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ORIGINAL ARTICLE

The longitudinal effects of behavioral, health, and socio-demographic factors on body mass index among older Chinese adults

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Abstract
Objectives To examine the effects of behavioral, health, and socio-demographic factors on being overweight or obese among older Chinese adults.
Methods This research uses panel data from the China Health and Nutrition Survey, which was designed to examine how social and economic transformation affected the health and nutritional status of residents. For these analyses, we used all available information on adults aged 60 years or older surveyed in 1997, 2000, 2004, and 2006 ($N = 3{,}591$). Body mass index (BMI) was dichotomized as normal (18.5–24.9 kg/m^2) and overweight (25.0–29.9 kg/m^2)/obese ($\geq$30 kg/m^2). Generalized estimating equations were used to estimate population-averaged (marginal) effects.
Results The combined prevalence of overweight or obese was approximately 33%. Moderate or heavy non-leisure physical activities (OR = 0.39; 95% CI = 0.32–0.49) and smoking (OR = 0.69; 95% CI = 0.57–0.84) decreased the odds of being overweight or obese, while drinking alcohol (OR = 1.25; 95% CI = 1.05–1.50) increased the odds. For individuals in all income levels, the amount of non-leisure physical activity strongly affected the BMI among the older Chinese adults.
Conclusions Active lifestyle interventions may help counter what could otherwise be a growing obesity epidemic in China.

Keywords Behavioral factors · Body mass index · Older Chinese adults · International health

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Introduction

Obesity is a global epidemic. Excess body weight is widely recognized as one of the leading health threats in most countries and a major risk factor for type 2 diabetes, hypertension, other cardiovascular diseases, and physical impairment (Steinberg and Dietz 2008). Historically, most populations suffering from obesity resided in high-income, industrialized countries (Caballero 2007); however, in more recent decades, the most dramatic increases in obesity are seen in lower-income countries such as Mexico, Thailand, and China (Doak and Popkin 2008). The increasing rate of obesity in lower-income countries is thought to be attributable to increasing urbanization and the globalization of food production and marketing (Caballero 2007). When examining this trend, scholars coined the term—"the nutritional transition"—to emphasize the tremendous shifts in dietary habits and physical activity patterns in low-income countries in the last decades of the twentieth century (Popkin and Gordon-Larsen 2004).

The global epidemic of obesity is not restricted to individuals of any particular age. In the United States in 2007–2008, 27.5% of adults aged 20–39 were obese [body

mass index (BMI, kg/m^2) $\geq$ 30], while 37.1% of those aged 60 years or older were obese (Flegal et al. 2010; Ogden et al. 2006). Among Chinese adults aged 65 years and older, the combined prevalence of overweight or obesity [body mass index (BMI, kg/m^2) $\geq$ 25] significantly increased from 10.5% in 1991 to 24.1% in 1999–2000 (Wildman et al. 2008). A recent study projected that approximately 669 million (59.7%) and 141 million (12.6%) Chinese adults will be overweight or obese, respectively, by 2030 (Kelly et al. 2008). Although the prevalence of obesity in the Chinese population is relatively low compared with Western countries, it is the rapid increase in the prevalence of these conditions in China that is a growing public health concern (Wu 2006).

As in the US, obesity-related adverse health effects in China are likely to affect the solvency of the Chinese healthcare system. Aging men and women who are overweight or obese had 6–17% higher lifetime healthcare expenditures than those of normal weight (Yang and Hall 2008). Further, a recent study estimated annual direct medical costs of chronic diseases attributable to overweight and obesity among adults in China to be $2.74 billion, accounting for 3.7% of national total medical costs (Zhao et al. 2008). A Chinese case study also found that the indirect economic effects of obesity and obesity-related dietary and physical activity patterns accounted for 3.58% of that country's gross national product (GNP) in 2000. Estimates indicate that figure will increase by almost 150 to 8.73% of GNP in 2025 (Popkin et al. 2006).

As an individual health concern, being an obese older adult increases the likelihood of suffering from serious chronic conditions, functional impairments (Ferrucci and Alley 2007), and a lower quality of life (Yan et al. 2004). These obesity-related adverse health outcomes may in turn lead to the loss of productivity due to activity limitations, early retirement, and days absent from work (Schooling et al. 2006). Previous research has examined the effects of behavioral, health-related, and social factors affecting BMI (Zhang and Wang 2004). Research, however, continues to focus on younger populations and highly industrialized societies (Witham and Avenell 2010).

Researchers in these earlier studies almost universally found that obesity is more prevalent among those of lower socioeconomic status (SES) (Zhang and Wang 2004). However, it is unclear whether these relationships can be found among older Chinese adults or older adults in other low-income countries. The associations of BMI with behavioral, health, and socio-demographic factors among adults in low-income countries have received little attention. This raises a concern that the findings in these earlier studies may not generalize across settings or populations.

An examination of the relationships between overweight/obesity and the associated health and socio-behavioral factors among older Chinese adults will provide an interesting test of the generalizability of these earlier studies. In addition, research on older Chinese adults is important because of the country's sheer size in terms of its potential economic might, populations, and the global impact of its public's health. China is one of the most rapidly aging countries in the world (Central Intelligence Agency 2010); accounting for a fifth of the world's adults aged 60 years or older (United Nations 2006). If obesity increases among older Chinese adults, the health and economic ramifications may extend beyond its borders. Thus, the purposes of this study were to: (1) document the extent to which older Chinese adults were overweight or obese; (2) examine factors associated with overweight or obesity over time; and (3) examine factors associated with overweight or obesity over time by income tertiles.

Methods

Data source and study population

We examined data from the China Health and Nutrition Survey (CHNS), which was designed to examine how social and economic transformation in eight provinces affected the health and nutritional status of residents (Beydoun and Popkin 2005). The survey, which relied on an extensive interviewer-administered questionnaire and a set of anthropometric and clinical measurements, was conducted in 1989, 1991, 1997, 2000, 2004, and 2006. For these analyses, we used all available data from adults aged 60 years or older surveyed in 1997, 2000, 2004, and 2006 (n = 1,901 women and n = 1,690 men). Individuals with missing information on age were excluded. Participants who were underweight (n = 589) were also excluded because we intended to identify the factors associated with being overweight or obese as compared to normal weight. Due to missing values and excluded respondents, each survey wave had a different number of participants: 1,618 in 1997, 1,707 in 2000, 2,074 in 2004, and 2,267 in 2006. The number of participants who responded to all four survey waves was 582 (16%), another 666 people (19%) responded to a minimum of three survey waves, and another 1,047 people (30%) responded to a minimum of two survey waves. As such, the percentage of cohort groups by survey years accounted for 47% (1997), 17% (2000), 22% (2004), and 14% (2006). The study sample was similar to the Chinese National sample for sex ratio and rural residence: sex ratio (i.e., 0.89 for the study sample; 0.93 for the National sample) and rural residence (i.e., 60% for the study sample; 57% for the National sample) (Central Intelligence Agency 2010).

Variables and measures

Dependent variable

The BMI was calculated from measured weight in kilograms divided by the square of measured height in meters and rounded to the nearest tenth as recommended by the original Quetelet calculation (Garrow and Webster 1985). The BMI was categorized using the World Health Organization (1998) criteria: normal (BMI = 18.5–24.9 kg/m^2), overweight (BMI = 25–29.9 kg/m^2), and obese (BMI $\geq$ 30 kg/m^2), which led to a binary variable (normal vs. overweight/obese) for the purpose of the study.

Behavioral factors

A 3-day average daily caloric intake was calculated in kilocalories, which were divided by 100 for interpretation in the multiple regression analyses. Physical activity was based on non-leisure physical activity levels: having no physical activity, or engaging in very light (e.g., officer worker, watch repairer), light (e.g., salesperson, laboratory technician, teacher), moderate (e.g., student, driver, electrician, metal worker), heavy (e.g., farmer, dancer, steel worker, athlete), or very heavy physical activity (e.g., loader, logger, miner, stonecutter). We categorized these responses as no physical activity or very light (scored 0), light (scored 1), and moderate or heavy (scored 2). Although there are no previous studies to test reliability or validity on this variable, a previous study has found it to be significant predictor of weight (Ball et al. 2001). The indicator for smoking was based on responses to the survey item, "Do you still smoke cigarettes (including hand-rolled or device-rolled) now: yes or no." Alcohol consumption was based on responses to the survey item, "Last year, how often did you drink beer or any alcoholic beverage: almost every day, 3–4 times a week, once or twice a week, once or twice a month, no more than once a month, or none." This variable was then dichotomized into "no" and "yes", indicating whether or not they had consumed alcohol over the past year.

Health-related factors

Participants were asked to report if they had any of the following acute symptoms during the past 4 weeks: (1) fever, sore throat, cough; (2) diarrhea, stomachache; (3) headache, dizziness; (4) joint pain, muscle pain; (5) rash, dermatitis; (6) eye/ear disease; (7) any other infectious disease; and (8) other noncommunicable diseases (Beydoun and Popkin 2005). These responses were used to create a binary variable (yes, health problems in last 4 weeks, or no). As a proxy for cognitive impairment, participants were asked how their memory had changed in the past 12 months, choosing from improved, stayed the same, or deteriorated. The resulting data were dichotomized into memory deterioration (value = 1) or no deterioration (value = 0).

Socio-demographic factors

Marital status was recorded into never married, married, divorced, widowed, and separated. These responses were collapsed into two categories—living with a spouse (value = 0) or living without a spouse (value = 1). Participants also reported their gender (male or female) and age. Each province of the nine provinces consisted of four rural counties and two urban counties, which were used to create an indicator of the participants' residential rurality (urban or rural). Household income was computed as the sum of all sources of income in the household, inflated to a 2006 price index, and divided by household size. The current study examined tertiles of per capita income based on the distribution of the continuous form of this variable in the selected study sample (Beydoun and Popkin 2005). The education level of each older person was coded into "illiterate or no formal education" (value = 0), "primary level of education" (value = 1), or "intermediate or more education" (value = 2) based on their completed years of education (Beydoun and Popkin 2005). As an enabling factor, health insurance was coded into a binary variable. The current study used all baseline (first response) explanatory variables except rural and gender, which are assumed unchangeable after 60 years or older.

Statistical analysis

Generalized estimating equations (GEE) were used to estimate population-averaged (marginal) effects taking into account the dependence among individuals nested in survey clusters. The current study used population-averaged logistic regression rather than a subject-specific model because we were interested in describing how the entire population evolved over time (Fitzmaurice et al. 2004). After testing various covariance structures, we selected exchangeable working correlation, which had the same correlation for all pairs of units. For this study, GEE was preferred over ordinary logistic regression because it yields more efficient estimates when the working correlation is similar to the true dependence structure (Rabe-Hesketh and Skrondal 2008). With an exchangeable correlation structure, we used robust variance estimator, which is always consistent even when the covariance structure is misspecified, after realizing that GEE estimates of marginal effects may not be robust against misspecified regression structures (Rabe-Hesketh and Skrondal 2008). The GEE model

can be useful in handling missing data. If the responses are missing at random, maximum likelihood estimation of the model gives consistent parameter estimates (Rabe-Hesketh and Skrondal 2008).

When interpreting and estimating regression parameters in models for longitudinal data, issues arise when a covariate is both time-varying and stochastic (Fitzmaurice et al. 2004). For example, if the caloric intake variable is a stochastic time-varying covariate, increased intake of calories leads to an increased BMI, which in turn may affect the volume of caloric intake and thus may indicate the existence of a confounding factor. Instead, we used the time-stationary (baseline) covariates for all behavioral, health, and socio-demographic factors except age, rural residence, and years in cohort. *Stata* (version 10; StataCorp, College Station, TX) and SAS (version 9.2; SAS Institute, Cary, NC) were used to perform the regression analysis. Additionally, other population-averaged models were built to determine how the factors and their associations varied by income tertiles. Odds ratios with 95% confidence intervals are displayed.

Results

The demographic characteristics of the samples are presented in Table 1. Overall, 32.8% of the sample was overweight or obese (28.9% before excluding underweight sample). For the behavioral factors, the average caloric intake was 2,118 kilocalories (kcal) on an average a day (SD = 699), and 46.7% of the sample reported no, or very light, non-leisure physical activity level. At baseline, 26.3 and 29.2% of the sample were smokers or drinkers, respectively. Over 19% reported an acute medical condition, and 43.9% reported memory deterioration. In addition, the sample contained larger proportions of participants who were living with a spouse (74.7%), female (52.9%), and rural residents (60.1%). Approximately 35% of the sample reported having health insurance and 40.0% had no formal education at all.

Table 2 indicates that being overweight or obese was not affected by the number of years a participant remained in the study (OR = 1.01; 95% CI = 0.99–1.02; $P = 0.363$). Instead, having an older age at baseline decreased the odds of being overweight or obese (OR = 0.97; 95% CI = 0.96–0.99; $P = 0.001$). This table also indicates that all of the behavioral factors at baseline in the model were significantly associated with being overweight or obese among these older Chinese adults over the survey period. The odds of being overweight or obese were higher for those who consumed more calories (OR = 1.01; 95% CI = 1.00–1.03; $P = 0.010$) and those who drank alcohol (OR = 1.25; 95% CI = 1.05–1.50; $P = 0.015$). Conversely, having moderate or heavy non-leisure physical activity levels (OR = 0.39; 95% CI = 0.32–0.49; $P < 0.001$) and smoking (OR = 0.69; 95% CI = 0.57–0.84; $P < 0.001$) decreased the odds of

Table 1 Demographic characteristics of the study population in the 1997, 2000, 2004, and 2006 China Health and Nutrition Survey ($n = 3,591$)

Variables	Distribution (%) or mean (SD)
Dependent variables	
Body mass index[b]	
Normal (18.5–24.9)	67.2
Overweight (25–29.9)/obese (≥30)	32.8
Behavioral factors	
Caloric intake (kcal)[a]	2,118 (699)
Non-leisure physical activity level[a]	
No or very light	47.7
Light	22.7
Moderate or heavy	30.6
Smoking[a]	26.3
Alcohol[a]	29.2
Health-related factors	
Acute medical condition[a]	19.2
Memory deterioration[a]	43.9
Socio-demographic factors	
Marital status[a]	
Living with a spouse	74.7
Living without a spouse	25.3
Female	52.9
Age[a]	66.0 (6.51)
Female	52.9
Rural residence	60.1
Income tertiles[a]	
Low	34.2
Middle	34.5
High	31.3
Education[a]	
Illiterate or no formal education	40.0
Primary	36.1
Intermediate	23.9
Health insurance[a]	34.7
Cohort	
1997	47.2
2000	16.9
2004	21.6
2006	14.3

SD standard deviation

[a] At baseline

[b] Before excluding sample with underweight, the proportion of BMI categories was 12.4% (underweight), 58.9% (normal), and 28.9% (overweight or obese)

Table 2 Factors associated with overweight or obesity over time in older Chinese adults in the 1997, 2000, 2004, and 2006 China Health and Nutrition Survey ($n = 3{,}156$)

Variables	OR (95% CI)
Behavioral factors	
Caloric intake (100 kcal)[a]	1.01 (1.00, 1.03)*
Non-leisure physical activity level (vs. no or very light)[a]	
Light	0.88 (0.73, 1.05)
Moderate or heavy	0.39 (0.32, 0.49)**
Smoking (vs. no)[a]	
Yes	0.69 (0.57, 0.84)**
Alcohol (vs. no)[a]	
Yes	1.25 (1.05, 1.50)*
Health-related factors	
Acute medical condition (vs. no)[a]	
Yes	1.19 (0.99, 1.45)
Memory deterioration (vs. no)[a]	
Yes	0.98 (0.85, 1.14)
Socio-demographic factors	
Marital status (vs. living with a spouse)[a]	
Living without a spouse	0.82 (0.68, 0.99)*
Gender (vs. male)	
Female	1.33 (1.10, 1.61)**
Age[a]	0.97 (0.96, 0.99)**
Residence (vs. urban)	
Rural	0.99 (0.84, 1.16)
Income tertiles (vs. low)[a]	
Middle	1.09 (0.91, 1.31)
High	1.40 (1.14, 1.71)**
Education (vs. illiterate or no formal education)[a]	
Primary	1.11 (0.92, 1.34)
Intermediate	1.08 (0.86, 1.35)
Health insurance (vs. no)[a]	
Yes	1.33 (1.13, 1.58)**
Cohort (vs. 1997)	
2000	1.25 (1.01, 1.53)*
2004	1.13 (0.92, 1.40)
2006	1.25 (0.97, 1.61)
Years in cohort	1.01 (0.99, 1.02)

CI confidence interval

[a] At baseline: * $P < 0.05$; ** $P < 0.01$

being overweight or obese. Additionally, living without a spouse (OR = 0.82; 95% CI = 0.68–0.99; $P = 0.038$) decreased the odds of being overweight or obese, whereas the odds were increased by being female (OR = 1.33; 95% CI = 1.10–1.61; $P = 0.002$), having a high income (OR = 1.40; 95% CI = 1.14–1.71; $P = 0.002$), and having health insurance (OR = 1.33; 95% CI = 1.13–1.58; $P = 0.002$). Having an acute medical condition or memory deterioration was not significantly associated with being overweight or obese.

Table 3 displays the way in which the factors of being overweight or obese vary by income level. At the significance level of 0.01, moderate or heavy non-leisure physical activities significantly decreased the risk of being overweight or obese for those of all income levels. Among low-income participants, age (OR = 0.95; 95% CI = 0.92–0.98; $P < 0.001$) was negatively associated with being overweight or obese. Among the high-income population, overweight or obesity was common among those who lived in rural areas (OR = 1.45; 95% CI = 1.11–1.89; $P = 0.006$) or had health insurance (OR = 1.47; 95% CI = 1.14–1.91; $P = 0.003$), whereas smoking (OR = 0.58; 95% CI = 0.42–0.80; $P = 0.001$) was negatively associated with being overweight or obese.

Discussion

Approximately one-third of these study participants reported being overweight or obese, ranging from 26.7% in 1997, 28.9% in 2000, 31.9% in 2004, to 31.8% in 2006. These prevalence rates are higher than the rate reported in other Chinese study (Wildman et al. 2008) and lower than the reported rate in the US (Flegal et al. 2010). Among this sample, the average of BMI slightly increased from 23.2 kg/m^2 in 1997 to 23.9 kg/m^2 in 2006. Although the prevalence of overweight or obesity in this study was still lower than in the US, trends of increasing BMI are beginning to emerge in lower-income countries including China (Popkin and Gordon-Larsen 2004). The current study suggests that overweight or obesity in China is associated with behavioral, health, and socio-demographic factors, which is consistent with previous research (Zhang et al. 2008).

Previous studies demonstrate that BMI among older adults can be controlled by a combination of physical activity and dietary interventions (Witham and Avenell 2010). Among the behavioral factors in this analysis of older Chinese, the level of non-leisure physical activities was the strongest predictor of a weight problem. Those who had moderate or heavy non-leisure physical activity levels were less likely to be overweight or obese regardless of their income level. The current study shows that these physically active people were 61% less likely to be overweight or obese. Previous study supports this protective effect of physical activity against obesity (Zhang et al. 2008). One possible explanation is that physical activity at work among Chinese adults, especially in the agricultural sector, has declined, and the prevalence of being overweight has increased among those with light work-related

Table 3 Factors associated with overweight or obesity over time in older Chinese adults by income tertiles in the 1997, 2000, 2004, and 2006 China Health and Nutrition Survey ($n = 3,156$)

Variables	OR (95% CI)		
	Low income ($n = 1,072$)	Middle income ($n = 1,058$)	High income ($n = 1,026$)
Behavioral factors			
Caloric intake (100 kcal)[a]	1.00 (0.98, 1.02)	1.02 (1.00, 1.04)	1.02 (0.99, 1.04)
Non-leisure physical activity level (vs. No or very light)[a]			
Light	0.78 (0.55, 1.11)	0.91 (0.66, 1.25)	0.90 (0.67, 1.20)
Moderate or heavy	0.39 (0.27, 0.56)**	0.39 (0.27, 0.56)**	0.37 (0.25, 0.54)**
Smoking (vs. no)[a]			
Yes	0.64 (0.45, 0.91)	0.86 (0.62, 1.20)	0.58 (0.42, 0.80)**
Alcohol (vs. no)[a]			
Yes	1.17 (0.83, 1.66)	1.14 (0.83, 1.58)	1.41 (1.05, 1.90)
Health-related factors			
Acute medical condition (vs. no)[a]			
Yes	1.11 (0.77, 1.61)	1.04 (0.74, 1.46)	1.36 (1.02, 1.82)
Memory deterioration (vs. no)[a]			
Yes	0.95 (0.71, 1.25)	1.02 (0.79, 1.31)	0.97 (0.76, 1.25)
Socio-demographic factors			
Marital status (vs. living with a spouse)[a]			
Living without a spouse	0.83 (0.59, 1.16)	0.71 (0.51, 0.98)	0.97 (0.69, 1.35)
Gender (vs. male)			
Female	1.13 (0.79, 1.61)	1.48 (1.05, 2.08)	1.34 (0.98, 1.82)
Age[a]	0.95 (0.92, 0.98)**	0.99 (0.97, 1.02)	0.97 (0.94, 0.99)
Residence (vs. urban)			
Rural	0.72 (0.53, 0.98)	0.84 (0.64, 1.11)	1.45 (1.11, 1.89)**
Education (vs. illiterate or no formal education)[a]			
Primary	1.00 (0.72, 1.39)	1.39 (1.03, 1.88)	0.89 (0.64, 1.27)
Intermediate	1.29 (0.83, 2.00)	1.29 (0.86, 1.93)	0.83 (0.57, 1.19)
Health insurance (vs. no)[a]			
Yes	1.43 (0.99, 2.04)	1.05 (0.79, 1.40)	1.47 (1.14, 1.91)**
Cohort (vs. 1997)			
2000	1.37 (0.92, 2.03)	1.21 (0.86, 1.70)	1.24 (0.86, 1.77)
2004	1.05 (0.68, 1.62)	1.49 (1.03, 2.16)	1.03 (0.73, 1.45)
2006	1.06 (0.61, 1.82)	1.41 (0.89, 2.21)	1.28 (0.86, 1.90)
Years in cohort	1.02 (0.99, 1.04)	0.99 (0.98, 1.02)	1.00 (0.98, 1.03)

CI confidence interval

[a] At baseline: ** $P < 0.01$

physical activity (Yu et al. 1999). The decreased physical activity among the Chinese people may be related to and accelerated by lifestyle changes, which are related to changes in modes of transportation. The Chinese increased their acquisition of motor vehicles between 1989 and 1997, and this has been associated with an increased obesity in both men and women (Bell et al. 2002).

Energy consumption is another determinant of being overweight or obese, although this relationship is more tenuous in our study (OR = 1.01). Caloric intake levels may affect BMI differently among older adults when compared to younger adults (US Department of Health and Human Services and US Department of Agriculture 2005). However, the combined interventions targeting diet and exercise have been shown to control BMI among older adults worldwide (Ferrucci and Alley 2007). As reported in a cross-sectional study of Chinese men, a higher BMI was related to higher total caloric intake (Lee et al. 2008). A recent report reported changes in the proportions, and sources, of dietary macronutrients over the past 20 years (Wu 2006). Energy intake from animal sources has increased from 8% in 1982 to 25% in 2002 (Wu 2006), and

the average energy intake from dietary fat among urban Chinese increased from 25 to 30%, which far exceeds the WHO recommendation (Wang et al. 2005).

Smoking decreased the risk of being overweight or obese, while drinking alcohol increased the odds of having a higher BMI. The inverse relationship between smoking and BMI has been supported by previous research (Lee et al. 2008). Reportedly, nicotine may play a critical role in changing a smoker's taste preferences and ingestive behaviors (Wack and Rodin 1982). As such, smokers weigh less because they consume less food and they gain weight when they stop smoking because they eat more (Wack and Rodin 1982). A study of Chinese men found that current smokers had a lower BMI and the ex-smokers were more likely to have greater central obesity than non-smokers (Xu et al. 2007).

Alcohol has also been previously reported as a factor for being overweight or obese (Suter and Tremblay 2005). Alcohol consumption may affect weight through two mechanisms. First, people who drink alcohol can gain weight directly since alcohol is an energy-dense calorie source (7 kcal/g) (Swinburn et al. 2004). Indirectly, alcohol consumption can be related to less nutritious dietary habits. We speculate that the Chinese people usually eat food while drinking, which is related to a social belief that drinking with good food enables them to drink more and avoid hangovers. To support this idea, our separate analysis between caloric intake and alcohol consumption showed that those who drank at baseline were likely to consume more calories.

Another noteworthy finding of the current study was the positive relationship between income and BMI. Older adults classified into a high-income category were 40% more likely to be overweight or obese. However, in high-income, industrialized countries including the United States, BMI has been shown to be inversely related to income levels (Lee et al. 2008). This relationship in the current study may be better understood when placed in the context of Chinese culture. In lower-income countries including China, the association between income and BMI may be different. Generally, as a country experiences an economic boom, its people have larger purchasing power to obtain fattier and saltier foods (Martinez-Alier 2006). The current study shows that the per capita household income in China has been significantly increased from 3,258 Chinese Yuan in 1997 to 6,816 Chinese Yuan in 2006. Chinese economic growth may play a role of shifting the dietary habit toward energy-dense diets. For example, 9.3% of low-income Chinese consumed 30% of energy from fat in 1989 and 33.5% from fat in 2006 while 18.5% of high-income Chinese consumed 30% of energy from fat in 1989 and 53.4% from fat in 2006 (Popkin 2008). China has the world's fastest growth in supermarkets, with sales in these stores increasing by 40% annually (Popkin 2008). A recent study found that older Chinese adults significantly increased snack consumption by 7.2%, increased caloric intake from fried foods by 4.6%, and decreased caloric intake from foods prepared with traditional methods by 6.4% (Wang et al. 2008). Nevertheless, the association between income and BMI should be further investigated in future research studies.

Additional research is needed to investigate the relationships between BMI and health outcomes. Although it is broadly accepted that obesity is a chronic metabolic disorder (Poirier et al. 2006), these associations become more complicated in the Chinese population. For example, both underweight and obesity were associated with increased mortality (Gu et al. 2006). Pre-existing health status may determine the association between obesity and mortality. A study found that among people with poorer health status, obesity was associated with better health outcomes, while among those with better health status, obesity was associated with worse health outcomes (Schooling et al. 2006). Findings from the aforementioned study emphasizes the need to examine the associations of various BMI levels used in international samples because the current BMI 'cut points' suggested by the WHO were created based on people in the West (Chow 2008). Instead, the Working Group on Obesity in China has recommended that a BMI of 18.5–23.9 should be considered as normal, 24–27.9 as overweight, and 28 and above as obese (Wu 2006). Nevertheless, additional sensitivity analysis classifying 24 or more of BMI as being overweight or obese did not generate significantly different results. In addition, multiple methodologies assessing obesity including waist circumference (WC) or waist-to-hip ratios are useful for verifying the current findings with other measurement techniques.

The current study has limitations. We used the baseline covariates to avoid confounding factors caused by stochastic time-varying covariates; thus important information may have been lost. As an alternative, a first-order autoregressive-response (lag-1 response) model could be used, but this model is only sensible if the occasions are equally spaced in time (Rabe-Hesketh and Skrondal 2008). Unfortunately, the CHNS data had uneven intervals between surveys. Next, the current study did not distinguish between overweight and obese population because of the sample distribution (i.e., $<5\%$ of older adults were obese). There are also potential impacts of the high attrition rate on estimates across survey periods. Although we cannot test directly whether missing data at each survey period occurred at random (an assumption of the GEE model), we performed additional logistic regression models to compare the baseline BMI (binary) and the last BMI (binary) observed, respectively, between groups of participants completing different number of survey waves (i.e., ranging from one survey wave to all four survey waves). We identified no significant differences, indicating there is

no systemic BMI pattern influenced by missing data. Therefore, we cannot foresee any possible bias on estimates caused by the high attrition rate. Finally, the physical activity variable focused on work-related activity available in the current study did not capture how often the study participants engaged in physical activity in everyday routines, and thus may have been somewhat limited. Non-work physical activity is important to examine as the Chinese economy continues to grow and its people have more leisure time.

Despite these limitations, the current study has much value in examining factors related to overweight or obesity in a rapidly industrializing society. Given the benefits of naturally occurring behavioral changes, we recommend the development and testing of planned programs or policies to combat overweight or obesity. The relationship between lifestyle changes and weight control among older adults is well documented (Witham and Avenell 2010). Intensive lifestyle education can lead to modest but sustained weight loss (Wu 2006). This should also be accompanied by public health interventions to overcome the prevailing traditional attitudes toward overweight or obesity. In Chinese culture, there is still a widespread belief that overweight or obesity represents health and prosperity (Wu 2006). Widespread education efforts should inform people about the adverse effects of overweight or obesity and the obesity prevention and control should be included in China's policy on health (Wu 2006). Coupled with prospering China's economy, modernization has contributed to an obesity epidemic by changing dietary habits, reducing levels of physical activity, and increasing sedentary lifestyle (Lee et al. 2008). If these trends continue, these traditional and modern factors will accelerate rates of overweight and obesity. As the Chinese population rapidly ages, the increasing obesity epidemic will threaten not only individual health but also place undue financial burdens on the healthcare system in China.

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Conflict of interest The authors declare that they have no conflict of interest.

References

Ball K, Owen N, Salmon J, Bauman A, Gore CJ (2001) Associations of physical activity with body weight and fat in men and women. Int J Obes 25(6):914–919

Bell AC, Ge K, Popkin BM (2002) The road to obesity or the path to prevention: motorized transportation and obesity in China. Obesity 10(4):277–283

Beydoun MA, Popkin BM (2005) The impact of socio-economic factors on functional status decline among community-dwelling older adults in China. Soc Sci Med 60(9):2045–2057

Caballero B (2007) The global epidemic of obesity: an overview. Epidemiol Rev 29(1):1–5

Central Intelligence Agency (2010) The world factbook. In: Central Intelligence Agency. https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html. Accessed August 9 2010

Chow CC (2008) Dietary habits, physical activity and obesity in Hong Kong residents. Obes Rev 9(s1):104–106

Doak CM, Popkin BM (2008) The rapid emergence of obesity in developing countries. In: Semba RD, Bloem MW (eds) Nutrition and health in developing countries, 2nd edn. Humana Press, Totowa, NJ, pp 617–638

Ferrucci L, Alley D (2007) Obesity, disability, and mortality: a puzzling link. Arch Intern Med 167(8):750–751

Fitzmaurice GM, Laird NM, Ware JH (2004) Applied longitudinal analysis. Wiley, Hoboken, NJ

Flegal KM, Carroll MD, Ogden CL, Curtin LR (2010) Prevalence and trends in obesity among US adults, 1999–2008. JAMA 303(3):235–241

Garrow JS, Webster J (1985) Quetelet's Index (W/H2) as a measure of fatness. Int J Obes 9(2):147–153

Gu D, He J, Duan X et al (2006) Body weight and mortality among men and women in China. JAMA 295(7):776–783

Kelly T, Yang W, Chen CS, Reynolds K, He J (2008) Global burden of obesity in 2005, projections to 2030. Int J Obes 32(9):1431–1437

Lee SJ, Go AS, Lindquist K, Bertenthal D, Covinsky KE (2008) Chronic conditions and mortality among the oldest old. Am J Pub Health 98(7):1209–1214

Martinez-Alier J (2006) Energy, economy, and poverty: the past and present debate. In: Byrne J, Toly N, Glover L (eds) Transforming power: energy, environment, and society in conflict. Transaction Publishers, New Brunswick, NJ, p 35

Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM (2006) Prevalence of overweight and obesity in the United States, 1999–2004. JAMA 295(13):1549–1555

Poirier P, Giles TD, Bray GA et al (2006) Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss. Arterioscl Thromb Vasc Biol 26(5):968–976

Popkin BM (2008) Will China's nutrition transition overwhelm its health care system and slow economic growth? Health Aff 27(4):1064–1076

Popkin BM, Gordon-Larsen P (2004) The nutrition transition: worldwide obesity dynamics and their determinants. Int J Obes 28:S2–S9

Popkin BM, Kim S, Rusev ER, Du S, Zizza C (2006) Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. Obes Rev 7(3):271–293

Rabe-Hesketh S, Skrondal A (2008) Multilevel and longitudinal modelling using Stata. Stata Press, College Station

Schooling CM, Lam TH, Li ZB et al (2006) Obesity, physical activity, and mortality in a prospective Chinese elderly cohort. Arch Intern Med 166(14):1498–1504

Steinberg KK, Dietz WH (2008) Workshop on estimating the health burden of overweight and obesity. Int J Obes 32:S1–S3

Suter PM, Tremblay A (2005) Is alcohol consumption a risk factor for weight gain and obesity? Crit Rev Clin Lab Sci 42(3):197–227

Swinburn BA, Caterson I, Seidell JC, James WPT (2004) Diet, nutrition and the prevention of excess weight gain and obesity. Public Health Nutr 7(1A):123–146

United Nations (2006) World population prospects: the 2002 revision. In: http://www.un.org/esa/population/publications/wpp2002/WPP2002-HIGHLIGHTSrev1.PDF. Accessed 10 Oct 2010

US Department of Health and Human Services and US Department of Agriculture (2005) Dietary guidelines for Americans, 2005, 6th edn. US Government Printing Office, Washington, DC

Wack JT, Rodin J (1982) Smoking and its effects on body weight and the systems of caloric regulation. Am J Clin Nutr 35(2):366–380

Wang Y, Rimm EB, Stampfer MJ, Willett WC, Hu FB (2005) Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. Am J Clin Nutr 81(3):555–563

Wang Z, Zhai F, Du S, Popkin B (2008) Dynamic shifts in Chinese eating behaviors. Asia Pac J Clin Nutr 17(1):123–130

Wildman RP, Gu D, Muntner P et al (2008) Trends in overweight and obesity in Chinese adults: between 1991 and 1999–2000. Obesity 16(6):1448–1453

Witham MD, Avenell A (2010) Interventions to achieve long-term weight loss in obese older people: a systematic review and meta-analysis. Age Ageing 39(2):176–184

World Health Organization (1998) Obesity: prevention and managing the global epidemic-report of a WHO consultation on obesity. Geneva

Wu Y (2006) Overweight and obesity in China. Br Med J 333(7564):362–363

Xu F, Yin XM, Wang Y (2007) The association between amount of cigarettes smoked and overweight, central obesity among Chinese adults in Nanjing, China. Asia Pac J Clin Nutr 16(2):240–247

Yan LL, Daviglus ML, Liu K et al (2004) BMI and health-related quality of life in adults 65 years and older. Obesity 12(1):69–76

Yang Z, Hall AG (2008) The financial burden of overweight and obesity among elderly Americans: the dynamics of weight, longevity, and health care cost. Health Serv Res 43(3):849–868

Yu Z, Song G, Guo Z et al (1999) Changes in blood pressure, body mass index, and salt consumption in a Chinese population. Prev Med 29(3):165–172

Zhang Q, Wang Y (2004) Trends in the association between obesity, socioeconomic status in US adults: 1971 to 2000. Obes Res 12(10):1622–1632

Zhang X, Sun Z, Zheng L et al (2008) Prevalence and associated factors of overweight and obesity in a Chinese rural population. Obesity 16(1):168–171

Zhao W, Zhai Y, Hu J et al (2008) Economic burden of obesity-related chronic diseases in Mainland China. Obes Rev 9(s1):62–67