yongfu	0	0.8	0	0	82.9	77.2	73.6	71.6	43.3

in the hair within the range by identifying the normal distribution of the sample. [Chojnacka et al. 2005; Chojnacka et al. 2006; Zaichick 2010].

As shown in Table 3, compared with the reference value of elements in the hair, the content is generally higher in Li, Mg, Mn, Ca, Zn, lower in Cd, Cr, Cu, Ni and no significant different to other elements. This commonality of chemical elements contents of centenarians may be the important factors for longevity.

Using Stepwise-MLR analysis, centenarians age ($\tilde{Y}$) as the dependent variable, with trace element contents in hair as the independent [Li et al. 2011], it was found that:

$$\tilde{Y} = 101.156 - 0.796Cr + 0.008Zn - 0.034Pb +$$
$$+ 2.270Se - 7.335Cd$$
$$\times (R^2 = 0.37; F(5,101) = 3.26, P < 0.01).$$

This shows that positive relation of zinc and selenium, negative relation of chromium, lead and cadmium is the main feature. This may suggest that supply of Se, Zn and less exposure of heavy metal are helpful for the health of centenarians.

Life and psychological characteristics of centenarians

Social environmental factors including family situation, physical health, self-care and activities of daily living, mental health status and lifestyle are of major impact on health and longevity. To understand this, the interview survey to centenarians and other elderly people were conducted, and 2674 questionnaires were collected from Sanshui district of Guangdong province, Mayang county of Hunan province, Zhongxiang city of Hubei province, Xiayi county of Henan province, Yongfu county of Guanxi autonomous region and other longevity areas. By statistical analysis, it was found that longevity people have not only healthy physiological function, but also in positive mental status, in addition they have a light style of meal, with high proportion of vegetable intake.

Healthy physiological function

Sleeping and disease status is the main indicator of health for the elderly. Fair sleeping quality and enough sleeping hour are the important effects for health and longevity. According to the study on the elderly people who had no sleeping interferers in Pittsburgh, it was shown that mortality could be increased with sleeping efficiency decreasing [Dew et al. 2003].

Concerning sleeping time in our survey, it was shown that centenarians had 9.6 sleeping hours in average, 80 to 99 year old people had 8.33 hours, and 60–79 years younger elderly had only 7.64 hours of sleeping time. This gave us an image that centenarians had more adequate sleeping time and its sufficiency could ensure the physical recovery of centenarians. We graded the sleeping quality of centenarians into five types as very good, good, fair, poor and very bad, and found that centenarians had very good and good sleeping accounted for 76.64 %.

The average illness and hospitalization times for centenarians were 0.71 and 0.76 per two years respectively, considerable lower than the national hospitalization average level of 5 times per year. Some research indicated that with age increasing, the elderly tended to use health services more frequency, our survey found that this tendency might stop at the very old age. Among older age groups, illness and hospitalization declined especially to the centenarians very much, and it suggested that these individuals were either more robust physically to begin with and/or better adapted to tackling the challenges brought about by old age.

Positive mental state

The longevity group had a relatively positive mental state, characterized by reporting that they had a "let it be" attitude when faced with adversity, and that they felt "as happy as when I was young". A negative mental state was characterized by reporting as "feeling nervous or fearful," and "feeling lonely". In the interviews, most of the longevity group had a positive

mental state, and more than 80 % of the aging group had a "let it be" attitude. The proportion for centenarians was even higher as "let it be" accounted for more than 50 % (Fig. 2).
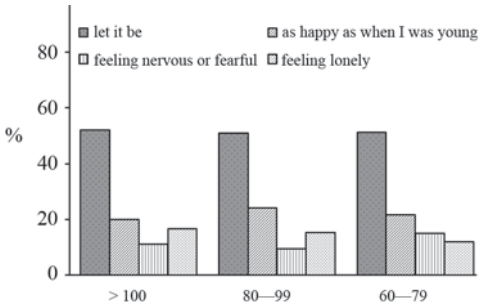

Fig. 2. The mental state of centenarians and elderly.

Light dietary and high proportion of vegetables

Regarding the food habit, the centenarians ate rice and flour as the major staple grains, accounting for 90 % of all staple food consumption. As shown in Fig. 3, they ate relatively light, plain food which means a light taste, not salty, not spicy, and not oily. The typical feature is that they had lots of vegetables for meal accounted for 60 % above every day.

DISCUSSION AND CONCLUSIONS

The longevity phenomenon is the integrated effect of many factors, including physical environment, custom habit, cultural characteristic, health care system and heredity factors and so on. Other factors may include
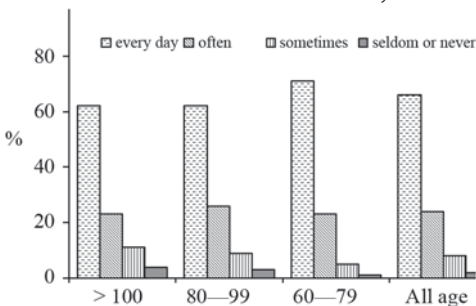

Fig. 3. The vegetables consumption for centenarians and elderly.

as life style, physical exercise, nutrition status, social relationships and the psychological factor. This paper intended to explain mainly the longevity mechanism from the prospect of geographical environment including natural and human environment. The main findings are as follows:

1) the distribution of centenarians are aggregated roughly in the south of China, especially along the Yangtze River basin, Pearl River and their Delta.

2) preferable natural environment factors, such as mild climate, clean water, sufficient trace elements including calcium, selenium, zinc, and cobalt in the environment and low exposure of heavy metals are beneficial for longevity and health.

3) health and longevity are also benefited from a favorable social environment factors, the common feature of centenarians is the positive mental state, the light meal with higher ratio of vegetable.

Longevity is the comprehensive indicator of the harmonious development on environment-society-economy-health. We believe that the "longevity county" is not simply shown how much population of longevity in certain region, but contains a wealthy content of the harmonious development in the regional environment, society, economy and health. The so-called comprehensive indicator, which contains a wide range of meanings, can be mainly summarized as four points:

First, the longevity is long term formed and could not be established in a short period. Because people's longevity is the result of long-term to maintain a healthy state in several decades or even centuries in the good natural environment, social and family conditions for the formation of long-term accumulation.

Second, the longevity is an interactions result from multi-factor and multi-condition of the genetic, psychological, physical and social environment. The longevity is also the result

of government, institutions, communities, families and individuals working together to continuously improve the social security, economic development, health care coverage, education, culture improvement, environmental protection and other aspects of the society.

Third, the longevity is the most concentrated expression of harmonious relations between the human and material world.

Fourth, the longevity is a dynamic development progress. Longevity embodies the harmonious development of man and the environment both in the past and the current situation, but it is also the enlightenment and requirements for the future development.

In summary, we must fully understand that longevity is the comprehensive result of regional development on environment, society, economy and human health, and improve the awareness of the construction of longevity society to achieve sustainable development.

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SUSTAINABILITY

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