Assessing longitudinal and cross-sectional effects of age on adult obesity in an Iranian population: results from a large population-based cohort study

Mahsa Rafiee Alhossaini
Tarbiat Modares University Faculty of Medical Sciences
Anoshirvan Kazemnejad (kazem_an@modares.ac.ir)
Tarbiat Modares University Faculty of Medical Sciences
Farid Zayeri
Shaheed Beheshti University of Medical Sciences
Masoumeh Sadeghi (m_sadeghi@crc.mui.ac.ir)
Isfahan University of Medical Sciences

Research Article

Keywords: Obesity, Adult, Age, Longitudinal, Cross-sectional

Posted Date: December 1st, 2020

DOI: https://doi.org/10.21203/rs.3.rs-21244/v3

Computational and Mathematical Methods in Medicine

Assessing longitudinal and cross-sectional effects of age on adult obesity in an Iranian population: results from a large population-based cohort study

Mahsa Rafiee Alhossaini[1], Anoshirvan Kazemnejad[1*], Farid Zayeri[2], Masoumeh Sadeghi[3*]

[1]Department of Biostatistics, Faculty of Medical Sciences, Tarbiat Modares University, P.O Box 14115111, Tehran, Iran

[2]Proteomics Research Center and Department of Biostatistics, School of Applied Medical Sciences, Shahid Beheshti University of Medical Sciences, P.O Box 19839-63113, Tehran, Iran

[3]Cardiac Rehabilitation Research Center, Isfahan Cardiovascular Research Institute, Isfahan University of Medical Sciences, P.O Box 58388994, Isfahan, Iran

* Corresponding authors:

Prof. Anoshirvan Kazemnejad, Email: kazem_an@modares.ac.ir

Prof. Masoumeh Sadeghi, Email: m_sadeghi@crc.mui.ac.ir

Abstract

The risk of obesity commonly changes with age, which is a longitudinal (aging) effect. Also, individuals who enter the study of the same age have similar living conditions that may influence their obesity risk in a particular way; this is a cross-sectional effect. To assess the cross-sectional and longitudinal effects of age, using a Marginal Logistic Regression model. In the current study, we used the information of individuals who had participated in the Isfahan Cohort Study. Participants were a large group of Iranian adults over 35 years of age in 2001, who lived in the central region of Iran. Repeated measurements were obtained in 2001, 2007, and 2013. From 2001 to 2013, the percentage of obesity in men and women has raised from 13% to 18% and from 31% to 44%, respectively. Both cross-sectional and longitudinal effects of age were significantly associated with the odds ratio of obesity. There was a rise in the probability of obesity for individuals with a baseline age of 35 to 60 and a decline for the older ones. The odds of obesity had about a 2% increase (on average) with each year of aging, regardless of the baseline age. The high frequency of individuals with obesity and its fast growth has been a serious public health issue among Iranian adults aged 35-60 years, especially in women. To better understand the effect of age on obesity and identify the related factors, both cross-sectional and longitudinal effects of age should be considered.

Introduction

Obesity is a significant risk factor for NCDs, metabolic diseases, and heart diseases. It has an association with age, gender, education, economic, inappropriate diet, and a sedentary lifestyle[1, 2]. The global prevalence of obesity is growing in low and middle-income countries and Also, in high-income countries [3]. In Iran, several studies reported a high and rising prevalence of obesity [1, 4-10]. Age, place of residence, educational level, gender, and marital status, were associated with inequality in obesity in Iran [5, 10, 11]. Obesity distribution patterns differ by age due to biological and sociocultural differences [12]. In some limited studies, longitudinal and cross-sectional effects of age on obesity were investigated separately[12-15]. The decomposition of these two effects could provide valuable information [12, 13]. These two sources of information for age (age is a time-varying covariate) can make conflict about the nature and magnitude of the age effect [16]. The longitudinal effect of age (aging effect) refers to the common developmental changes that are associated with particular ages or stages across the life course resulted from accumulated exposure and/or the social and biological changes [12, 14]. Cross-sectional effects of age describe the changes that characterize populations of the same age but are independent of the process of aging [12, 17, 18]. By cross-sectional effect of age on obesity, we can compare the effect of age on obesity for individuals with different ages. while with the longitudinal effect of age on obesity we understand the age effect on obesity across each individual's life course. To distinguish the longitudinal effect from the cross-sectional effect of age, longitudinal studies in which individuals are measured repeatedly through time are required. The objectives of this study are (i) to assess the cross-sectional and longitudinal effects of age on obesity using a Marginal Logistic Regression (MLR) model and (ii) to determine how obesity changes with age in the target population. This study is a large community-based study in a group of Iranian adults over 35 years of age who live in the central region of Iran. The current study is the first study in Iran that measures the longitudinal and cross-sectional effects of age on obesity. Investigation of changes in obesity in a population-based study provides opportunities to target subpopulations who need more care and attention in public health interventions.

Material and methods

In the current study, we used the information of individuals who participated in the Isfahan Cohort Study (ICS). ICS was a longitudinal population-based study. It was conducted in 2001 using a multi-stage random sampling of adults with Iranian nationality, mentally competent, not pregnant, without a history of CVDs, aged over or equal to 35-years-old, and from urban or rural areas of three provenances in the central part of Iran (Isfahan, Arak, and Najafabad)[19]. Repeated measurements of all related factors were obtained in 2001, 2007, and 2013. All subjects gave written informed consent and ethical permission was issued by the Ethics Committee of Isfahan Cardiovascular Research Center (ICRC)[19]. In our study, we only used the information of the individuals who lived in Isfahan and Najafabad on three measurement occasions. The number of participants was 3181, 1769, and 1735 in 2001, 2007, and 2013, respectively. Changes in phone numbers and addresses were mentioned as the leading cause of loss to follow-up in ICS [20]. The loss to follow-up was at random (MAR) and it was not biased. Details of the study design and ICS challenges were described in previous papers[19, 20].

Variables understudy

Body Mass Index (BMI) was defined as the weight (Kg) divided by height squared (m^2) [21]. Obesity is defined as BMI greater than or equal to 30 kg/m^2 by the World Health Organization (WHO) [21, 22]. Although baseline measurements for all individuals in our study were recorded at the same calendar time (2001), the age of individuals varied at the entry time to the study. Accordingly, obesity variations had two potential sources of information related to age. First, the cross-sectional (or between-subject) information which represents how baseline age affected obesity changes. Second, the longitudinal (or within-subject) information was raised since individuals were measured repeatedly through the study time. The 'baseline age' was defined as the individual age (year) at baseline measurement. The 'age - baseline age' was defined as the years passed since baseline measurement ('age' is the current age at each measurement time and 'age' minus 'baseline age' was considered as 'age - baseline age') [15, 16]. We also considered and controlled other related factors including gender, place of residence (urban or rural region), education level (illiterate, elementary school, middle school or high school, and university degree), job (governmental, nongovernmental, housewife, retired), marriage status (married, single, divorced, widowed), and Smoking status (current, past, or never smoker).

Statistical analysis

The characteristics of the participants at the three measurement occasions are presented as a percentage or mean and standard deviation (SD) when appropriate. Considering the outcome as a binary variable (individual with obesity ($Y_{ij} = 1$) or without obesity ($Y_{ij} = 0$)), Marginal Logistic Regression Model was used (Equation 1). The parameters in the model were estimated using Generalized Estimating Equations (GEE) method.

$$log_e \left\{ \frac{P(Y_{ij})=1}{P(Y_{ij})=0} \right\} = \beta_0 + \beta_1 X_{ij1} + \cdots + \beta_P X_{ijP}. \quad (1)$$

In Equation 1, Y_{ij} denotes the binary response variable for the ith individual on the jth occasion. Also, X_{ij} denotes a $p \times 1$ vector of covariates, associated with the response at each occasion, for each individual.

In our study, the main effects include 'baseline age' (Age_{i1}), 'age - baseline age' ($Age_{ij} - Age_{i1}$), 'baseline age squared' ($Age_{i1}{}^2$), and 'age squared - baseline age squared' ($Age_{ij}{}^2 - Age_{i1}{}^2$) (Equation 2). This model considers separate parameters for the longitudinal and cross-sectional effects of age on the binary response (obese ($Y_{ij} = 1$) or not obese ($Y_{ij} = 0$)) and provides an estimation of both effects of age, simultaneously [16]. We also considered and controlled other related factors including Gender, Place of Residence (Urban or Rural region), Education level (Illiterate, Elementary school, Middle school or High school, and University degree), Job (Governmental, Nongovernmental, Housewife, Retired), Marriage status (Married, Single, Divorced, Widowed), Smoking status (Current, Past, or Never smoker), and Total daily physical activity score.

The final model with only significant factors is presented in Equation 2.

$$log_e \left\{\frac{P(Y_{ij})=1}{P(Y_{ij})=0}\right\} = \beta_0 + \beta_1 Age_{i1} + \beta_2\, Age_{i1}{}^2 + \beta_3 \left(Age_{ij} - Age_{i1}\right) + \beta_4 Gender_i + \beta_5 Place\ of\ Residence + \beta_6\ Education\ level1 + \beta_7\ Education\ level2 + \beta_8\ Education\ level3 \quad (2)$$

In Equation 2, the linear combination of β_1 and β_2 indicates the cross-sectional effect of age. They describe how the log odds ratio (OR) of obesity changes with age at baseline. On the other hand, β_3 indicates the longitudinal effect of age because it represents how within-subject differences in the log OR of obesity are associated with within-subject changes in age [17, 23]. Statistical analysis was performed using R v. 3.6.3. The significance level was considered as 0.05.

Results

The study population was approximately balanced according to sex (51.3% women and 48.7% men). The characteristics of the individuals in this study are represented in Table 1 by gender and measurement time (2001, 2007, and 2013).

Table 1. Characteristics of the Study Participants in 2001, 2007, and 2013 by Gender

		2001			2007			2013		
		Female	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
Number of Participants		1633	1548	3181	904	865	1769	881	854	1735
urban residence(%)		78.9	79.1	79	80.2	81.4	80.8	80.8	87.6	81.8
education† (%)	**level 1**	34.5	20.3	27.6	28.7	16.5	22.8	29.2	14.7	21.9
	level 2	39.2	35	37.2	42	37	39.5	40	35.4	37.7
	level 3	22.7	33.4	27.9	25	33	28.9	25.2	34.4	29.8
	level 4	3.6	11.3	7.3	4.3	13.5	8.8	5.6	15.5	10.5
married(%)		82.6	98.4	90.3	80.9	97.9	89.1	77.9	95	86.3
smoker(%)	**current**	2.5	33.2	17.4	1	26.2	13.3	2.2	25.6	13.7
	past	1.4	11.2	6.2	1	14.2	7.5	0.9	12.6	6.7
	never	96.1	55.6	76.3	97.8	59.2	79.2	96.3	61.4	79.1
age*		50	51	50.5	54.3	56.2	55.2	60	60.6	60.3

	(11.3)	(11.8)	(11.6)	(10)	(11)	(10.5)	(9.7)	(9.7)	(9.7)
BMI*	28.5	25.9	27.2	28.9	26.2	27.6	29.4	26.5	27.9
	(5.1)	(4.1)	(4.8)	(4.6)	(3.8)	(4.4)	(4.8)	(4.3)	(4.8)

*Data are presented as Mean (SD).
†level 1, illiterate; level 2, elementary school; level 3, middle school or high school; level 4, university degree

In this study, most of the participants had less than 12 years of education (92.7% in 2001) and were married (90.3 in 2001). Also, 76.3% were nonsmokers (never smoked) and 79% were living in urban areas in 2001. The average age of participants was 50.5, 55.2, and 60.3 in 2001, 2007, and 2013, respectively. The Baseline age was categorized into seven groups (35–39, 40–44, 45–49, 50-54, 55-59, 60-64, and ≥ 65 years) for descriptive analysis. For each of the Baseline age groups, the frequencies of individuals with obesity at the three measurement occasions are displayed in Table 2. These percentages were reported based on the available data.

Table 2. Frequencies of individuals with obesity in 2001, 2007, and 2013 by Gender for each baseline age categories

baseline age categories	**2001**			**2007**			**2013**		
	Female	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
35-39	32.4 (27,37)*	12.9 (9,16)	23.7 (20,26)	38.9 (32,45)	18.2 (12,23)	29.9 (25,34)	44.4 (38,50)	15.8 (11,20)	31.4 (27,35)
40-44	37.4 (32,42)	15.2 (11,19)	26.2 (23,29)	45.8 (38,52)	17.9 (12,23)	31.7 (27,36)	49 (41,56)	18.1 (13,23)	32.6 (28,37)
45-49	39.4 (33,45)	16.3 (11,21)	29.1 (25,33)	45.1 (37,52)	16.5 (9,23)	33.2 (27,38)	39.6 (32,47)	20.3 (13,27)	31.2 (26,36)
50-54	40.9 (33,48)	20.9 (15,26)	30.3 (25,35)	43.4 (33,53)	18.8 (11,26)	30.7 (24,36)	45.7 (34,56)	21.4 (14,28)	31.3 (25,37)
55-59	42.4 (34,50)	19.5 (13,26)	31.4 (26,36)	38 (26,49)	16 (7,24)	26.7 (20,33)	40 (28,51)	16.9 (8,25)	27.9 (20,35)
60-64	30.3 (22,38)	13.9 (7,20)	22 (17,27)	37.5 (24,50)	11 (4,18)	22.5 (15,29)	43.5 (30,57)	15.1 (5,24)	28.3 (20,37)
≥ 65	28.2 (22,34)	10.2 (6,14)	18.8 (15,22)	20.9 (11,30)	7.1 (2,12)	12.7 (7,17)	22.8 (12,33)	17.5 (7,27)	20.2 (13,27)
Total	35.5 (33,37)	15 (13,16)	25.5 (24,27)	40.5 (37,43)	15.9 (13,18)	28.5 (26,30)	42.8 (39,46)	18 (15,20)	30.4 (28,32)

Data are presented as percentage.
Obesity, BMI≥30 (World Health Organization recommendation)
*Confidence Interval 95%

According to Table 2, 35.5%, 40.5%, and 42.8% of women had obesity in 2001, 2007, and 2013, respectively, which is more than double the percentage of obesity among men (15%, 15.9%, and 18% in 2001, 2007, and 2013, respectively). From 2001 to 2013, the percentage of obesity raised from 15% to 18% in men, from 35.5% to 42.8% in women, and from 25.5% to 30.4% in the total population.
Furthermore, we can identify the cross-sectional effect of age by considering obesity percentage in each of the measurement occasions and comparing it over different baseline age groups as it is shown in Figure 1.

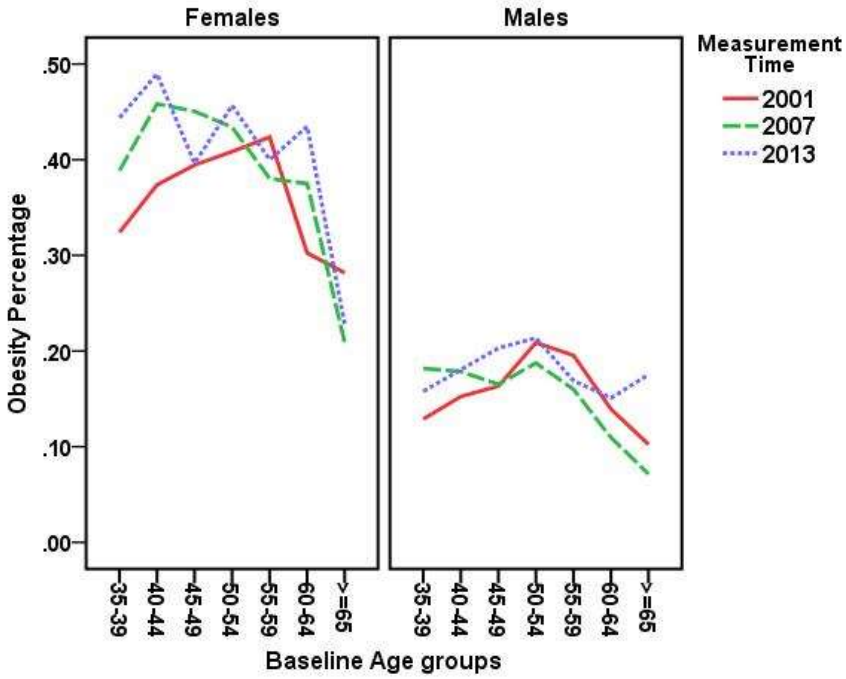

Figure 1. Frequencies of individuals with obesity in three measurement occasions for each baseline age group

In Figure 1, there is approximately an elevated probability for obesity in baseline ages less than 50-54 years for men and less than 55-59 years for women, followed by a modest decrease in probability for those in the older baseline age groups. This shows the curvilinear effect of the baseline age. The women with baseline age 55-59 (women born between 1942-1946) and the men with baseline age 50-54 (men born between 1947-1951) had the highest percentages of obesity.

Furthermore, the highest percentage of obesity among women in 2001 belonged to those with the baseline age 55-59, but in 2007 and 2013 belonged to those with the baseline age 40-44. Among men, those with the baseline age 50-54 had the highest percentage of obesity in all three measurement times.

Besides, to identify the longitudinal effect of age, we can consider each Baseline age group separately and compare the percentages of obesity through time as it is shown in Figure 2.

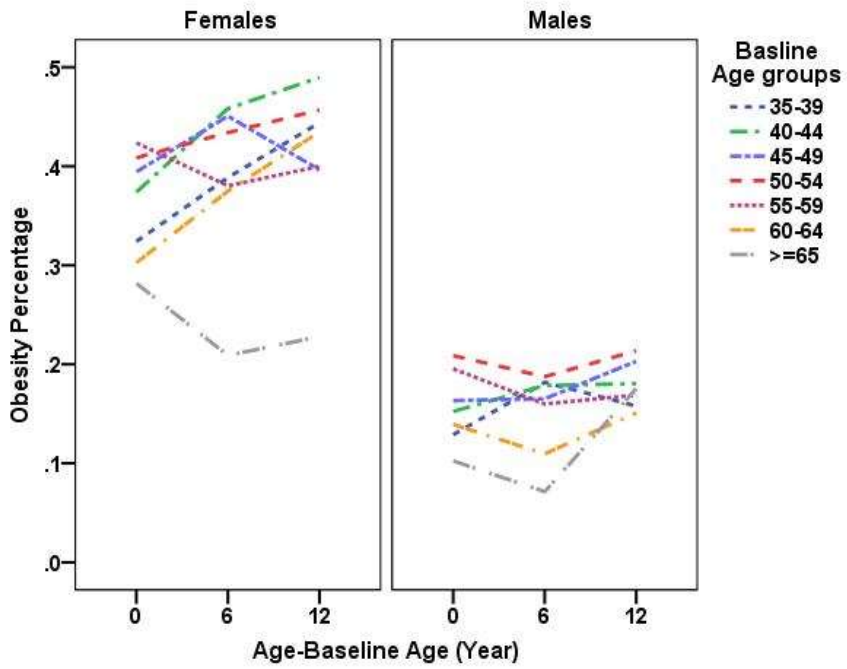

Figure 2. Frequencies of individuals with obesity in each baseline age group through time

During the study time, the probability of obesity changed for the people in each baseline age group. In general, the percentages of obesity in almost all baseline age groups increased or remained near the previous amount after 12 years.

According to Table 2 and Figures 1 and 2, an MLR model including 'baseline age' (p-value < 0.001), 'age - baseline age' (p-value < 0.05), 'baseline age squared' (p-value < 0.001), and 'age squared - baseline age squared' (p-value > 0.05) was fitted (age and baseline age were considered as continues variables). In this model, we also considered and controlled other factors including gender (p-value < 0.001), place of residence (p-value < 0.05), education level (p-value < 0.05), job (p-value > 0.05), marital status (p-value > 0.05), and smoking status (p-value > 0.05). After omitting the non-significant factors, the final model was chosen as presented by Equation 2.

Table 3. Results from MLR Model to assess longitudinal and cross-sectional effects of age on obesity

Parameter		Estimate (β)	Standard Error	P-value	OR	95% CI OR
baseline age		0.13	0.03	<0.001	1.13	(1.06, 1.22)
baseline age squared		-0.0014	0.0003	<0.001	0.998	(0.998, 0.999)
age- baseline age		0.02	0.0041	<0.001	1.02	(1.01, 1.03)
gender (women)		1.14	0.08	<0.001	3.12	(2.63, 3.66)
place of residence (urban region)		0.24	0.10	0.013	1.27	(1.05,1.55)
education†	Level 1	0.50	0.20	0.011	1.64	(1.11,2.43)
	Level 2	0.71	0.18	<0.001	2.03	(1.41,2.91)
	Level 3	0.43	0.19	0.021	1.53	(1.06,2.22)

QIC= 12070.3512; QICu= 12066.9720

†level 1, illiterate; level 2, elementary school; level 3, middle school or high school; level 4, university degree(Reference)

In Table 3, significant coefficients of 'baseline age' and 'Baseline age squared' show that the log OR of obesity changed with 'baseline age' and the changes had a curvilinear shape (P-value < 0.001). According to Table 3, the linear combination of the significant coefficients for 'baseline age' and 'baseline age squared' in the model can be interpreted as the cross-sectional effect of age (controlling for the longitudinal effect of age and other related factors) [13]. The reason for the curvilinear effect of 'Baseline age' on obesity can be understood according to the frequencies in Table 2 and Figure 1. Moreover, the significant coefficients for 'age - baseline age' in the model can be interpreted as the longitudinal effect (controlling for the cross-sectional effect of age and other related factors) [13]. It shows the odds of obesity changed over time within individuals. The odds of obesity had about a 2% increase (on average) with each year of aging, regardless of the baseline age $(\mathrm{EXP}(0.02) = 1.02)$.

According to Table 3, women were more likely $(\mathrm{EXP}(1.14) = 3.12)$ for obesity (almost three times) than men (controlling for other related factors). The residents of urban areas were more likely $(\mathrm{EXP}(0.24) = 1.27)$ for obesity (about 27%) than residents of rural areas (controlling other related factors). Besides, individuals without university education were more likely for obesity than those who had university degrees (64%, 103%, and 53% for individuals with level 1, level 2, and level 3 of education, respectively).

Discussion

Our study was a large community-based study in a group of Iranian adults over 35 years of age who lived in the central region of Iran. In our study, the total frequency of individuals with obesity increased from 25.5% in 2001 to 30.4% in 2013 in Isfahan and Najafabad. According to the National Health Survey in Iran (NHSI), the prevalence of obesity in the total population of Iranian adults over 20 years of age was reported 12% in 2000 and raised to 22% in 2011. Also in NHSI, increases in obesity among Iranian adults were reported in both sexes, all ages, and all places of residence [7]. We can conclude that between 2001 and 2011, the percentage of obesity in our target population in the central region of Iran was higher (about 10%) than the total population of the country. In our study, there was an 8% increase in the frequency of individuals with obesity during 12 years. In NHSI there was a 10% increase during 11 years. These massive increases are comparable to the increase in obesity prevalence in the American adult population (the obesity prevalence raised from 20% in 2000 to 29% in 2016) [22, 24]. The result of our study showed that between 2001 and 2013 the frequency of individuals with obesity increased from 13% to 18% in adult men and from 31% to 44% in adult women. Women not only had a higher percentage of obesity than men in all three phases but also had a higher rise throughout the study period. According to the NHSI data, from 2000 to 2011 the prevalence of obesity has raised from 6.6% to 14.6% and from 17% to 27.9 for Iranian men and women adults, respectively [7]. Moreover, the result of the Tehran Lipid and Glucose Study provided that the prevalence of obesity in the population of the capital city of Iran, Tehran, raised from 15.8% in 2001 to 21.1% in 2008 among men, and from 31.3% to 38.6% among women [5]. That shows the higher prevalence of obesity among people who live in Tehran in comparison with the inhabitants of other parts of Iran. Shifts in diets and eating habits including energy-dense foods high in sugars and fat, higher consumption of red meat, salt, and saturated fatty acids, less physical activity due to the sedentary work styles, types of transportation, and changes in lifestyle, all increase the possibility of obesity [22].

In our study, applying an MLR model, a difference between the cross-sectional and longitudinal effects of age on the probability of obesity in the target population was detected. The results of our study on the association between the probability of obesity and age are comparable to the results of the other studies [10, 11, 25]. In two studies in China and France, both cross-sectional and longitudinal effects of age had a significant effect on BMI and prevalence of obesity [13, 18]; but in two studies in the United States of America (USA), only a longitudinal effect of age had a significant effect on the prevalence of obesity [12, 14]. The longitudinal and cross-sectional effects of age might be different in the presents of period or cohort effects [16]. The cohort effect will cause bias in the cross-sectional estimate but not the longitudinal estimate. The period effect will cause bias in the longitudinal estimate but not the cross-sectional estimate. Alternatively, differences between longitudinal and cross-sectional effects of age may be due to the biasing effects of selective dropouts [16]. In our study, as mentioned previously, there was no selection bias in dropouts [20]; therefore, cohort or period effects are probable and for a more accurate assessment, an Age-Period-Cohort (APC) study is recommended.

The cross-sectional effect of age shows differences among people in their baseline age. In our study, there was approximately an elevated probability for obesity in younger baseline age cohorts, less than 50-54 years for men (men born in around 1947 and later) and less than 55-59 for women (women born in around 1942 and later), followed by a modest decrease in probability for people who were in the older baseline age groups. This showed the curvilinear effect of the baseline age. Also, the highest proportion of obesity was for women with baseline age 55-59 (women born between 1942-1946) and for men with baseline age 50-54 (men born between 1947-1951). This could be because of some common life conditions for the individuals born in a special cohort, which is called a cohort effect. Since individuals in a cohort grow older together, they experience the same historical and social events at the same time points[12, 17, 18]. In other studies, it is reported that Iranian adults gain weight until the age of about 50-60 years old, and after this age, BMI tends to decrease [5, 10, 25, 26]. Similarly, in three studies in the USA and China, the curvilinear effect of age was reported. These studies reported that BMI had a tendency to be higher in individuals with middle-aged in comparison to young adults and also tended to be constant or decrease in older individuals The younger cohorts are more probable to be at higher risk of an obesogenic environment because of a sedentary lifestyle and high-calorie diet [12, 17, 18]. With increasing age, there are alterations in food intake, energy consumption, and appetite besides bone and muscle loss that affect body composition [7]. Also, midlife adults are exposed to an elevated risk of obesity due to hormonal changes, lifestyle, and metabolism [12, 14]. According to body mass studies, after the age of 30, fat mass increases but fat-free mass (FFM) decreases progressively. The maximal FFM and the maximal fat mass are usually reached at the age of 20-30 and 60-70 years, respectively. Afterward, both fat measures reduce during old age [26].

The longitudinal effect of age shows changes over time within individuals. In our study, during 12 years follow up, the probability of obesity increased or remained near the previous amount in almost all baseline age groups. The odds of obesity had about a 2% increase (on average) with each year of aging, regardless of the baseline age. In this study, like most of the other studies, there was an obvious aging effect on the high prevalence of obesity in middle age. In Iran, Azizi et al. (2005) indicated that the prevalence of obesity was most rapidly rising in the 30 to 40-year-old group in both men and women in Tehran, between 1998-1999 to 2001-2002 [5]. Also, in a study by Sarrafzadegan et al. on ICS (Isfahan Cohort Study) data (2001-2007), it was reported that younger individuals gained weight more than older ones [10]. Several factors might be responsible for the reduction in the old baseline age groups. The decrease in appetite and abdominal obesity in the elderly are the most possible reasons [25]. Frequent medical check-up and treatment in older people might be another reason [9, 27]. Moreover,

older people may not be interested in modern lifestyles, such as the changes in dietary preferences [27].

Additionally, in our study, women were more likely for obesity (almost three times) than men. The higher prevalence of obesity among women in comparison with men was reported in several studies in Iran [1, 8, 10, 11, 25, 26, 28, 29]. Among women, lower physical activity level, pregnancy, menopause, a higher rate of depression, lack of employment, lower socioeconomic status, lower educational level, and gender differences in food intake maybe some of the causes for the higher prevalence of obesity in comparison with men [7, 30]. Iranian women may pay less attention to their body shape in comparison to European and Oceanic women. Also, less information and knowledge about weight loss may be another cause [5].
Also, in our study, urban residents were more likely for obesity than rural residents, controlling for other related factors. Similar results were reported in other studies in Iran [1, 6, 8, 25, 26, 29, 31]. Urban residents generally have a higher BMI in comparison with rural residents. In urban areas, people are more likely to eat fast foods and have a sedentary lifestyle. In most countries, urban residents generally consume a higher proportion of fat and protein, a lower proportion of carbohydrates, and have higher availability of calories [8].
Besides, individuals with less than 12 years of education were more likely for obesity in comparison whit individuals who had university degrees. The impact of education level on obesity and BMI was reported in other studies [1, 8, 29, 32]. Generally, higher education is associated with a lower probability of obesity specifically among women [33]. More educated people are more aware of health-related factors. Furthermore, one benefit of education is that individuals with high education levels are more likely to have higher income and to have access to better health care[34].
This study had several strengths, including its large sample size from a longitudinal community-based study of adults living in urban or rural areas in the central region of Iran. Furthermore, in this study, we assessed both longitudinal and cross-sectional effects of age on the probability of obesity. However, despite the unique coverage of our study in comparison with other studies in Iran, the sample represented the population of central parts of Iran, and it limits the generalizability of our findings to the entire country. Also, our study assessed the longitudinal effect of age based on only three measurements. To improve the accuracy of results, using data with more repeated measures for individuals is recommended.

Conclusion

Obesity is a severe public health issue among Iranian adults, specifically in the central region of the country. Available data in our study indicates a high frequency of individuals with obesity and its fast growth among Iranian adults aged 35-60 years, especially in women. To better understand the effect of age on obesity and identify the related factors, both cross-sectional and longitudinal effects of age should be considered. Investigation of changes in obesity in a population-based study provides opportunities to target subpopulations who need more care and attention in public health interventions.

Data Availability

The data that support the findings of this study are available on request from the corresponding author Prof. Anoshirvan Kazemnejad (kazem_an@modares.ac.ir). The data are not publicly available due to privacy.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Funding Statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgments

The authors state their appreciation to the Isfahan Cardiovascular Research Institute personnel. The current paper has been loaded onto the Research Square preprint server and it is available via the link: https://www.researchsquare.com/article/rs-21244/v2.

References:

[1] Emamian MH, Fateh M, Hosseinpoor AR, Alami A, Fotouhi A, "Obesity and its socioeconomic determinants in Iran", *Economics & Human Biology*, vol. 26, no., pp. 144-50, 2017.

[2] Seidell JC, Halberstadt J, "The global burden of obesity and the challenges of prevention", *Annals of Nutrition and Metabolism*, vol. 66, no. Suppl. 2, pp. 7-12, 2015.

[3] Kilpi F, Webber L, Musaigner A et al., "Alarming predictions for obesity and non-communicable diseases in the Middle East", *Public health nutrition*, vol. 17, no. 5, pp. 1078-86, 2014.

[4] Rahmani A, Sayehmiri K, Asadollahi K et al., "Investigation of the prevalence of obesity in Iran: a systematic review and meta-analysis study", *Acta Medica Iranica*, vol., no., pp. 596-607, 2015.

[5] Azizi F, Azadbakht L, Mirmiran P, "Trends in overweight, obesity and central fat accumulation among Tehranian adults between 1998–1999 and 2001–2002: Tehran lipid and glucose study", *Annals of nutrition and metabolism*, vol. 49, no. 1, pp. 3-8, 2005.

[6] Bahrami H, Sadatsafavi M, Pourshams A et al., "Obesity and hypertension in an Iranian cohort study; Iranian women experience higher rates of obesity and hypertension than American women", *BMC public health*, vol. 6, no. 1, pp. 1-9, 2006.

[7] Bakhshi E, Etemad K, Seifi B et al., "Changes in obesity odds ratio among Iranian adults, since 2000: Quadratic inference functions method", *Computational and mathematical methods in medicine*, vol. 2016, no., pp., 2016.

[8] Janghorbani M, Amini M, Willett WC et al., "First nationwide survey of prevalence of overweight, underweight, and abdominal obesity in Iranian adults", *Obesity*, vol. 15, no. 11, pp. 2797-808, 2007.

[9] Khosravi-Boroujeni H, Sarrafzadegan N, Sadeghi M et al., "Secular trend of metabolic syndrome and its components in a cohort of Iranian adults from 2001 to 2013", *Metabolic syndrome and related disorders*, vol. 15, no. 3, pp. 137-44, 2017.

[10] Sarrafzadegan N, Talaei M, Sadeghi M et al., "Determinants of weight change in a longitudinal study of Iranian adults: Isfahan Cohort Study", *Archives of Iranian medicine*, vol. 17, no. 8, pp. 539-44, 2014.

[11] Djalalinia S, Peykari N, Qorbani M, Larijani B, Farzadfar F, "Inequality of obesity and socioeconomic factors in Iran: a systematic review and meta-analyses", *Medical journal of the Islamic Republic of Iran*, vol. 29, no., pp. 241, 2015.

[12] An R, Xiang X, "Age–period–cohort analyses of obesity prevalence in US adults", *Public Health*, vol. 141, no., pp. 163-9, 2016.

[13] Jaacks LM, Gordon-Larsen P, Mayer-Davis EJ, Adair LS, Popkin B, "Age, period and cohort effects on adult body mass index and overweight from 1991 to 2009 in China: the China Health and Nutrition Survey", *International journal of epidemiology*, vol. 42, no. 3, pp. 828-37, 2013.

[14] Keyes KM, Utz RL, Robinson W, Li G, "What is a cohort effect? Comparison of three statistical methods for modeling cohort effects in obesity prevalence in the United States, 1971–2006", *Social science & medicine*, vol. 70, no. 7, pp. 1100-8, 2010.

[15] Mujahid MS, Diez Roux AV, Borrell LN, Nieto FJ, "Cross-sectional and longitudinal associations of BMI with socioeconomic characteristics", *Obesity research*, vol. 13, no. 8, pp. 1412-21, 2005.

[16] Fitzmaurice GM, Laird NM, Ware JH. Applied longitudinal analysis: John Wiley & Sons; 2012.
[17] Diggle P, Diggle PJ, Heagerty P et al. Analysis of longitudinal data: Oxford University Press; 2002.
[18] Diouf I, Charles MA, Ducimetière P et al., "Evolution of obesity prevalence in France: an age-period-cohort analysis", *Epidemiology (Cambridge, Mass)*, vol. 21, no. 3, pp. 360, 2010.
[19] Sarrafzadegan N, Talaei M, Sadeghi M et al., "The Isfahan cohort study: rationale, methods and main findings", *Journal of human hypertension*, vol. 25, no. 9, pp. 545, 2011.
[20] Sarrafzadegan N, Hassannejad R, Roohafza H et al., "A 10-year Isfahan cohort on cardiovascular disease as a master plan for a multi-generation non-communicable disease longitudinal study: methodology and challenges", *Journal of human hypertension*, vol. 33, no. 11, pp. 807-16, 2019.
[21] Sadeghi M, Talaei M, Gharipour M et al., "Anthropometric indices predicting incident hypertension in an Iranian population: The Isfahan cohort study", *Anatolian journal of cardiology*, vol. 22, no. 1, pp. 33, 2019.
[22] World Health Organization.Noncommunicable diseases country profiles 2018. https://www.who.int/nmh/publications/ncd-profiles-2018/en/ (Accessed 12 March 2020). [
[23] Fitzmaurice G, Davidian M, Verbeke G, Molenberghs G. Longitudinal data analysis: CRC Press; 2008.
[24] Blüher M, "Obesity: global epidemiology and pathogenesis", *Nature Reviews Endocrinology*, vol. 15, no. 5, pp. 288, 2019.
[25] Asgari F, Biglarian A, Seifi B et al., "Using quadratic inference functions to determine the factors associated with obesity: findings from the STEPS Survey in Iran", *Annals of epidemiology*, vol. 23, no. 9, pp. 534-8, 2013.
[26] Bakhshi E, Seifi B, Biglarian A, Mohammad K, "Factors associated with obesity in Iranian elderly people: results from the national health survey", *BMC research notes*, vol. 4, no. 1, pp. 538, 2011.
[27] Hickson M, "Malnutrition and ageing", *Postgraduate medical journal*, vol. 82, no. 963, pp. 2-8, 2006.
[28] Blüher M, "Obesity: global epidemiology and pathogenesis", *Nature Reviews Endocrinology*, vol. 15, no. 5, pp. 288-98, 2019.
[29] Rashidy-Pour A, Malek M, Eskandarian R, Ghorbani R, "Obesity in the Iranian population", *Obesity reviews*, vol. 10, no. 1, pp. 2-6, 2009.
[30] Azizi F, Allahverdian S, Mirmiran P, Rahmani M, Mohammadi F, "Dietary factors and body mass index in a group of Iranian adolescents: Tehran lipid and glucose study-2", *International journal for vitamin and nutrition research*, vol. 71, no. 2, pp. 123-7, 2001.
[31] Kelishadi R, Alikhani S, Delavari A et al., "Obesity and associated lifestyle behaviours in Iran: findings from the first national non-communicable disease risk factor surveillance survey", *Public health nutrition*, vol. 11, no. 3, pp. 246-51, 2008.
[32] Hajian-Tilaki K, Heidari B, "Association of educational level with risk of obesity and abdominal obesity in Iranian adults", *Journal of Public Health*, vol. 32, no. 2, pp. 202-9, 2010.
[33] Sassi F, Devaux M, Church J, Cecchini M, Borgonovi F, "Education and obesity in four OECD countries", vol., no., pp., 2009.
[34] Kim Y-J, "The long-run effect of education on obesity in the US", *Economics & Human Biology*, vol. 21, no., pp. 100-9, 2016.

Figures

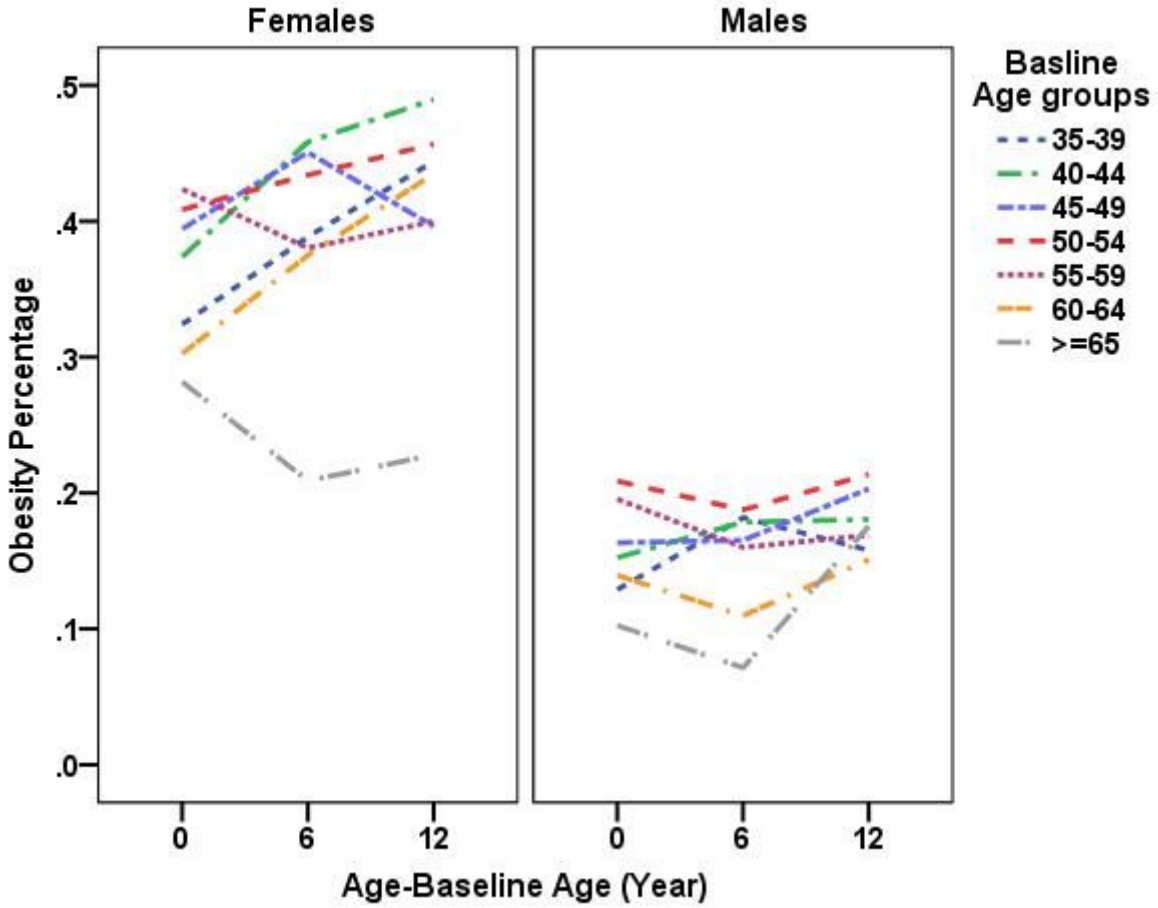

Figure 1

Frequencies of individuals with obesity in three measurement occasions for each baseline age group

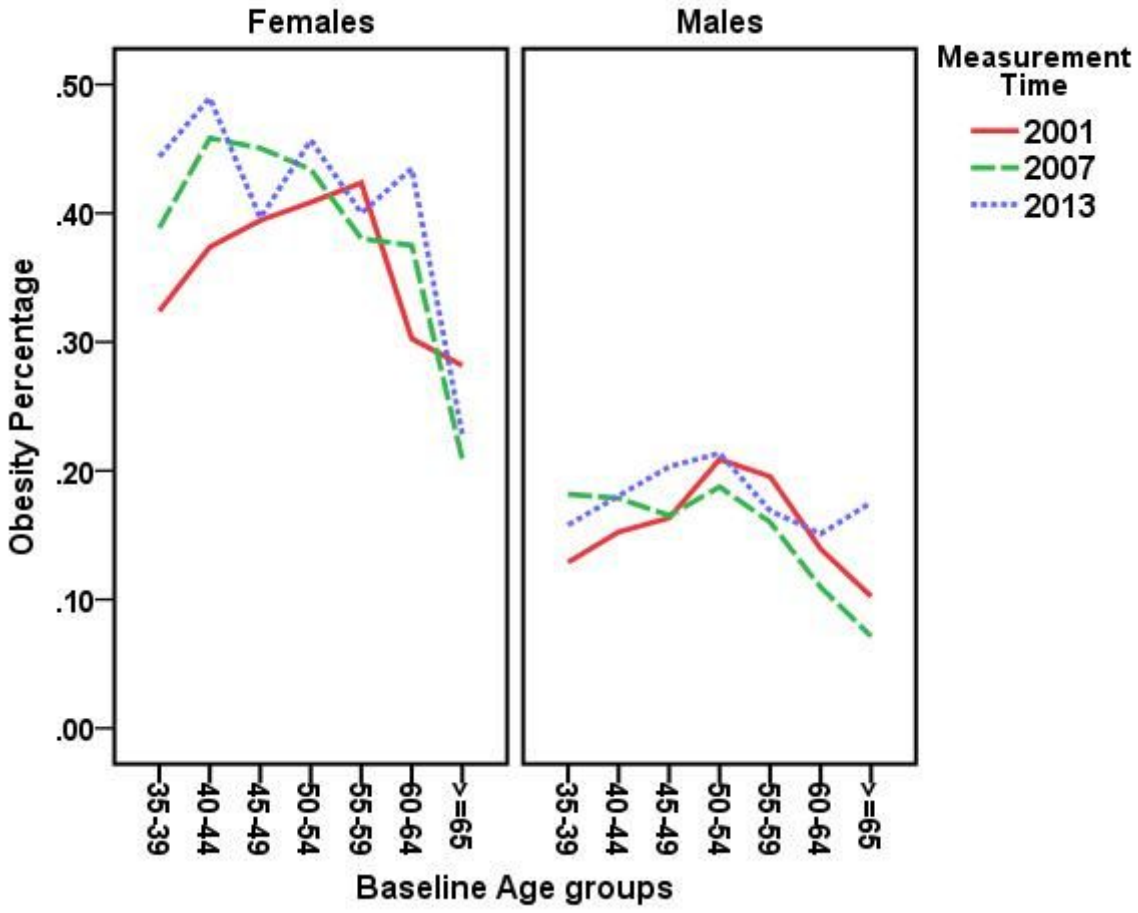

Figure 2

Frequencies of individuals with obesity in each baseline age group through time