

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

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## Research article

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

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30 **Abstract**

31 **Background**

32 Obesity is a significant risk factor for Noncommunicable diseases, and it is related to many  
33 adverse health consequences. The risk of obesity commonly changes with age, which is called  
34 a longitudinal or aging effect. Also, individuals born or enter to the study of the same age have  
35 similar living conditions that may influence their obesity risk in a particular way; this is a cross-  
36 sectional effect. In the current study, an advanced statistical model is used to distinguish  
37 between longitudinal and cross-sectional effects of age on the risk of obesity for men and  
38 women.

39 **Methods**

40 Participants are a group of 6504 Iranian adults over 35 years of age in 2001, who live in the  
41 central region of Iran. They were followed up for 12 years in a large community-based study.  
42 Various medical indexes, including Body Mass Index, were collected in 2001, 2007, and 2013.  
43 The Marginal Logistic Regression model, which includes linear and quadratic effects of the  
44 Baseline Age and its difference with current age, is used.

45 **Results**

46 Between 2001 and 2013, the prevalence of obesity raised from 13% to 18% in men and from  
47 31% to 44% in women. The odds of obesity for women was approximately three times the odds  
48 of obesity for men on average adjusting for the age effects. Both cross-sectional and  
49 longitudinal effects of age were significantly associated with the odds ratio of obesity. There  
50 was a rise in the prevalence of obesity for individuals with Baseline Age 35 to 55 and a decline  
51 thereafter. Also, the odds ratio of obesity across one's life course, had about 3% increase, on  
52 average, by each year aging, regardless of the age at baseline.

53 **Conclusions**

54 The high rate of obesity and its fast growth is a serious public health issue among Iranians,  
55 especially in adults age 35-55, and women. In the present study, Baseline Age was more  
56 strongly associated with the risk of obesity than aging. Considering both cross-sectional and  
57 longitudinal effects of age, helps us to understand the effect of age on obesity better and to  
58 identify the related factors.

59

60 **Key Words:**

61 Obesity, Adult, Age, Longitudinal, Cross-sectional, Prevalence

62

63 **Background**

64 Noncommunicable Diseases (NCDs) account for more than 70% of early deaths all over the  
65 world(1, 2). Obesity, as a significant risk factor for NCDs, has an association with life  
66 expectancy reduction (3), and it raises the risk of metabolic diseases to a considerable  
67 extend(1). Also, obesity is associated with several adverse health consequences, and it is tied  
68 to an increased risk of conditions. Furthermore, obesity leads to a reduction in the quality of  
69 life, lack of employment, lower productivity, and inadequate social points. The World Obesity  
70 Federation and other organizations have defined obesity not only as a risk factor for several  
71 diseases but also as a chronic progressive disease (3). Obesity is defined as excessive fat  
72 accumulation that might have a negative effect on health by the World Health Organization  
73 (WHO) and is identified as Body Mass Index (BMI) over or equal to 30 kg/m<sup>2</sup> (4, 5).

74 Obesity has an association with age, gender, household income, urbanization, and lifestyle (6).

75 It is a chronic and complex disease determined by lifestyle behaviors associated with positive  
76 energy balance, such as an inappropriate diet and a sedentary lifestyle(7, 8).

77 The prevalence of obesity has risen all over the world to pandemic proportions during the last  
78 50 years (9, 10). Obesity and BMI prevalence vary across different countries according to the  
79 steepness of increases, slowing-down, and acceleration periods (11). The global prevalence of  
80 obesity almost tripled since 1975 and continues to grow in low- and middle- income countries,  
81 although it can be considered as a problem for high-income countries(10, 12, 13). A systematic  
82 review by Rahmani et al. (2015), reported the prevalence of obesity in Iran has increased  
83 between 1995 and 2010 (14). Also, Azizi et al. (2005) indicated that the prevalence of obesity  
84 was most rapidly rising in the 30 to 40-year-old group in both men and women in Tehran(15).  
85 Furthermore, in a study by Sarrafzadegan et al. on ICS (Isfahan Cohort Study) data (2001-  
86 2007), it was reported that younger individuals gained weight more than older ones(16). In a  
87 systematic review in Iran, increased age, urbanization, low educational levels, the female  
88 gender, and being married, were indicated as some variables that are associated with inequality  
89 in obesity (17).

90 Due to biological and sociocultural differences, obesity distribution patterns differ by gender  
91 and age (18). The risks of many chronic diseases commonly increase with age, which is called  
92 aging or longitudinal effect. Also, people born or enter the study of the same age have similar  
93 living conditions that may affect their disease risk in a particular way; this is a cohort or cross-  
94 sectional effect (19). Therefore, decomposition of cohort and aging effects could provide some  
95 valuable information. The changes in the risk of obesity were assessed using longitudinal and  
96 cross-sectional effects of age, in some studies (20-22). In many research, separation of these  
97 two effects of age on obesity is of interest. Estimates of the effect of age from cross-sectional  
98 analyses may confound Cohort effects on obesity. Longitudinal assessment is needed to  
99 determine the aging effect. In contrast with cross-sectional studies, a longitudinal study is  
100 defined as a study in which individuals are measured repeatedly through time. Longitudinal

101 studies help us to distinguish changes over time within individuals (longitudinal effect) from  
102 differences among people in their baseline levels (cross-sectional effect) (23, 24).

103 A limited number of longitudinal analyses of the prevalence of obesity in population-based  
104 samples were done to separate aging and cohort effects and allow simultaneous assessment of  
105 aging-related changes and secular trends. In the current study, a longitudinal approach is used  
106 to distinguish between cross-sectional and longitudinal effects of age. This study is a large  
107 community-based study in a group of 6504 Iranian adults over 35 years of age who live in the  
108 central region of Iran. Based on BMI, repeated measurements of obesity were obtained in 2001,  
109 2007, and 2013. A Marginal Logistic Regression (MLR) model was used: 1-To determine  
110 whether the prevalence of obesity changes with age in the target population and whether the  
111 patterns of change in obesity are the same for women and men. 2-To assess the cross-sectional  
112 and longitudinal effects of age. The current study is the first study in Iran that measures the  
113 longitudinal and cross-sectional effects of age on obesity, using an advanced statistical  
114 modeling approach for longitudinal measurements, the MLR model. This study is benefiting  
115 from a population-based cohort study with 12 years of follow-up and is performed among the  
116 Iranian adult population. Investigation of prevalence and trend of obesity in a population-based  
117 study provides opportunities to target subpopulations who need more care and attention in  
118 public health interventions.

119

## 120 **Methods**

### 121 Study population

122 Isfahan Cohort Study is a longitudinal ongoing population-based study, including 6504 adults  
123 aged over or equal to 35-year-old at the first measurement occasion, from three provenances in  
124 the central area of Iran (Isfahan, Arak, and Najafabad), living in urban or rural areas. The  
125 participants had been involved in the first survey of the Isfahan Healthy Heart Program (IHHP),

126 a community trial for prevention and control of Cardiovascular Diseases (CVDs) (25, 26).  
127 These three cities were selected due to their population consistency and a smaller number of  
128 migrants in comparison with the capital and other cities in Iran. Also, Isfahan is the third-largest  
129 city in Iran. The multistage random cluster sampling method was used for sampling these  
130 provinces, which represent their society's distribution of age, genders, and residential area  
131 (urban/rural). Ethical permission was issued by the Ethics Committee of Isfahan  
132 Cardiovascular Research Center. Questionnaires and anthropometric information were  
133 collected after obtaining informed written consent in 2001, 2007, and 2013 (25). The number  
134 of individuals in the first measurement occasion was 6504, and then during the follow-up, the  
135 number decreased to 3284 and 1735 at the second and third phases, respectively. Details of the  
136 study design and ICS challenges, which led to a decrease in sample size, were described in  
137 previous papers (25-27).

#### 138 Variables under study

139 Measurement of height was conducted using a secured metal ruler in barefoot and, weight was  
140 measured in light clothing using a calibrated scale (26). BMI was defined as the weight (Kg)  
141 divided by height squared ( $m^2$ ) (5). A BMI over or equal to 30 indicates obesity, according to  
142 the World Health Organization definition (12). Also, waist circumference (WC) (cm) was  
143 measured horizontally. It is defined as the smallest circumference below the lowest ribs (26).  
144 In our study, although baseline measurements for all individuals were recorded at the same  
145 calendar time, age of individuals varied at the entry to the survey. Accordingly, the variations  
146 in the prevalence of obesity with age have two potential sources of information. First, the cross-  
147 sectional (or between-subject) information is about how obesity changes with age in the  
148 baseline observations obtained in 2001. Second, since individuals were measured repeatedly  
149 through the study time, the longitudinal (or within-subject) information raised. "Baseline Age"  
150 was defined as the individual age (year) at baseline and is used to assess the cross-sectional

151 effect of age. “Age - Baseline Age” was defined as the years passed since baseline and is used  
152 to assess the longitudinal effect of age.

153 Statistical analysis

154 The characteristics of the participants at the three measurement occasions (2001, 2007, and  
155 2013) are presented as a percentage or mean and standard deviation (SD) when appropriate.

156 Considering the outcome as a binary variable (obese or not obese), Marginal Logistic  
157 Regression Model was used (equation (1)). The parameters in the model were estimated using  
158 Generalized Estimating Equations (GEE) method.

159

$$160 \log_e \left\{ \frac{P(Y_{ij}=1)}{P(Y_{ij}=0)} \right\} = \beta_0 + \beta_1 X_{ij1} + \dots + \beta_p X_{ijp}. \quad (1)$$

161

162 In equation (1),  $Y_{ij}$  denotes the binary response variable for the  $i^{th}$  individual on the  $j^{th}$   
163 occasion. Also,  $X_{ij}$  denotes a  $p \times 1$  vector of covariates, associated with the response at each  
164 occasion, for each individual. In our study, the main effects include Baseline Age, Age -  
165 Baseline Age, and Gender. This model considers separate parameters for the longitudinal and  
166 cross-sectional effects of age on the binary response and provides an estimation of both effects  
167 of age, simultaneously (28). The hypothesis of the equality of the longitudinal and cross-  
168 sectional effect of age was examined, using the multivariate Wald test for contrasts. SPSS 19  
169 and SAS 9.4, PROC GENMOD were used for the analysis, and the significance level was  
170 considered as 0.05.

171

172 **Results**



173 The study population was approximately balanced according to sex (51.3 percent women and  
174 48.7 percent men). The characteristics of the individuals who participated in this study are  
175 represented in table 1 by gender and measurement time (2001, 2007 and 2013).

#### 176 Table 1

177 In this study, most of the participants had less than 12 years of education (93.9% in 2001, 91.7  
178 in 2007, and 88.7 in 2013) and were married (90.6 in 2001, 89.1 in 2007, and 86.3 in 2013).

179 The average age of participants was 50.2 in 2001, 56.1 in 2007, and 60.3 in 2013.

180 For both men and women, the average BMI and WC were increased over 12 years (2001 –  
181 2013). Also, women had an average BMI and WC more than men in all three phases. The

182 prevalence of general obesity was calculated in men and women in 2001, 2007, and 2013.

183 According to table 1, the percentages of women classified as obese were 31 in 2001, 39 in  
184 2007, and 44 in 2013, which is more than double the percentages of obese men (13 in 2001, 15

185 in 2007, and 18 in 2013). In other words, between 2001 and 2013, the prevalence of obesity  
186 raised from 13% to 18% in men and from 31% to 44% in women. In the total population, the

187 prevalence of obesity raised from 22% in 2001 to 31% in 2013.

188 The percentages of individuals indicated as obese at each of the three measurement occasions  
189 for the Baseline Age groups of 35–44, 45–54, 55–64, and  $\geq 65$  years in men and women and

190 longitudinal changes in the prevalence of obesity over the follow-up period, are displayed in  
191 table 2. These percentages were reported based on the available data at each occasion in each

192 age-gender group.

#### 193 Table 2

194 In table 2, the rates of obesity for women are higher in all ages and on all three occasions. Also,  
195 we can identify the cross-sectional effect of age, by considering obesity prevalence in each year

196 of measurement and compare it over different Baseline Age groups.

197 The associations between Baseline Age and prevalence of obesity in each occasion by gender  
 198 are shown in Figure 1 in an additional file [see Additional file 1]. Growth in the prevalence of  
 199 obesity from 35 to 55 Baseline Age groups can be identified, followed by a decrease for higher  
 200 Baseline Age in all three phases and both genders, except for females in 2013, which had a  
 201 peak in obesity prevalence in 55-65 Baseline Age groups. In other words, there is  
 202 approximately an elevated probability for obesity for people in 35-55 Baseline Age groups,  
 203 followed by a modest decrease in probability for people who were in the older age group ( $\geq 55$ ).  
 204 Also, to identify the longitudinal effect of age, we can consider each Baseline Age group  
 205 separately and compare the prevalence of obesity in different measurement times. The  
 206 associations between aging and the probability of obesity by Baseline Age groups are shown in  
 207 Figure 2 in an additional file [see Additional file 2]. It shows obesity prevalence for the same  
 208 people over time. Obesity prevalence for each group raised with time through the study except  
 209 for Baseline Age  $\geq 65$  in both men and women that means obesity prevalence increased with  
 210 aging for individuals in Baseline Age groups 35-65. For women in higher than 65 Baseline Age  
 211 groups, there is a moderate decrease after six years, and then the probability of obesity tending  
 212 to be almost constant by aging. Also, for men in Baseline Age groups  $\geq 65$ , there was a decrease  
 213 after six years and then a moderate increase after twelve years.

214 According to the rates of obesity in table 2 and Figure 1 which show the curvilinear effect of  
 215 age on the rate of obesity and higher rates of obesity for women of all ages, an MLR model  
 216 including gender, linear and quadratic age, and the gender by age interactions was fitted  
 217 (equation (2)). Individuals were classified as obese ( $Y_{ij} = 1$ ) or not obese ( $Y_{ij} = 0$ ).

218

$$\begin{aligned}
 219 \quad \log_e \left\{ \frac{P(Y_{ij} = 1)}{P(Y_{ij} = 0)} \right\} &= \beta_0 + \beta_1 \text{Gender}_i + \beta_2 \text{Age}_{ij} + \beta_3 \text{Age}_{ij}^2 + \beta_4 \text{Gender}_i \times \text{Age}_{ij} \\
 220 \quad &+ \beta_5 \text{Gender}_i \times \text{Age}_{ij}^2. \qquad (2)
 \end{aligned}$$

221

222 In this model, the gender by age interactions was not significant (P-value=0.45 and 0.35 for  
223 gender by age and gender by age squared respectively and the multivariate Wald test,  $H_0: \beta_4 =$   
224  $\beta_5 = 0$  Chi-Square=2.75, DF=2, P-value=0.25), so the interaction terms were omitted from  
225 the model. It shows there is no significant difference in changes (trend) of log OR of obesity  
226 between men and women. The results are presented in an additional file [see Additional file 3  
227 Table 1]. Also, the significant coefficients of age and age squared showed that the log OR of  
228 obesity changes with age curvilinearly (P-value<0.0001). Next, to assess the longitudinal and  
229 cross-sectional effects of age on log OR of obesity, another MLR model including linear and  
230 quadratic effects of the Baseline Age and Age - Baseline Age ( $Age_{i1}$  and  $Age_{ij} - Age_{i1}$ ,  
231 respectively), was fitted. According to descriptive statistics and the coefficient in the model,  
232 the quadratic effect of Age - Baseline Age had a little and negligible effect on the prevalence of  
233 obesity ( $\beta = -0.0006$  and  $EXP(\beta)=0.999$ ). Therefore, to simplify the model, we preferred to  
234 omit this effect also, and the model in equation (3) was considered.

235

$$236 \log_e \left\{ \frac{P(Y_{ij}=1)}{P(Y_{ij}=0)} \right\} = \beta_0 + \beta_1 Gender_i + \beta_2 Age_{i1} + \beta_3 Age_{i1}^2 + \beta_4 (Age_{ij} - Age_{i1}). \quad (3)$$

237

238 In equation (3), the linear combination of  $\beta_2$  and  $\beta_3$  indicates the cross-sectional effect of age.  
239 They describe how the log odds ratio (OR) of obesity changes with age at baseline. On the  
240 other hand,  $\beta_4$  indicates the longitudinal effect of age because it represents how within-subject  
241 differences in the log OR of obesity are associated with within-subject changes in age (23, 29).  
242 Then, using the multivariate Wald test for contrasts, the hypothesis of equality of cross-  
243 sectional and longitudinal effects was examined. The hypothesis is equivalent to equality of  
244 the coefficients of (Baseline Age) with (Age- Baseline Age) or  $H_0: \beta_2 = \beta_4$  in equation (3).

245 The Wald test was significant (Chi-Square=12.63, DF=1, P-value<0.0004), which means the  
246 longitudinal effect is not equal to the cross-sectional effect of age and it shows the effect of  
247 aging on the odds of obesity.

248 Table 3

249 In table 3, Alpha1, Alpha2, and Alpha3 are pairwise log OR among measurement occasions.  
250 The pairwise log OR between adjoining occasions are almost 2.9 and 3.5, which indicate that  
251 the OR for the within-subject association is about 18 and 33, respectively (or  $e^{2.9}$  and  $e^{3.5}$ ).  
252 Therefore, there is a severe positive association among the indicators of obesity status at all  
253 measurement occasions.

254 The significance coefficient of sex shows that log OR of obesity is different between women  
255 and men. By controlling the age effects (longitudinal and cross-sectional effects), odds of being  
256 obese for women is approximately  $\exp(1.15) = 3.17$  times the odds of being obese for men  
257 on average (Gender=1 was considered for men in the dataset and reference group in the model).  
258 Hence, women are more likely to be obese (almost three times) than men.

259 For cross-sectional and longitudinal effects of age, the results of the model are compatible with  
260 the results of descriptive statistics. According to table 3, the linear combination of the  
261 significant coefficients for Baseline Age and Baseline Age squared in the model can be  
262 interpreted as the overall Baseline Age group (or cross-sectional) effect controlling for the  
263 longitudinal effect of age and sex (20). The log OR of obesity alters curvilinearly with Baseline  
264 Age. According to the rates of obesity in table 2, we understand there is an increase in the  
265 prevalence of obesity for individuals with Baseline Ages from 35 to 54 and a decline thereafter.  
266 Moreover, the significant coefficients for (Age - Baseline Age) in the model can be interpreted  
267 as the longitudinal effect controlling for the cross-sectional effect of age and gender (20). The  
268 odds of obesity changes over time within individuals. In other words, the odds of obesity across  
269 one's life course, on average, has about 3% increase by each year aging, regardless of the

270 Baseline Age group which the individuals are come from ( $\text{EXP}(0.0295)= 1.029$ ). According to  
271 table 2, we can conclude that obesity prevalence for each Baseline Age group raised with time  
272 during the study for both men and women except for Baseline Age group  $\geq 65$ . In other words,  
273 obesity prevalence increased with aging for individuals in Baseline Age group 35-65.  
274 Also, according to the estimated coefficients and ORs in Table 3, in this study, the cross-  
275 sectional effect of age was more considerable than the longitudinal effect of it. In other words,  
276 the Baseline Age was more strongly associated with odds of obesity than aging (linear  
277 combination of 0.1266 and -0.0013 for cross-sectional effect vs. 0.0295 for longitudinal effect).

## 278 **Discussion**

279 The goals in this study were first, to determine whether the probability of obesity changed with  
280 age and whether patterns of change in obesity were the same for women and men, and second,  
281 to assess the cross-sectional and longitudinal effects of age. Our study was a large community-  
282 based study in a group of 6504 Iranian adults over 35 years of age who live in the central region  
283 of Iran. In our study, the prevalence of obesity (in total) increased from 22% in 2001 to 31%  
284 in 2013, while according to the WHO report, between 2000 and 2016, in all WHO regions and  
285 income groups, the global prevalence of obesity raised from 9% in 2000 to 13% in 2016 (12).  
286 It shows that the prevalence of obesity in Iran was higher than the global prevalence of obesity  
287 (almost double) in the same period. Also, the amount of increase in the prevalence of obesity  
288 in Iran was more than global prevalence (in Iran, an 8% increase in 12 years; global average,  
289 4% in 16 years). This massive increase is almost as large as the increase in the American  
290 population, which increased from 20% in 2000 to 29% in 2016 (12). Also, the result of our  
291 study showed that, between 2001 and 2013, the prevalence of obesity increased from 13% to  
292 18% (5 percentage points increase) in adult men and from 31% to 44% (13 percentage points  
293 increase) in adult women, while between 1975 and 2014, the global prevalence of obesity  
294 raised from 3.2% to 10.8% in men and from 6.4% to 14.9% in women (1). Shifts in diets and

295 eating behavior which include energy-dense foods, high in sugars and fat, higher consumption  
296 of red meat, salt, and saturated fatty acids among individuals because of the increasing  
297 economic status, and less physical activity due to the sedentary work styles, types of  
298 transportation and changes in lifestyle are combining to increase the possibility of becoming  
299 obese (4). This rate of increase is also reported by other studies (1, 6, 15, 16, 30). In both  
300 developed and developing countries and specifically in middle-east countries, the prevalence  
301 of obesity is rising at alarming rates (1, 4, 13).

302 Additionally, in our study, using the GEE model and descriptive analysis, the odds of being  
303 obese for women is more than for men. It is approximately  $\exp(1.15) = 3.158$  times of odds  
304 of being obese for men on average and by controlling the age effects (aging and cross-sectional  
305 effects). In other words, we can conclude that women are more likely to be obese (almost three  
306 times) than men. In another national study in Iran (the National Health Survey), the adjusted  
307 odds of obesity for women among Iranian adults aged 20-59 years were 2.4, 2.35, and 1.58  
308 times of odds of being obese for men in 2000, 2007, and 2011, respectively (31).

309 In our study, for both groups of men and women, the average BMI and WC were raised over  
310 12 years (2001 – 2013), but women had a higher average BMI and WC than men in all three  
311 phases. Among women, lower physical activity level, pregnancy, menopause, a higher rate of  
312 depression, lack of employment, lower socioeconomic status, lower educational level, and  
313 gender differences in food intake may be some of the causes for the higher prevalence of  
314 obesity in comparison with men (30, 32-34). Iranian women pay less attention to their body  
315 shape in comparison to European and Oceanic women and also, less information and  
316 knowledge about weight loss may be another cause (15)

317 Considerable regional differences in BMI alters through time were reported in different studies.  
318 In Southern Asia (Bangladesh, Bhutan, India, Nepal, and Pakistan), in southeast Asia (  
319 Malaysia, Indonesia, Philippines, Sri Lanka, Vietnam, and Thailand), in the Caribbean (Cuba,

320 Belize, Jamaica, Puerto Rico, and the Dominican Republic), and in southern Latin America ( 321 Brazil, Argentina, Paraguay, Uruguay, and Chile), an accelerated rise in BMI was reported (1). 322 In our study, applying an MLR model, it was shown that there is a difference between the cross- 323 sectional effect and longitudinal effect of age on obesity prevalence in the target population, 324 controlling for the gender effect. In this study, the cross-sectional effect of age was more 325 considerable than the longitudinal effect of it. In other words, the Baseline Age was more 326 severely associated with the odds of obesity than aging. The cross-sectional effect of age shows 327 differences among people in their Baseline Age. There was a growth in the prevalence of 328 obesity for individuals with Baseline Ages from 35 to 55 and a decline thereafter. In other 329 studies, it is reported that Iranian adults gain weight until the age of about 50-60 years old, and 330 after this age, BMI tends to decrease. The results of our study on the association between the 331 probability of obesity and age are close to some of the other studies(16, 17, 35-38). Previous 332 studies reported that BMI had a tendency to be higher in individuals with middle-aged in 333 comparison with young adults and also tended to be constant or decrease in older individuals. 334 Also, in a study in the United States of America (USA), NHANES-III, BMI had tendency to 335 go up for ages 20 to 29 years till ages 50 to 59 years, and after the age of 59, BMI tended to 336 decline (38). In another study in the USA, an independent cross-sectional effect of age on 337 obesity was reported and also, a higher probability for obesity in younger Baseline Age groups 338 in comparison to older individuals after controlling the aging effects were observed (21). With 339 increasing age, there are alterations in food intake, energy consumption, and appetite besides 340 bone and muscle loss that affect body composition (30).

341 Also, the longitudinal effect of age shows changes over time within individuals or changes 342 across one's life course, regardless of the Baseline Age group for individuals. In our study, 343 obesity prevalence for each group increased with time within the study for both men and 344 women except for Baseline Age group  $\geq 65$  in women. It can be concluded that obesity

345 prevalence increasing with aging for individuals in Baseline Age groups 35-65. For women in  
346 more than 65 Baseline Age groups, there is a moderate decrease after six years, and then the  
347 probability of obesity tending to be almost constant after twelve years. Also, for men in  
348 Baseline Age group  $\geq 65$ , there was a decrease after six years and then a moderate increase after  
349 twelve years. Odds of obesity across one's life course, on average, have about a 3% increase  
350 by each year aging, regardless of the membership in each of Baseline Age groups. Most studies  
351 confirmed a severe aging effect on the high prevalence of obesity in middle age. For example,  
352 in a study in the USA, a shape similar to an inverted U for age effect on obesity and a lifted  
353 probability for obesity as an individual transition from young adulthood to midlife and a  
354 moderate decrease probability as one approaches the end of life was reported (21). Several  
355 factors might be responsible for the reduction in the old Baseline Age group; the most possible  
356 is the decrease in appetite and abdominal obesity in the elderly. Frequent medical check-up and  
357 treatment in older people may be another cause for this result. Moreover, older people may not  
358 be interested in modern lifestyles, such as the changes in dietary preferences(39, 40).

359 This study had several strengths, including its large sample size from a longitudinal ongoing  
360 community-based study of adults living in urban or rural areas from three providences in the  
361 central region of Iran (Isfahan Healthy Heart Program). Furthermore, in this study, we assessed  
362 both longitudinal effect (aging effect) and cross-sectional (Baseline Age effect) of age on  
363 obesity prevalence. However, despite the unique coverage of our study in comparison with  
364 other studies in Iran, the sample represented the population of central parts of Iran, and it limits  
365 the generalizability of our findings to the entire country. Also, our study assessed the  
366 longitudinal effect based on only three measurements; using data with more repeated measures  
367 for individuals, the accuracy of results will improve. Also, in our study, the goal was only to  
368 assess the relationship between obesity prevalence with the cross-sectional and longitudinal  
369 effect of age in men and women, but other confounders were not considered.



370

371 **Conclusions**

372 Obesity is a severe public health issue among Iranian adults. Available data in our study  
373 indicates a high rate of obesity and its fast growth, especially in adults age 35-55 and women.  
374 Also, Baseline Age was more strongly associated with the risk of obesity than aging.  
375 Considering both cross-sectional and longitudinal effects of age, helps us to understand the  
376 effect of age on obesity better and to identify the related factors. It is necessary to determine  
377 the factors contributing to the growth in the prevalence of obesity.

378

379 **List of Abbreviations**

380 Noncommunicable Diseases (NCDs), World Health Organization (WHO), Body Mass Index  
381 (BMI), Isfahan Healthy Heart Program (IHHP), The Isfahan Cohort Study (ICS), Waist  
382 Circumference (WC), Standard Deviation (SD), Cardiovascular Diseases (CVDs), Generalized  
383 Estimating Equations (GEE), Odds Ratio (OR), United States of America (USA), Marginal  
384 Logistic Regression (MLR)

385

386 **Declarations**

387 Ethics approval and consent to participate

388 Ethical approval was obtained from the Ethics Committee of Isfahan Cardiovascular Research  
389 Center (ICRC), a World Health Organization-collaborating center, and all subjects gave written  
390 informed consent.

391 Consent for publication

392 Not applicable

393 Availability of data and materials

394 The data that support the findings of this study are available on request from the corresponding  
395 author MS. The data are not publicly available due to privacy.

396 Competing interests

397 The authors declare that they have no competing interests

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400 Authors' contributions

401 MR developed and wrote the manuscript. AK, FZ, MS screened the literature, designed, edited,  
402 and approved the final version. All authors read and approved the final manuscript.

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524

525 **Tables**

526

527 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
<b>Number of Participants</b>	3336	3168	6504	1680	1604	3284	881	854	1735
<b>Education (%)</b>									
Level 1†	80.7	63.4	72.3	76.7	59.1	68.1	68.3	49.8	59.1
Level 2†	16.7	26.8	21.6	19.7	27.6	23.6	24.9	34.3	29.6
Level 3†	2.5	9.6	6	2.9	12.5	7.6	5.5	15.4	10.4
<b>Married(%)</b>	83.5	98.1	90.6	80.8	97.8	89.1	77.3	95.4	86.3
<b>Age*</b>	49.7 (11.5)	50.7 (12)	50.2 (11.7)	55.5 (10.2)	56.7 (10.8)	56.1 (10.5)	60 (9.6)	60.6 (9.8)	60.3 (9.7)
<b>BMI*</b>	27.9 (5.1)	24.5 (4)	26.7 (4.7)	28.7 (4.6)	26.1 (3.8)	27.7 (4.4)	29.4 (4.8)	26.5 (4.3)	28 (4.8)

<b>WC*</b>	96.4 (13.4)	92.3 (12)	94.4 (12.9)	96.2 (12.2)	93.8 (25)	95 (19.5)	98.3 (12.2)	97.4 (10.6)	97.8 (11.4)
<b>Obesity (%)</b>	31	13	22	39	15	27	44	18	31

528 \*Data are presented as Mean (SD).

529 †Level 1, Illiterate or elementary school; Level 2, intermediate school or high school; Level 3, university degree

530

531 Table 2. Prevalence of general obesity 2001, 2007, and 2013 by Gender

Baseline Age categories	2001			2007			2013		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
<b>35-44</b>	31.1	11.4	21.7	40.5	13.4	27.9	46.3	17	32.1
<b>45-54</b>	35.5	15.5	25.9	41.8	19.3	30.7	42.7	21.5	31.8
<b>55-64</b>	33.7	14.3	23.9	37.8	14.5	25.1	47.8	17.2	30.8
<b>≥ 65</b>	24.5	10.8	17.2	21.9	9.3	15.4	22.4	16.4	19.7
<b>Total</b>	31.4	13	22.4	38.5	14.8	27	43.6	18.3	31

532 Data are presented as percentage.

533 Obesity, BMI $\geq$ 30 (World Health Organization recommendation)

534

535 Table 3. Results from MLR Model to assess Gender and longitudinal and cross-sectional Age  
536 effects on obesity

Parameter	Estimate ( $\beta$ )	Standard Error	P-value	OR	95% CI OR
<b>Intercept</b>	-4.9664	0.6952	<0.001	0.006	(0.001, 0.027)
<b>Gender (Female)</b>	1.1546	0.0583	<0.001	3.172	(2.830, 3.555)
<b>Baseline Age</b>	0.1266	0.0269	<0.001	1.134	(1.076, 1.196)
<b>Baseline Age squared</b>	-0.0013	0.0003	<0.001	0.998	(0.998, 0.999)
<b>Age- Baseline Age</b>	0.0295	0.0038	<0.001	1.029	(1.022, 1.037)
<b>Alpha1</b>	2.9046	0.1050	<0.001	18.257	(14.861, 22.432)
<b>Alpha2</b>	2.6129	0.1421	<0.001	13.638	(10.323, 18.018)
<b>Alpha3</b>	3.5040	0.1754	<0.001	33.248	(23.575, 46.885)

537 QIC= 12070.3512; QICu= 12066.9720

538

### 539 Additional Files

540 File name: Additional file 1.pdf

541 File format: pdf

542 Title of data: Figure 1. Cross-sectional effect of age on prevalence of obesity in men and  
543 women

544 File name: Additional file 2.pdf

545 File format: pdf

546 Title of data: Figure 2. Longitudinal effect of age on prevalence of obesity in men and women

547 File name: Additional file 3.pdf

548 File format: pdf

549 Title of data: Table 1. Results from MLR Model to assess Gender and Age effects on obesity

# Figures

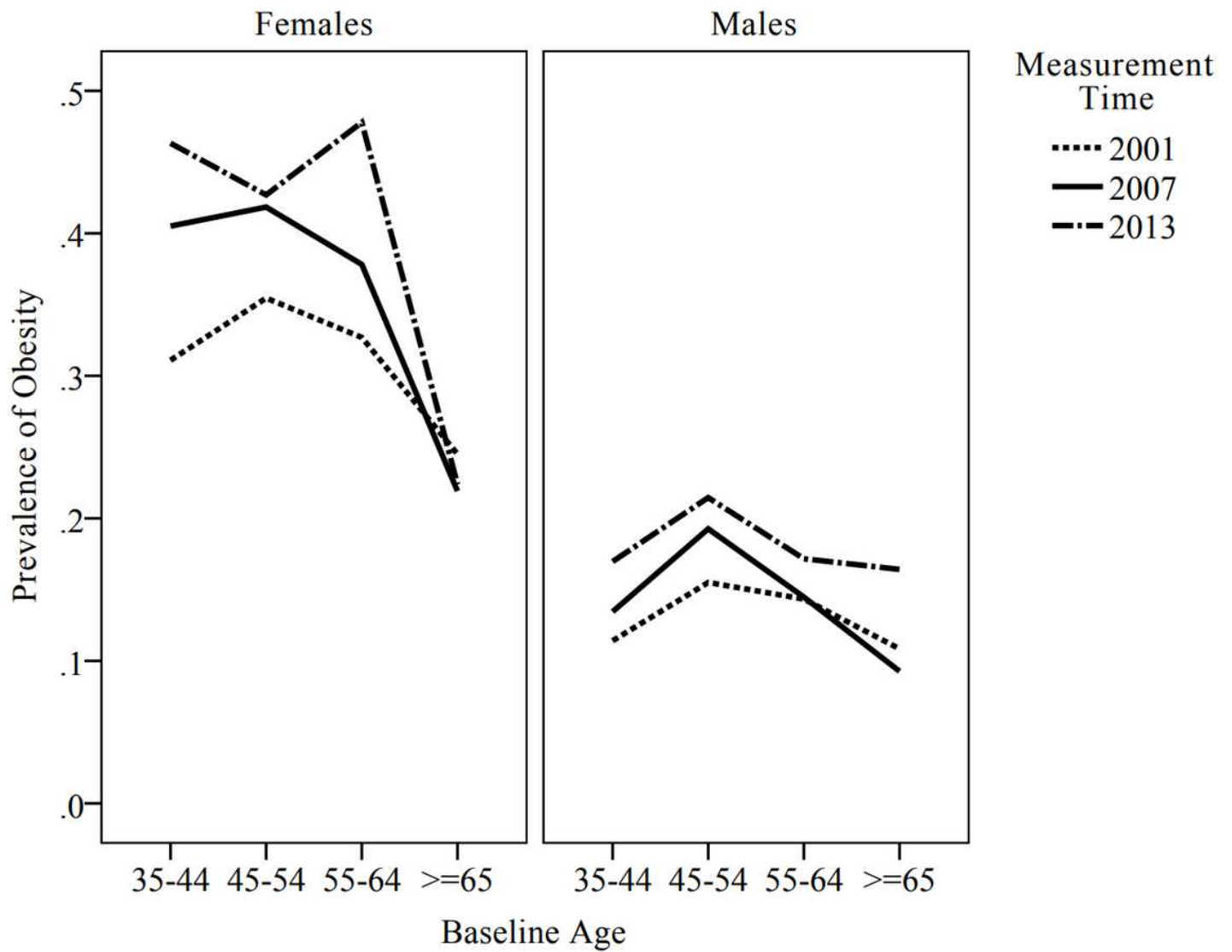
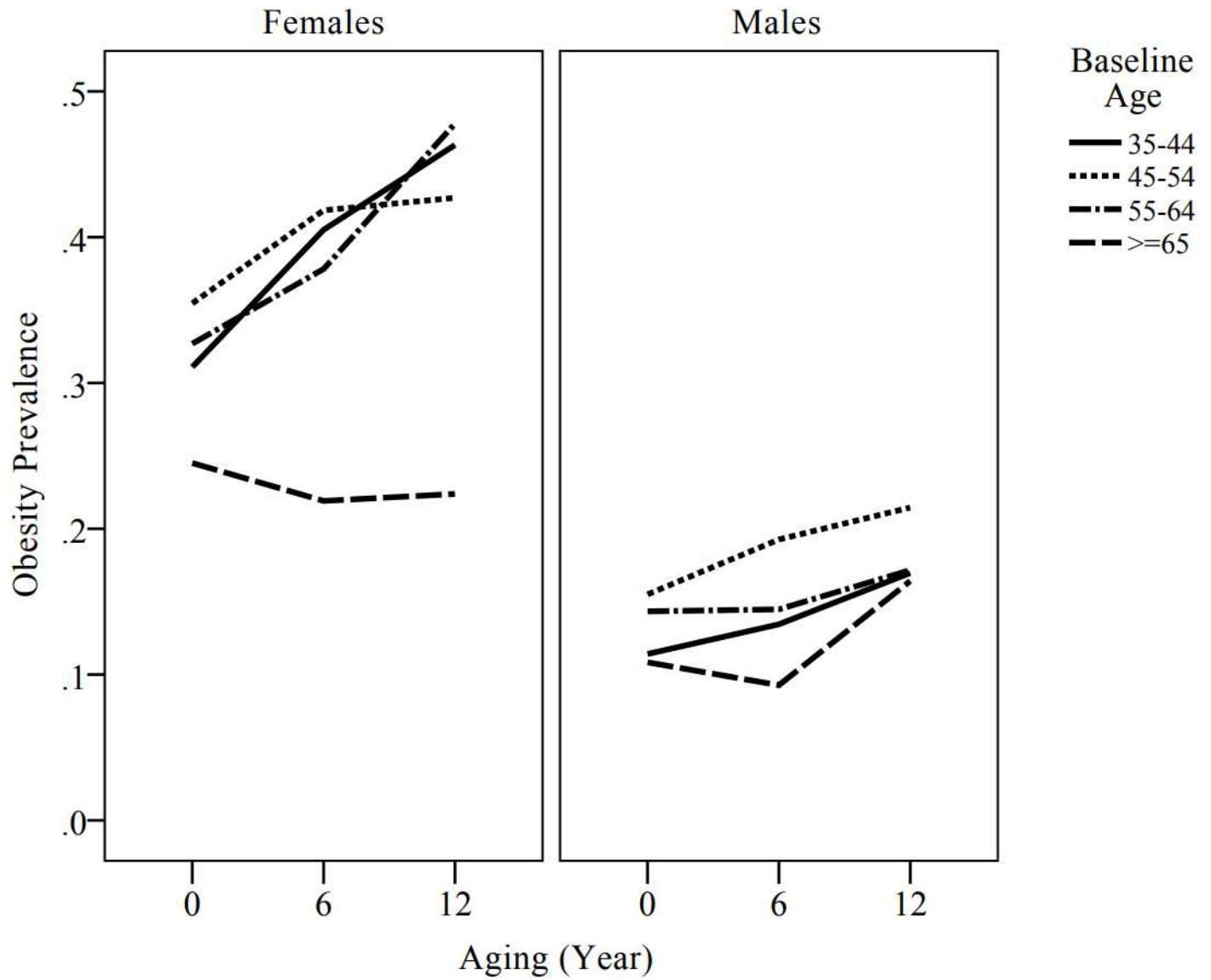


Figure 1

Cross-sectional effect of age on prevalence of obesity in men and women



**Figure 2**

Longitudinal effect of age on prevalence of obesity in men and women

## Supplementary Files

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