The Association between Body Mass Index and Mortality among the Oldest Old in China

by

Yunfan Ge

Global Health Program
Duke Kunshan and Duke University

Date:________________________
Approved:

____
Lijing Yan, Supervisor

____
Chenkai Wu

____
Shenglan Tang

Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
in the Graduate School of Duke University

2019

ABSTRACT

The Association between Body Mass Index and Mortality among the Oldest Old in China

by

Yunfan Ge

Global Health Program
Duke Kunshan and Duke University

Date:_______________________
Approved:

____
Lijing Yan, Supervisor

____
Chenkai Wu

____
Shenglan Tang

An abstract of a thesis submitted in partial
fulfillment of the requirements for the degree
of Master of Science in the Duke Global Health Institute
in the Graduate School of Duke University

2019

Abstract

Background and Aim: This study examined the association between body mass index (BMI) and all-cause mortality among the oldest old (≥80 years) in China.

Method: I used data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) a large, prospective cohort study of older adults in China. The baseline survey was conducted in 1998 and participants were followed every 2-3 years. The sample I used size had 10217 oldest old participants (at least 80 years of age), who participated in the 2008 wave of the CLHLS. BMI was calculated as measured standing height (meter) divided by measured body weight (kg) squared. I classified BMI into six categories based on sample distribution: BMI<=16 kg/m^2, 16 kg/m^2<BMI<=18 kg/m^2, 18 kg/m^2<BMI<= 20 kg/m^2, 20 kg/m^2<BMI<=22 kg/m^2, 22 kg/m^2<BMI<=24 kg/m^2 and BMI>24 kg/m^2. Deaths were ascertained from family members during follow-up. We used the Kaplan-Meier approach to estimate the survival probability for men and women, separately in different BMI categories. We further used age adjusted and fully adjusted Cox proportional hazard models to determine the association between BMI and mortality. Socio-demographics (age, educational level, residence, and ethnicity), lifestyle variables (smoking, drink, and physical activity), and chronic condition (hypertension, diabetes, stroke, heart disease, cancer and bedsores) were adjusted in the full models. In addition, I used the Cox models to identify the association between BMI and mortality in different age groups (80-90, 90-100 and 100+ years.) All the analyses were performed separately for males and females.

Results: Of the 11,858 included participants, 5020 (44.24%) participants were aged 80-90, 4313 (37.32%) were aged 90-100 years, and 2484 (26.89%) were over 100 years; 4739 (39.10%) were males and 7119 (60.90%) were females. The mean value of BMI in men was 20.20 (Standard Deviation 3.16) and in women were 19.42 (Standard Deviation 3.41). There were 1296 (10.93%), 2582 (21.77%), 2900 (24.46%), 2448 (20.64%), 1488 (12.55%), and 1144 (9.56%) participants in the groups with BMI <16 kg/m^2, 16-18 kg/m^2, 18-20 kg/m^2, 20-24 kg/m^2 and >24 kg/m^2 respectively. The average weight, height, and BMI were 50.17 kg, 159.54 cm, and 20.26 respectively. Over an average follow-up time of 5.6 years, 7039 died (59.3%); the death rates were 192 per 1000 for males and 204 per 1000 for females. The Kaplan-Meier curve showed that participants with BMI<16 kg/m^2 had the lowest survival probability. In men, within the unadjusted model, making BMI<16 as the reference group, hazard rate in people with BMI 22-24 kg/m^2 (HR 0.59, CI 0.5-0.69) was lower than people in BMI16-18 kg/m^2 (HR 0.81, CI 0.71-0.93), 18-20 kg/m^2 (HR 0.86, CI 0.74-0.99) 20-22 kg/m^2 (HR 0.69, CI 0.6-0.8), and >24 kg/m^2 (0.66, CI 0.51-0.89). In women, the people with BMI>24 kg/m^2 carried the lowest hazard rate (HR 0.63, CI 0.56-0.72). The hazard rates in BMI 16-20 kg/m^2 (HR 0.74, CI 0.68-0.81), BMI 20-22 kg/m^2 (HR 0.70, CI 0.63-0.77), BMI 22-24 kg/m^2 (HR 0.66, CI 0.59-0.75) were lower then people with the highest BMI. In men, the age adjusted model shows that the hazard rate was the lowest among participants with BMI 22-24 kg/m^2 (HR0.7, CI 0.6-0.83). In women, participants with BMI 22-24 kg/m^2, has the lowest hazard rate (HR 0.79, CI 0.7-0.89). For age group 80-90 in the unadjusted model, people with the highest BMI>24 had the lowest hazard rate (HR 0.63, CI 0.49-0.83). The hazard rate in 5 BMI groups (BMI 16-18, 18-20, 20-22, 22-24, >24) has the declining rate (HR 0.81, 0.76, 0.74, 0.63). In the fully-adjusted model, the lowest BMI (BMI 16-20) had the lowest hazard risk (HR 0.74, CI 0.65-0.85). For age group 90-100 in the unadjusted model, people with BMI 22-24 kg/m^2 had the lowest hazard rate (HR 0.68, CI 0.57, 0.82). In the fully adjusted model, the lower BMI group tended to have lower mortality risk in age 90-100. For age group > 100 in all unadjusted, age adjusted and fully adjusted model, the highest BMI group had the highest hazard rate (HR 0.9, CI 0.71-1.13; HR 0.9, CI 0.72-1.14; HR 0.92, CI 0.72-1.17). Therefore, higher BMI groups tended to have higher mortality risk in age >100.

Conclusion: We found that very low BMI kg/m^2 was associated with increased risk of mortality among the oldest-old Chinese men and women. We did not observe significant sex or age difference in the associations. Further studies are needed to confirm the findings and explore the explanation. In the future, if time or budget is allowed, measuring tool with much more precise results could be applied to measure the actual fatness among older adults.

Contents

1. Introduction

1.1 Aging in the world and in China

1.1.1 Aging in the World

The world is facing a situation where there are older adults (Age > 65 years) than children and more people than ever before are reaching extreme old age. Today, 8.5 percent of people worldwide are at least 65 years old. The World Health Organization (WHO) estimates that by 2050, the number of old people is expected to be nearly 1.5 billion. By 2050, the global life expectancy at birth is projected to increase by around 8 years, climbing from 68.6 years in 2015 to 76.2 years in 2050. The size of the oldest old population—aged 80 years and older—is expected to more than triple, increasing from 126.5 million in 2015 to 446.6 million in 2050. The publication, An Aging World: 2015, commissioned by the National Institute on Aging (NIA), stated that older people are a rapidly growing population of the world's population (NIH 2016). The aging population phenomenon will occur in nearly every country, and especially in Asia. Asia's 65 and older population is expected to more than double from under 8 percent in 2015 to 18.8 percent by 2050 (Stempak 2016).

Although people are living longer, the fact does not mean that they are living healthier. The growth in an aging population may contain various health challenges that are associated with old age. The estimated future burden of disability emphasizes the need for effective public health prevention and interventions to tackle the main risk factors for all-cause mortality, including socio-economic factors such as: education levels, place of residence, income, social status, martial status and employment; poor health habits: smoking, alcohol intake, physical activities, meat intake, vegetable intake and quality of sleep; and past health conditions/diseases: hypertension, stroke, diabetes, bedsore, cancer, heart diseases and other chronic diseases. Aging is one of the biggest threats in the world (WHO 2018); it affects many aspects of public health frameworks including health system reconstruction, health financing, and service provision. Therefore, there is a lot of potential for learning from aging population. Many studies were conducted among old population in the world.

1.1.2 Aging in China

In the late 1970s and early 1980s, the Chinese government advocated a "later, longer, fewer" lifestyle, which encouraged people to marry late and have wide gaps between generations, resulting in fewer children overall. Then, it instated the famously controversial "one-child policy." These attempted to curb the population growth and help modernize the economy (Bailey 2012). The one child policy made Chinese family have fewer children, but having a smaller generation following a booming generation and longer life expectancies. The first generation to be influenced by the "one child policy" will have the largest old population over several decades. By 2050, the generations before 1970s and 1980s, would become the old population and represent the largest proportion compared to other generations. Therefore, the aging crisis is imminent in China, and will become a vital health topic to be studied.

According to the UN statistics database, China's population is getting older faster than most other countries in the world. China's dependency ratio for retirees could rise as high as 44% by 2050 (Rapoza 2017). The dependency ratio is comparing the difference between people who are not in the labor force with people who are working. According to the UN, China will double its elderly population from 10% to 20%, between 2017 and 2037. The UN estimates that China's old population will increase from approximately 100 million since 2005 to approximately 330 million by 2050. The UN also indicates that in the next 25 years, the percentage of people in China aged 65 years or over is expected to double from 12.4% (168 million) to 28% (402 million) in 2040 (UN DESA 2013). The oldest old adults, people aged over 80, constituted 22.6 million in 2013 and is be expected to increase fourfold to 90.4 million; which will represent the largest oldest old population in the world (UN DESA 2013).

An aging society involves a progressive shift in the burden of disease. The burden of diseases among aging countries has shifted from maternal, child, and communicable disorders to chronic communicable disease (WHO, Ageing report of China 2017). According to the 2015 WHO country profile, non-communicable diseases are the leading cause of death among Organization for Economic Co-operation and Development OECD countries. As an example: in 2013, of the 202 million older people in China (Wu & Dang, 2013), more than 100 million had at least one chronic disease (Wang & Chen 2014); many had multiple chronic diseases at the same time. As the old population increases, age-dependent chronic diseases like heart disease, diabetes, hypertension, cancer, stroke, bedsore are likely to increase regarding the absolute number of people affected (Prince 2015). Thus, continuous research into, and careful consideration of, the implications of this change in the age structure regarding to the mortality rate is necessary (Kuroda 1987), especially in China.

1.1.3 Health Threatens among Oldest old population

The oldest old population is set to grow much faster than any other age group in China (LANCET 2017). With weaker physical and cognitive conditions, the oldest old population poses challenges for health systems and social care, as the age group needs the most physical ad mental assistance and healthcare. Also, the oldest old population consumes more healthcare resources and facilities. Studying oldest old population would give a sense for future recommendation on sustainable health development. The conclusion among the oldest old people group were controversial: some studies suggested that people are living longer and in better health condition including physical condition, higher muscle density and better cognitive condition. In contract, other studies were done in the Europe or America suggested that people were living worse while aging. Therefore, the oldest old population needs to be studied.

1.2 Relationship between body weight and mortality

1.2.1 Weight and Height

Weight and height are common health variables that are related to people's health status. In general, heavier people are linked to major health problems such as hypertension, diabetes, stroke, heart disease and physical disability. However, the relationships between weight and mortality are different for older adults, especially within the oldest old population. Previous study determined that overweight and obesity are established risk factors for shortened survival in younger or middle-aged populations but not in older populations. The relative risks for mortality typically decline with increasing age. The importance of overweight and obesity as predictors of health status in older adults has been questioned. However, weight loss advice is routinely given to patients of all ages even though the published articles does not support the idea that obesity or overweight are strong risk factors for health condition among people who are aged 65. Therefore, understanding the relation of weight to and mortality into old age has important implications for clinical decisions and public health policy (Diehr 2013).

1.2.2 Body Mass Index

In order to understand the precise association between weight and health condition, body mass index (BMI) is used an indicator of weight status or nutritional health status. BMI is also an important indictor for determinants on overweight and obesity. BMI is a value derived from the weight and height of an individual. BMI is calculated as the weight divided by the square of the body height, and is university expressed in unites of kg/m^2. BMI is generally used as the correlation between groups related by general weight that can serve as vague means of determining fatness. BMI categories are generally assigned as a satisfactory tool for measuring whether individuals are underweight, normal weight, overweight and obesity. Based on the WHO standard, BMI value under 18.5 is considered underweight; 18.5 to 25 as normal weight; 25 to 30 as overweight; and over 30 is considered obese. Since different race people carry different body dense, the BMI category in different race is slightly different from the WHO BMI standard. For example, in Hongkong, under 18.5 is considered as underweight; 18.5 to 23 as normal weight; 23 to 25 as overweight; and over 25 is considered as obesity. Since, the body dense in older adults may be even lower than young adults, the BMI category in older population is also different from younger population.

1.2.3 Body mass index and mortality

In the past, BMI has been highlighted by researchers due to its possible relationship with mortality and its prevalence among the older adults. However, there is a study gap on the association between BMI and mortality. Literature review revealed that only a few studies have discussed the association. Based on the literature review of the recent studies, when the age and gender were considered, the association between BMI and mortality was inconsistent and controversial. Past studies have demonstrated that BMI were associated with mortality in old people, however the results are different. A survey based on a large contemporary Danish population showed that the association between BMI and mortality is decreasingly U-shaped, with BMI increasing for participants aged 70-95 years (Thinggaard 2010). However, some researchers suggest that the association might not appear in oldest old people (Age>80), which are unique factors that impact BMI, like the decreased height and muscle. The fact may return result in relatively higher body fact percentages (Wang 2017). Some researchers indicated that the association with BMI might only affect male group. Also, studies that explore BMI and BMI changes to mortality based on oldest old Chinese are sparse (Wang 2017). Despite the less studies about the association between BMI and mortality among oldest old Chinese, the existing studies' sample sizes were too small to yield a conclusion, which contains varies of limitations and confounding factors. The figure 1 showed that only a few studies were carried out in developing countries, and the results are different between all the studies. Therefore, researchers need to pay attention to the older population for the association between BMI and mortality.

1.3 Research question and study objectives

The research question of the study is to examine the association between BMI and all-cause mortality among the oldest old adult in China. I also examined whether the association differed by sex and age.

2. Method

2.1 Data source: CLHLS

The CLHLS dataset was first conducted in 1998, and repeated in 2000, 2002. 2005, 2008, 2011, and 2017 in randomly selected half of the country and cities in 22 provinces of China. The CLHLS is the first national longitudinal survey on determinants of health aging China and is becoming the largest sample of old individuals in China. Almost all the centenarians were invited to be interviewed at baseline. The study was conducted on the determinants of healthy human longevity and olds mortality. The CLHLS data were collected on a large percent of the old population, including centenarian and nonagenarian and collected information on health, socio-demographic characteristics, lifestyle, and family characteristics. The data was derived from respondents' health conditions, daily functioning, self-perceptions of health status and quality of life, mental health condition, life satisfaction, and awareness of aging (Zeng 2017). The respondents in the survey were asked about their state of health including diet and nutrition, use of medical services, drinking, and smoking habits; health condition including hypertension, cataracts, glaucoma, Parkinson's disease, bedsores and other diseases; demographic information including age, sex, ethnicity, family members, living condition, information of parents and children, living arrangements, education and occupations.

2.2 Data Collection and measurements

Participants were interviewed in their homes by community health workers using a questionnaire to conduct the study. All the interviewers were trained before the survey. The study was originally approved by the Biomedical Ethics Committee of Peking University. All the participants in the study have signed and agreed to the consent forms at the baseline and each follow-up study. The study was further approved by Duke Kunshan University. The participants in the study have signed the data usage agreement form.

2.3 Study Population: CLHLS 2008

A total of 16,954 old adults were selected at baseline from the fifth wave of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) in 2008. CLHLS 2008 is the first wave that measured height variables, including the variables from 2008-2014. Therefore, CLHLS 2008 is the first CLHLS dataset to potentially examine BMI. The 2008 dataset is also the largest dataset among other waves. The 2008 dataset has total 6 years of follow-up (2008-2014). The respondents in the survey were asked about their state of health including diet and nutrition, use of medical services, drinking, and smoking habits; health conditions including: hypertension, cataracts, glaucoma, Parkinson's disease, bedsores and other diseases; demographic information including: age, sex, ethnicity, family members, living condition, information of parents and children, living arrangements, education and occupations.

2.4 Exposure variables: BMI

The exposure variable is the calculated BMI based on the measured weight and height by following the standard BMI measurement equation. Height was measured to the nearest 1cm and weight was measured to the nearest 100 grams. The BMI was calculated as weight in kilograms divided by height in meter squared, based on the excluded criteria of weight and height. Due to difference between the oldest old and younger adults in their weight and health status, we categorized BMI in equal intervals instead of the standard cut-off points. The American standards were: 18.5 kg/m^2, 24 kg/m^2, 28 kg/m^2, and 30 kg/m^2. Asian including Chinese standards were 18.5 kg/m^2, 24 kg/m^2, and 28 kg/m^2. We used two-unit intervals to set the categories except the two extreme groups. The histogram of BMI in Figure 2 shows that very few (<10%) participants had BMI under 16 kg/m^2 or over 24 kg/m^2. Therefore, I finalized 6 unique BMI categories in my study: $BMI \le 16$ kg/m2, $16\ kg/m^2 < BMI \le 18\ kg/m^2$, $18\ kg/m^2 < BMI \le 20\ kg/m^2$, $20\ kg/m^2 < BMI \le 22\ kg/m^2$, $22\ kg/m^2 < BMI \le 24\ kg/m^2$ and $BMI > 24\ kg/m^2$. In my BMI category, the cut-off points of weight in male participants were from 35kg to 90kg, excluding 57 participants of the original dataset. Cut points of weight in female participants were from 25kg to 80kg, excluding 23 participants. Cut points of height in male participants were from 135cm to 186cm, excluding 26 participants. Cut points of height in female participants were from 120cm to 178cm, excluding 34 participants.

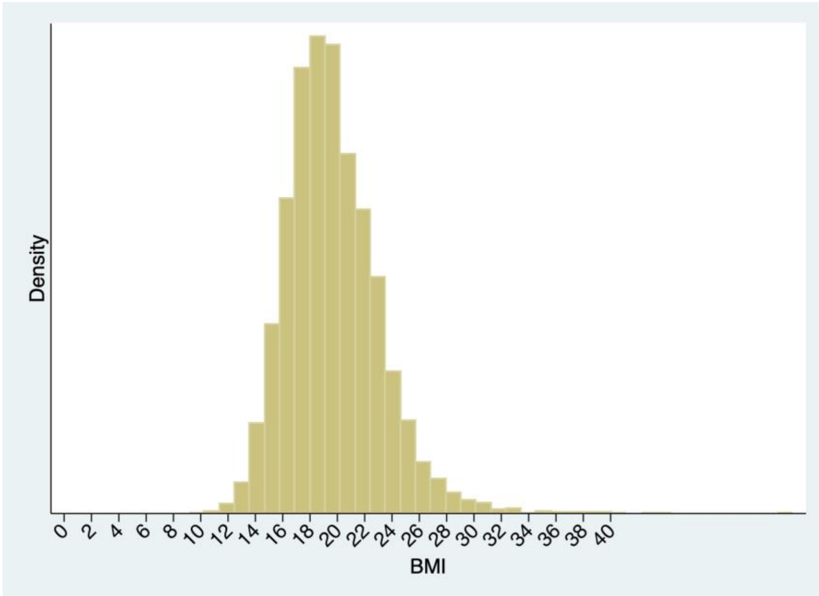

Figure 1. Histogram of BMI among Chinese 80 years and older, CLHLS 2008

Table 1. BMI Category

BMI	Numbers	Proportion
<16	1296	10.93%
16-18	2582	21.77%
18-20	2900	24.46%
20-22	2448	20.64%
22-24	1488	12.55%
>24	1144	9.65%
Total	**11,858**	**100%**

2.5 Outcome variable: Mortality

Survival status was ascertained during the follow-up survey. The studies assess whether subjects died and the date of death, completed the study or were lost to follow-up. “Lost to follow-up” and “Missing” status was assigned to the participants who were either not found or unsuccessfully contacted in the follow-up study in 2014. Participants who survived or were lost to follow up/missing were censored at 1 year. The information on deaths was collected by onsite interviews with participants’ close family members.

2.6 Covariates

I have included socio-demographic factors, lifestyle factors and variables of health conditions as my covariates in my study.

Socio-demographic factors: Educational status was determined by school years. Residence status was classified as living in rural or urban area. Ethnicities were self-reported and classified as Han vs. minorities.

Lifestyle factors: Cigarette smoking status was categorized into never smoker, previous smoker, and current smoker based on the current and past history of smoking. Alcohol drinking was categorized into current drinker and never drink. Information on physical activities was using the question "Do you exercise regularly at present?"

Health conditions: Total number of chronic diseases (NCD) was calculated including hypertension, diabetes, stroke, heart disease, cancer and bedsores. All the diseases variables used in the studies were self-reported.

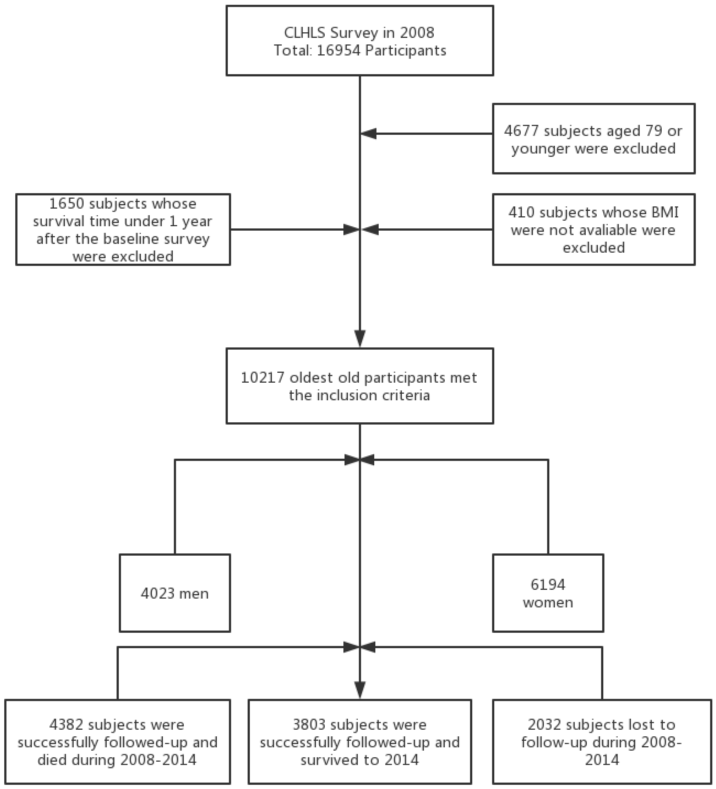

Figure 2. Flow chart of sample selection

2.7 Study sample

The study used the 2008 and 2014 waves of the CLHLS because height was not available in waves prior to 2008. Figure 1 described the selection criteria of the study participants. Specifically, 4677 individuals were excluded because they were younger 80 years of age. The cut-off points for weight, height, and BMI were set by analyzing the edges appearing in the STATA histograms and box plots. The cut-off points of weight in male participants were from 35kg to 90kg, excluding 57 participants from the original dataset. Cut points of weight in female participants were from 25kg to 80kg, excluding 23 participants. Cut points of height in male participants were from 135cm to 186cm, excluding 26 participants. Cut points of height in female participants were from 120cm to 178cm, excluding 34 participants. Therefore, 140 individuals were excluded from exclusion of BMI criteria. 410 individuals were excluded due to missing BMI. The analytic sample has 11,867 persons, in which 4,629 were men and 7,238 were women. A total of 4,732 persons were successfully followed-up for the 6 years until 2014; 4803 subjects were successfully followed-up and survived to 2014, and 2332 subjects were lost to follow-up during the time period 2008-2014.

Characteristics among the variables were checked such that potential confounders were selected. I have selected socio-economic factors including age, gender, residence, ethnicity and educational level; lifestyle variables including smoke, drink, meat intake, milk intake, fruit intake and physical activities; diseases variables including hypertension, diabetes, bedsores, cancer, heart disease, stroke and bedsore. All the continuous variables were presented for its mean and standard deviation and all the category variables were presented for its proportion.

2.8 Statistical Analysis

The Chi square test was performed to test statistical significance among covariates in BMI by gender difference. For each participant, years of follow-up were calculated from the date of the baseline survey to the date of death, lost to follow-up or the last follow-up in 2014. All the analyses were performed separately for men, women and three age groups: 80-90, 90-100 and 100+. First, the incidence rates of mortality across five BMI groups, sex, and age were calculated. Splines was used to fit Cox proportional hazards models to survival data for unadjusted and adjusted BMI among men, women and the 3 different age groups: 80-90, 90-100 and >100. The BMI values were converted to categorical variables. The results represented the estimated cox proportional ratios and 95% confidential interval. For BMI categories, the proportionality assumption was presented, and Kaplan-Meier survival curve by BMI categories was presented. Then the Kaplan-Meier approach, known as the product limit estimator, was used for estimating death risk in gender different among the 6 BMI groups. Cox proportional hazards models were used to determine the associations of BMI with all-cause mortality. The unadjusted and two adjusted associations between BMI and all-cause mortality were analyzed by using Cox proportional hazard models.

Adjusted model includes age-adjusted model and fully adjusted model. Age, diabetes, heart disease, hypertension, stroke, alcohol intake, smoke status, vegetable intake, fruit intake, residence status and educational level were adjusted in the fully adjusted models. Males and females were analyzed separately.

Subgroup analysis was performed by censoring at the end of follow up (6 years) or removing all lost to follow up and missing values. Subgroup analysis in the study, including gender and age groups, were performed by the Cox-Proportional test. Subgroup analysis was used to find the potential high risk among unique groups. Different in gender and age may produce the different result in death risk.

All analysis was conducted in STATA version 14.0. The P value < 0.05 was considered statistical significance.

3. Results

3.1 Baseline Characteristic

At baseline, after excluding people aged under 80 and censored within a year, 4520 (44.24%) participants were aged 80-90, 3813 (37.32%) were aged 90-100 years, and 1884 (26.89%) participants were aged over 100 years. The average weight, height, and BMI were 50.17 kg, 159.54 cm, and 20.26 respectively. The baseline characteristics including: weight, height, BMI, socio-economic factors, and disease factors were presented in Table 1. A total of 10217 participants were included in the study, of which 4023 participants were men and 6194 were women. During the 6 years of follow-up, and referring to the figure 1, 4382 people were successfully followed-up and died during 2008-2014, 3803 subjects were successfully followed-up and survived to 2014 and 2032 subjects were lost to follow-up during 2008-2014.

Table 2. Selected Baseline Characteristics of the Study Population by BMI Category

Variable	<16	16-18	18-20	20-22	22-24	>24
Age	94.91(7.23)	93.18(7.31)	92.21(7.41)	91.4(7.34)	90.92(7.39)	92.73(7.42)
Gender						
Male	340(26%)	1972(36%)	1067(43%)	729(48.99%)	520(45.45%)	462(39.01%)
Female	956(74%)	3510(64%)	1381(56%)	759(51.01%)	624(54.55%)	723(60.99%)
Residence						
City	181(13%)	978(17%)	539(22%)	362(24.33%)	299(26.14%)	236(19.90%)
Town	277(21%)	1158(21%)	457(19%)	290(19.49%)	188(16.43%)	237(20.00%)
Rural	838(64%)	3346(61%)	1452(59%)	836(56.18%)	657(57.43%)	713(60.11%)
Ethnicity						
Han	1173(90%)	5084(93%)	2322(95%)	1438(96.64%)	1095(95.72%)	1112(93.71%)
Hui	9(0.7%)	36(0.7%)	18(0.7%)	5(0.34%)	9(0.79%)	7(0.65%)
Zhuang	92(7.%)	195(4%)	62(2%)	24(1.61%)	16(1.40%)	38(3.28%)
Yao	6(0.5%)	32(0.6%)	3(0.1%)	4(0.27%)	1(0.09%)	4(0.39%)
Korea	0(0%)	2(0.04%)	0(0%)	0(0%)	2(0.17%)	4(0.03%)
Man	6(0.5%)	0(0%)	10(0.4%)	7(0.47%)	8(0.70%)	6(0.56%)
Mongolia	0(0%)	36(0.7%)	1(0.04%)	0(0%)	1(0.09%)	2(0.02%)
Others	10(0.8%)	97(2%)	32(1%)	10(0.67%)	12(1.05%)	11(1.36%)
Educational Level						
No Education	236(23%)	1075(24%)	560(28%)	350(28.59%)	276(28.57%)	249(21.28%)
Under Primary	111(10%)	436(10%)	187(9%)	127(10.38%)	79(8%)	94(7.92%)
Primary School	268(25%)	1118(25%)	494(24%)	297(24.26%)	193(20%)	237(20.12%)

Middle School	261(25%)	1146(26%)	497(24%)	290(23.69%)	251(26%)	246(21.09%)
High School	128(12%)	452(10%)	216(11%)	128(10.46%)	124(13%)	104(8.95%)
College or Above	35(3%)	172(4%)	79(4%)	30(2.45%)	43(4%)	35(2.88%)
Drink at Present						
Yes	151(11%)	750(14%)	422(17%)	265(17.81%)	209(18%)	179(15.14%)
No	1145(88%)	4732(86%)	2026(82%)	1223(82%)	935(82%)	1070(84.86%)
Smoke Status						
Current Smoker	145(11%)	752(13%)	355(15%)	249(16.75%)	166(15%)	167(14.05%)
Used to Smoke	171(13%)	773(14%)	378(15%)	251(16.88%)	221(19%)	196(15.14%)
Never Smoke	979(75%)	3954(72%)	1715(70%)	987(66.38%)	757(66%)	899(70.81%)
Fruit Intake						
Almost Everyday	110(8%)	588(11%)	306(13%)	230(15.46%)	189(16%)	144(12.00%)
Quite Often	261(20%)	1285(23%)	621(25%）	379(25.47%)	329(29%)	276(24.24%)
Occasionally	502(38%)	2059(38%)	897(36%)	528(35.48%)	391(34%)	430(37%)
Rarely or Never	423(32%)	1549(28%)	624(25%)	351(23.59%)	235(21%)	386(27%)
Vegetables Intake						
Almost Everyday	675(52%)	3132(57%)	1486(61%)	923(62.03%)	721(63%)	694(59%)
Quite Often	393(30%)	1530(28%)	648(26%)	367(24.66%)	284(25%)	324(27%)
Occasionally	156(12%)	636(12%)	256(10%)	159(10.69%)	107(9%)	134(11%)
Rarely or Never	72(5%)	182(3%)	58(2%)	39(2.62%)	32(3%)	33(3%)
Hypertension						
No	1088(86%)	4424(83%)	1958(82%)	1185(81%)	830(73%)	941(82%)
Yes	171(13%)	905(17%)	442(18%)	286(19%)	300(27%)	216(18%)
Diabetes						
No	1242(98%)	5292(99%)	2368(98%)	1424(97%)	1080(95%)	1143(98%)
Yes	16(1%)	69(1%)	39(2%)	42(3%)	52(5%)	29(2%)
Heart Disease						
No	1187(93%)	4985(93%)	2206(91%)	1339(90%)	995(88%)	1078(92%)

Yes	79(6%)	371(7%)	205(9%)	135(9%)	138(12.18%)	93(8%)
Stroke						
No	1192(94%)	5094(95%)	2292(95%)	1380(94%)	1038(91.62%)	1104(94%)
Yes	70(6%)	282(5%)	126(5%)	90(6%)	95(8.38%)	66(6%)
Cancer						
No	1249(99%)	5319(99%)	2406(99%)	1466(99%)	1129(99.56%)	1157(99%)
Yes	5(0.4%)	25(0.5%)	7(0.3%)	7(0.5%)	5(0.44%)	4(0.4%)

3.2 Crude Association between BMI and Mortality

Over an average 5.18 years of follow-up, 4382 deaths occurred. The overall death rate was 194 per 1000 person-year in men and 199 per 1000 person-year in women (Table 3). In the Kaplan-Meier survival estimation, there was the linear association between age group, gender, BMI and mortality (Figure 3). The Kaplan-Meier approach was utilized to graphically check the trends of death rate among genders. The Kaplan-Meier survival curve estimates that in both men and women, BMI <16 carries the highest mortality risk, and BMI 22-24 carries the lowest mortality risk. The curve also shows that participants with higher BMI tend to be survivors.

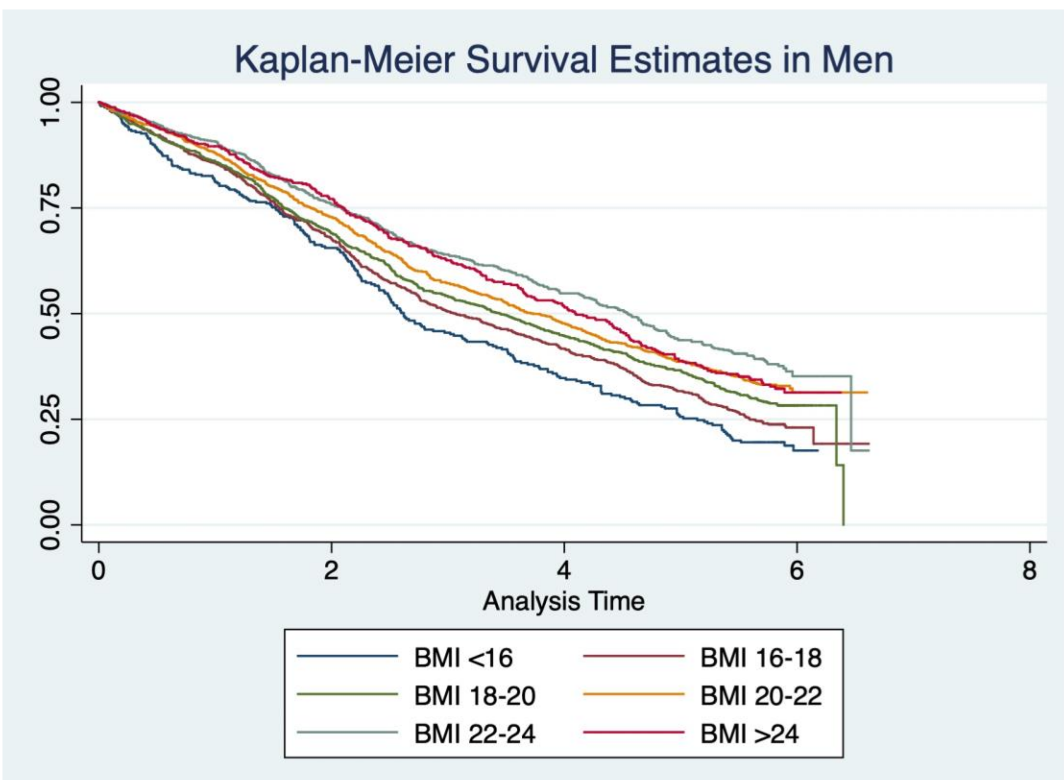

Figure 3-A. Kaplan Meier Survival Curves among Men

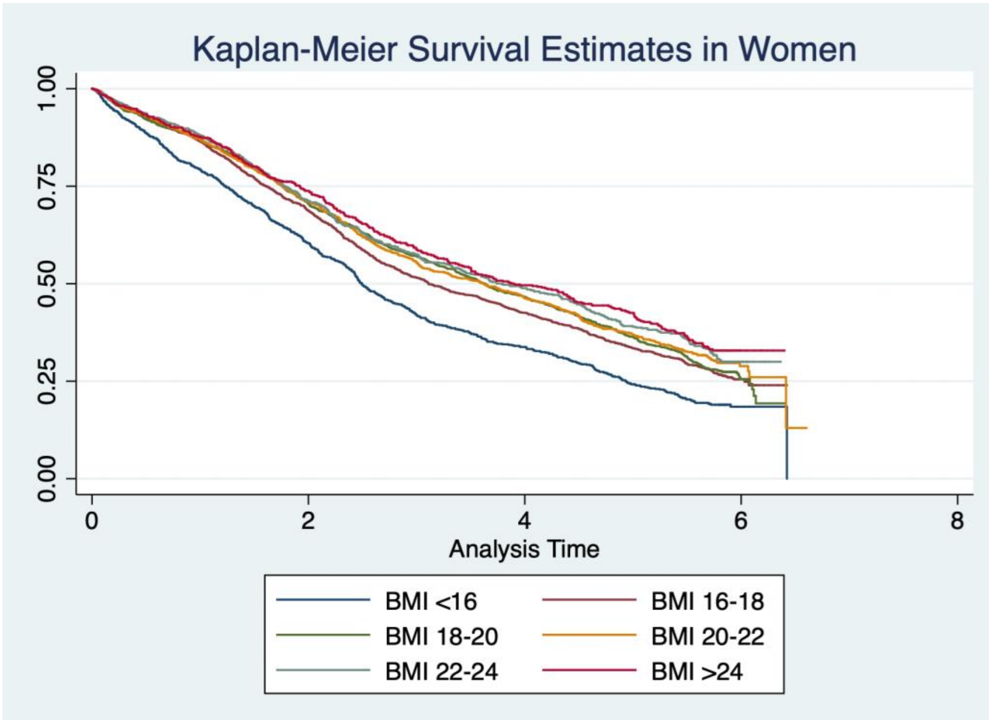

Figure 3-B. Kaplan Meier Survival Curves among women

Table 3. Crude Association between BMI categories and Mortall

	<16	16-18	18-20	20-22	22-24	>24	Total
Male							
Death Number	240	555	659	604	381	293	2732
Follow Time (Years)	3.88	4.47	4.96	5.51	6.40	5.80	5.18
Event per 1000 (95% CI)	257 (226, 292)	223 (205, 243)	201 (186, 217)	181 (167, 196)	156 (141, 172)	172 (153, 193)	192 (185, 200)
Female							
Death Number	666	1067	1058	783	428	355	4357
Follow Time (Years)	3.67	4.73	5.05	5.20	5.45	5.66	4.88
Event Per 1000 (95% CI)	272 (252, 293)	211 (199, 224)	197 (179, 205)	191 (179, 205)	183 (166, 201)	176 (159, 195)	204 (198, 210)

3.3 Relationship between BMI and mortality by sex and age

3.3.1 Unadjusted subgroup results by sex

The unadjusted and adjusted Cox regression results are shown in Tale 4. In men, making BMI<16 as the reference group, hazard rate in people with BMI 22-24 (HR 0.59, CI 0.5-0.69) was lower than people in BMI16-18 (HR 0.81, CI 0.71-0.93), 18-20 (HR 0.86, CI 0.74-0.99) 20-22 (HR 0.69, CI 0.6-0.8), and >24 (0.66, CI 0.51-0.89). It shows that people with larger BMI tend to survive longer than other smaller BMI populations among men. In women, the people with BMI>24 carried the lowest hazard rate (HR 0.63, CI 0.56-0.72). The hazard rates in BMI 16-20 (HR 0.74, CI 0.68-0.81), BMI 20-22 (HR 0.70, CI 0.63-0.77), BMI 22-24 (HR 0.66, CI 0.59-0.75) were lower then people with the highest BMI. Therefore, the unadjusted models suggested that, compared with larger BMI population and for smaller BMI population, the mortality risk was lower. In addition, the Kaplan-Meier survival curve estimates that in both men and women, BMI <16 carries the highest mortality risk, and BMI 22-24 carries the lowest mortality risk. The curve also shows that participants with higher BMI tend to be survivors.

3.3.2 Adjusted subgroup results by sex

In men, the age adjusted model shows that the hazard rate was the lowest among participants with BMI 22-24 (HR0.7, CI 0.6-0.83). Participants with lower BMI have a higher hazard rate. In women, the hazard rates among all 5 BMI groups (BMI 16-18, 18-20, 20-22, 22-24 and >24) are around the same. However, statistically speaking, people with BMI 22-24, has the lowest hazard rate (HR 0.79, CI 0.7-0.89). Therefore, it suggested that with an age-suggested model: lower BMI tend to have lower mortality risk. Higher BMI tended to be associated with a lower hazard risk. With the fully adjusted model (adjusting for Age, diabetes, heart disease, hypertension, stroke, alcohol intake, smoke status, vegetable intake, fruit intake, residence status and educational level), m en had the lowest hazard rate in BMI 22-24 (HR 0.71, CI 0.60-0.83). However, similar to the age adjusted group, the hazard rates among the four women BMI groups did not have significant differences; yet still people with BMI 22-24, had the lowest hazard rate (HR 0.81, CI 0.71-0.83). Therefore, by interpreting all the results, in men and women, people with higher BMI, had lower mortality risk.

Table 4. Hazard Ratios and 95% Confidence Intervals for All-Cause Mortality by BMI Category and Gender

	Age Adjusted HR (95% CI)	Fully-Adjusted HR (95% CI)
Male		
<16	Ref	Ref
16-18	0.91 (0.77, 1.02)	0.89 (0.75, 0.99)

18-20	0.86 (0.74, 0.99)	0.83 (0.72, 0.97)
20-22	0.79 (0.68, 0.91)	0.79 (0.68, 0.92)
22-24	0.70 (0.60, 0.83)	0.71 (0.60, 0.83)
>24	0.77 (0.65, 0.91)	0.78 (0.66, 0.93)
Female		
<16	Ref	Ref
16-18	0.81 (0.74, 0.88)	0.83 (0.76, 0.91)
18-20	0.80 (0.72, 0.89)	0.81 (0.74, 0.90)
20-22	0.80 (0.72, 0.89)	0.83 (0.75, 0.92)
22-24	0.79 (0.70, 0.89)	0.81 (0.71, 0.92)
>24	0.80 (0.70, 0.90)	0.83 (0.73, 0.95)

3.3.3 Unadjusted subgroup results by age

For age group 80-90 in the unadjusted model, people with the highest BMI>24 had the lowest hazard rate (HR 0.63, CI 0.49-0.83). The hazard rate in 5 BMI groups (BMI 16-18, 18-20, 20-22, 22-24, >24) has the declining rate (HR 0.81, 0.76, 0.74, 0.63). For age group 80-90 in the age adjusted model, people with the highest BMI>24 also had the lowest hazard rate (HR 0.71, CI 0.54-0.93). There was a rapid decline between the three lower BMI groups and BMI >24 (HR 0.83, 0.80, 0.83, 0.71). In the fully adjusted model, people with a BMI > 24 had the lowest hazard rate (HR 0.75, CI 0.57, 0.99). Therefore, the people with a BMI >24 had the significant lower mortality risk than other three lower BMI groups. For age group 90-100 in the unadjusted model, people with BMI 22-24 had the lowest hazard rate (HR 0.68, CI 0.57, 0.82).

3.3.4 Adjusted subgroup results by age

In the age-adjusted model, the lowest BMI (BMI 16-20) had the lowest hazard risk (HR 0.74, CI 0.65-0.85). In the fully adjusted model, the BMI > 24 had the lowest hazard rate (HR 0.75, 0.57-0.99). Therefore, the lower BMI group tended to have lower mortality risk in age 90-100. For age group > 100 in all unadjusted, age adjusted and fully adjusted model, the highest BMI group had the highest hazard rate (HR 0.9, CI 0.71-1.13; HR 0.9, CI 0.72-1.14; HR 0.92, CI 0.72-1.17). Therefore, higher BMI groups tended to have higher mortality risk in age >100.

Table 5. Hazard Ratios and 95% Confidence Intervals for All-Cause Mortality by BMI Category and Age Group

	Event Per 1000 (95% CI)	Age Adjusted HR (95% CI)	Fully-Adjusted (95% CI)
Age 80-90			
<16	179 (157, 205)	Ref	Ref
16-18	143 (135, 152)	0.83 (0.68, 1.01)	0.86 (0.70, 1.06)
18-20	137 (122, 155)	0.82 (0.66, 0.99)	0.85 (0.73, 1.04)
20-22	131 (120, 144)	0.80 (0.64, 1.00)	0.83 (0.66, 1.04)
22-24	118 (104, 132)	0.83 (0.64, 1.07)	0.87 (0.67, 1.13)
>24	118 (103, 134)	0.71 (0.54, 0.93)	0.75 (0.57, 0.99)
Age 90-100			
<16	307 (279, 339)	Ref	Ref
16-18	251 (239, 264)	0.74 (0.65, 0.85)	0.86 (0.70, 1.05)
18-20	244 (221, 288)	0.76 (0.62, 0.88)	0.84 (0.69, 1.01)
20-22	238 (219, 259)	0.75 (0.64, 0.88)	0.83 (0.66, 1.04)
22-24	228 (205, 253)	0.80 (0.59, 0.85)	0.87 (0.71, 0.92)
>24	247 (220, 279)	0.80 (0.65, 0.97)	0.75 (0.57, 0.99)
Age >100			
<16	359 (319, 404)	Ref	Ref
16-18	315 (294, 337)	0.85 (0.73, 0.98)	0.85 (0.73, 0.99)
18-20	311 (288, 344)	0.83 (0.71, 0.91)	0.84 (0.72, 0.97)
20-22	318 (285, 354)	0.86 (0.72, 1.03)	0.85 (0.71, 1.03)
22-24	308 (214, 359)	0.86 (0.70, 1.07)	0.86 (0.69, 1.07)

>24	336 (282, 401)	0.90 (0.72, 1.14)	0.92 (0.72, 1.17)

4. Discussion

4.1 Key findings

The findings of the study suggested that for the oldest old people in China, people with BMI 22-24 predicted better survival and lower mortality over a 6 years period in both men and women, as compared with those whose BMI was <16 kg/m^2. Also, the Kaplan Meier graphs showed that lower BMI had much lower mortality risk among both man and women, since the trend in BMI < 16 was much lower than others. In adjusted results, when setting BMI<16 as the reference group, HRs in all others group were lower than 1. The fact indicated that BMI<16 had the highest mortality risk, which the participants in BMI<16, tended to be less survivor.

In the age-adjusted model among men, participants with BMI 22-24 tended to have the lowest mortality risk, which could be regarded that participants with BMI 22-24 are more likely to be survivors. In the fully adjusted model, results were similar, where BMI 22-24 tended to have the lowest mortality risk among men. The mortality risk had no huge differences among women.

In the different age groups, the higher BMI had much lower mortality risks among people in the age group 80-90. However, there was no much difference between BMI and mortality risk among age group 90-100 and 100+. The HR in men is declining while BMI is increasing. However, there are no huge differences in HR under BMI between different age group among women.

4.2 Comparative Studies

Based on my literature review, it was that found a few studies that have similar study goal and inclusion criteria. All of the study focused on older adults. Two studies were conducted in Europe and the United States. Three studies were conducted in China.

Compared to studies based on Caucasian participants (Italy and US), my findings were totally different. In both Italy and US studies as shown in Figure 1, they suggested that there were U-shaped associations between BMI and mortality (Winter 2014). Also, higher BMI may cause higher risk of mortality. However, U shaped association did not appear in my results. I found that there were inverse association between BMI and risk of mortality. In their studies with U-shaped association, the increased mortality happened when BMI was over 35. However, our studies did not follow the WHO standardized BMI. I have divided 6 BMI groups with similar numbers of participants, which could be a reason that U-shaped association did not occur in my study. Also, compared to the Caucasian participants, who were selected including healthy participants and patients from hospital, the participants in my study were all healthy survivors. The mean BMI was much lower than western studies. Following the standardized BMI categories, few participants had a BMI over 35, which were excluded at the early stage of the study. Based on the Winter's report, it is possible that people who were overweight or obese may have died early, yet the prevalence of high BMI is limited to the last three decades, especially in oldest old population, therefore the theory that among Caucasian participants may not fit Chinese populations.

The study published in JAMDA 2018 to examine the association of body mass index and waist circumference with 3 years mortality among the oldest old used 2011 CLHLS dataset (Lv 2018). Different from the study, the BMI category in his study followed the Chinese BMI guideline (<18.5, 18.5-24, 24-28, >28). After regrouping his original BMI groups, he divided his BMI group into three groups: low BMI (BMI<18.5), middle BMI (BMI: 18.5-24) and high BMI (BMI>24) Similar to our study, his study used sex-stratified cox proportional hazards model to examine the association, and was presented of penalized splines. His study showed that there were no significant interactions of BMI with most of the covariates for mortality risk; the reverse associations of BMI with mortality were observed in the subgroups for both men and women. After adjusting the covariates which were significantly interacted with BMI, such as age group, smoking status, and cardiovascular diseases (all the P values for interaction <. 05), similar results were observed in all those subgroups, and mortality risk was the highest among those with lower BMI. Also, the penalized splines showed that there was a U-shaped association between BMI and mortality in both men and women. However, in my Kaplan-Meier graphs, there was only reverse association between BMI and mortality. There is no U-Shaped association between the two variables. Also, in my age-adjusted and fully adjusted model, there were no significant differences in HRs among female participants within all the BMI categories. Reasons under the fact could be the difference in BMI grouping. My BMI grouping is more precise than his, since I have 6 total BMI groups with increment of 2. Each BMI group has outstanding numbers of participants. However, Dr. Lv used 3 BMI groups like low BMI, normal BMI and high BMI, which the high BMI group (>24) only carry 10% of the total population. Therefore, my results were more precise, and have a trend on increment of BMI for determining the association between BMI and mortality among oldest old participants.   Also, the exclusion criteria and the differences in dataset selection could be the reasons that the results are different from mine.

The study "Association between body mass index and all-cause mortality among oldest old Chinese (Dr. Wang)" also applied Kaplan-Meier estimates curve to analyze the results, which produced similar results of mine. However, compared to Dr. Wang's results, my BMI grouping was more precise. Dr. Wang used Chinese standardized BMI, which it has fewer participants in the section of either overweight or obesity. So, in his Kaplan-Meier Curve, the lines of overweight and obesity caught similar lope of curves. In addition, he did not do the sub group analysis of age. Since age is the major risk factor of mortality, doing the sub-group analysis of age is necessary. The subgroup analysis will estimate if age could be the confounder of the association between BMI and mortality. Also, the sub-group analysis on age would show if BMI would be a risk factor of mortality while aging. Also, compared to Dr. Wang's result, the sub-group analysis on age would give a direction on future studies among aging population.

In the previous study, most of people were born in 1910s and experienced hardship during the early and mid life (Wang 2018). Most participants have lived through wars, the 1960s famine, and the 1976's reforming with western food and lifestyle. Most of the people become nearly 70 when the westernized food cycle began. In the Framingham Cohort Study, it was reported that the duration of obesity was associated with the risk of mortality among adults aged 28-62 years (Abdullah 2011). In our study, it could be that the duration of obesity is not long enough to cause adverse effects. Thus it may not be appropriate to conclude that higher BMI has no effect on survival among oldest older Chinese. In the context of high BMI value and mortality, generational effects should not be ignored (Wang 2018). Different from Western countries, socioeconomic status is positively associated with higher BMI value in China. In our sample, education level increases with the increase of BMI, in which families with a higher educational background may have higher socio-economic status and higher income. Thus, the observed beneficial effects of obesity may be confounded by socioeconomic status. Although we had adjusted for education, residence, and other socio-economic status, yet residual confounding is possible, which was a reason that results were different from Western countries' studies.

4.3 Implications

From the results of my study, I hypothesize that body mass index could not reflect the fatness of a person, especially in older adults. The reason that participants with lower BMI (BMI<16) may have much higher mortality risk is likely due to participants have less muscle mass. My study also found that BMI is not a good indicator for body fat but muscle mass. Therefore, we could not use BMI to examine the fatness of a person. Since the BMI performance in men and women among oldest old adults were different, I assumed that the performance of BMI among young and old adults might also be different. Since BMI has been an indicator for determining adolescents or young adults' fatness (Steve 1990), BMI might not be precise determinants for fatness among older adults. In the future, if time and budget is allowed, measuring tool with much better precise results could be applied to measure the actual fatness among older adult, which the more precise value could produce a much clear association between BMI and mortality among oldest old adults.

4.4 Strengths

The strengths of the study are the relatively large sample size and the detailed information on lifestyle, socio-economic status, and diseases condition. The large and unique dataset is representative of the oldest old Chinese and findings are generalizable. In the study, several subgroup and sensitivity analyses were conducted by assessing the association between BMI and mortality among gender and 3 age groups. The subgroup analyses include analysis without any adjustment, age adjustment and fully adjustment, which made the result more precise. Also, in the study, the BMIs were divided into five different groups, which was more precise with oldest old population. In addition, the study excluded people whom had died within a year from the time at the baseline, which make the study more precise and eliminate confounders.

4.5 Limitations

There are some limitations in the study along with the findings. Firstly, the study used self-reported indicators for the main measurements including socio-economic status, diseases variables and lifestyle variables. Due to the oldness among oldest old people, the information that they provided at the baseline may not be precise. Also, since height was only measured once during the baseline, the oldest old people may have partially lost their height for osteoporosis or kyphosis. Therefore, the calculated BMI may be overestimated. Lastly, since China is a multi-cultural country, different ethnic group may have significantly different eating habits, and genetic difference on height. For example, Mongolian tends to be higher than Han people (Wang 2018). Therefore, a subgroup analysis among ethnic group may be needed in the future. Also, since the BMI was categorized in the unique standard. Misclassification may be occurred if more study were conducted based on the BMI category. Since, the dataset I used is 11 years from nowadays. Also, the eating habits and awareness on exercise may be different between past and nowadays. Therefore, the findings may not fully reflect the association in today's society. So, more studies in nowadays are needed regarding my findings.

5. Conclusion

In conclusion, lowest BMI was associated with increased risk of mortality among the oldest old adults in China. No significant differences were found between men and women or across road age groups. The results, obtained in a large, diverse population of community dwelling older people, counter our hypothesis that elevated BMI is associated with higher mortality at advanced ages. A variety of alternative models and subgroup analyses indicated the result that participants with the BMI<16 kg/m^2 have much higher risk of mortality to be robust. Therefore, our results suggest that weight goals appropriate in younger age groups may be inappropriate for older individuals. Further, studies are needed to confirm our results as well as identifying mechanisms for these associations if confirmed.

References

1. Afzal S, Tybjærg-Hansen A, Jensen GB, et al. Change in body mass index associated with lowest mortality in Denmark, 1976-2013. JAMA 2016;315: 1989e1996.

2. Stevens J, Cai J, Pamuk ER, et al. The effect of age on the association between body-mass index and mortality. N Engl J Med 1998;338:1e7.

3. Cruz-JentoftAJ,BaeyensJP,BauerJM,etal.Sarcopenia:Europeanconsensuson definition and diagnosis: Report of the European working group on sarcopenia in older people. Age Ageing 2010;39:412e423.

4. Thinggaard M, Jacobsen R, Jeune B, et al. Is the relationship between BMI and mortality increasingly U-shaped with advancing age? A 10-year follow-up of persons aged 70-95 years. J Gerontol A Biol Sci Med Sci 2010;65:526e531.

5. Flegal KM, Kit BK, Orpana H, et al. Association of all-cause mortality with overweight and obesity using standard body mass index categories: A sys- tematic review and meta-analysis. JAMA 2013;309:71e82.

6. WHO Consultation on Obesity. Obesity: Preventing and managing the global epidemic: Report of a WHO consultation. WHO technical report series 894. World Health Organ Tech Rep Ser 2000;894:iexii. 1e253.

7. China Ministry of Health. Guidelines for overweight and obesity of Chinese adult prevention and control. 2003.

8. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: A report of the American College of Cardiology/American Heart Association task force on practice guidelines and The Obesity Society. J Am Coll Cardiol 2014;63:2985e3023.

9. National Clinical Guideline Centre (UK). Obesity: Identification, Assessment and Management of Overweight and Obesity in Children, Young People and Adults: Partial Update of CG43. London: National Institute for Health and Care Excel- lence (UK); 2014.

10. Nybo H, Petersen HC, Gaist D, et al. Predictors of mortality in 2,249 non- agenariansdThe Danish 1905-Cohort Survey. J Am Geriatr Soc 2003;51: 1365e1373.

11. Mattila K, Haavisto M, Rajala S. Body mass index and mortality in the elderly. BMJ 1986;292(6524):867e868.

12. Dahl AK, Fauth EB, Ernsth-Bravell M, et al. Body mass index, change in body mass index, and survival in old and very old persons. J Am Geriatr Soc 2013; 61(4):512e518.

13. Samper-Ternent R, Kuo YF, Ray LA, et al. Prevalence of health conditions and predictors of mortality in oldest old Mexican Americans and non-Hispanic whites. J Am Med Dir Assoc 2012;13:254e259.

14. Takata Y, Ansai T, Soh I, et al. Association between body mass index and mortality in an 80-year-old population. J Am Geriatr Soc 2007;55:913e917.

15. Lisko I, Tiainen K, Stenholm S, et al. Body mass index, waist circumference, and waist-to-hip ratio as predictors of mortality in nonagenarians: The Vitality 90þ Study. J Gerontol A Biol Sci Med Sci 2011;66:1244e1250.

16. Fleischmann E, Teal N, Dudley J, et al. Influence of excess weight on mortality and hospital stay in 1346 hemodialysis patients. Kidney Int 1999;55: 1560e1567.

17. Bowman K, Delgado J, Henley WE, et al. Obesity in older people with and without conditions associated with weight loss: Follow-up of 955,000 primary care patients. J Gerontol A Biol Sci Med Sci 2017;72:203e209.

18. Stata Corp. Stata Statistical Software, Release 6.0. College Station, TX: Stata Corp., 1999.

19. Fitti, JE Kovar, MG. The Supplement on Aging 1984 National Health Interview Survey (DHHS Publication 87–1323). Washington, DC: Government Printing Office, 1987.

20. Allison DB, Gallagher D, Heo M et al. Body mass index and all-cause mortality among people age 70 and over: The Longitudinal Study of Aging. Int J Obes Relat Metab Disord 1997;21:424–431.

21. Sharp DS, Abbott RD, Burchfiel CM et al. Plasma fibrinogen and coronary heart disease in elderly Japanese-American men. Arterioscler Thromb Vasc Biol 1996;16:262–268.

22. Enright PL, Kronmal RA, Higgins MW et al. Prevalence and correlates of respiratory symptoms and disease in the elderly. Cardiovascular Health Study. Chest 1994;106:827–834.

23. Maxwell CJ, Hirdes JP. The prevalence of smoking and implications for quality of life among the community-based elderly. Am J Prev Med 1993;9: 338–345.

24. Paganini-Hill A, Hsu G. Smoking and mortality among residents of a California retirement community. Am J Public Health 1994;84:992–995.

25. Williamson DF. The prevention of obesity. N Engl J Med 1999;341:1140–1141
26. Willett WC, Dietz WH, Colditz GA. Guidelines for healthy weight. N Engl J

Med 1999;341:427–434. 27. Calle EE, Thun MJ, Petrelli JM et al. Body-mass index and mortality in a

prospective cohort of U.S. adults. N Engl J Med 1999;341:1097–1105. 28. Fried LP, Kronmal RA, Newman AB et al. Risk factors for 5-year mortality in

older adults: The Cardiovascular Health Study. JAMA 1998;279:585–592. 29. Diehr P, Bild DE, Harris TB et al. Body mass index and mortality in non- smoking older adults: The Cardiovascular Health Study. Am J Public Health

1998;88:623–629. 30. Cornoni-Huntley JC, Harris TB, Everett DF et al. An overview of body

weight of older persons, including the impact on mortality. The National Health and Nutrition Examination Survey I—Epidemiologic Follow-Up Study. J Clin Epidemiol 1991;44:743–753.

31. Tayback M, Kumanyika S, Chee E. Body weight as a risk factor in the elderly. Arch Intern Med 1990;150:1065–1072.

32. Mattila K, Haavisto M, Rajala S. Body mass index and mortality in the elderly. BMJ (Clin Res Ed) 1986;292:867–868.

33. Harris T, Cook EF, Garrison R et al. Body mass index and mortality among nonsmoking older persons. The Framingham Heart Study. JAMA 1988;259: 1520–1524.

34. Losonczy KG, Harris TB, Cornoni-Huntley J et al. Does weight loss from middle age to old age explain the inverse weight mortality relation in old age? Am J Epidemiol. 1995;141:312–321.

35. Wei M, Kampert JB, Barlow CE et al. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. JAMA 1999;282:1547–1553.

36. Pronk NP, Goodman MJ, O'Connor PJ et al. Relationship between modifiable health risks and short-term health care charges. JAMA 1999;282:2235–2239.

37. Rowland ML. Self-reported weight and height. Am J Clin Nutr 1990;52: 1125–1133.

38. Stevens J, Keil JE, Waid LR et al. Accuracy of current, 4-year, and 28-year self-reported body weight in an elderly population. Am J Epidemiol 1990; 132:1156–1163.

39. Solomon CG, Manson JE. Obesity and mortality: A review of the epidemio-logic data. Am J Clin Nutr 1997;66:1044S–1050S.

40. Manson JE, Willett WC, Stampfer MJ et al. Body weight and mortality among women. N Engl J Med 1995;333:677–685.

41. Kumar N, Cohen MA, Bishop CE et al. Understanding the factors behind the decision to purchase varying coverage amounts of long-term care insurance. Health Serv Res 1995;29:653–678.

42. Launer LJ, Harris T, Rumpel C et al. Body mass index, weight change, and risk of mobility disability in middle-aged and older women. The epidemio- logic follow-up study of NHANES I. JAMA 1994;271:1093–1098.

43. Pi-Sunyer FX. A review of long-term studies evaluating the efficacy of weight loss in ameliorating disorders associated with obesity. Clin Ther 1996;18: 1006–1035.

44. Serdula MK, Mokdad AH, Williamson DF et al. Prevalence of attempting