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PREVALENCE OF OBESITY AND RISK OF CHRONIC DISEASES IN THE ELDERLY: THE CASE OF TURKEY

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Abstract

Obesity is a major factor in the development of chronic diseases and can be influenced by some unobserved factors as well as genetic predisposition. Since obese older people are more likely to develop chronic diseases, a better understanding of the relationship between overweight/obesity and chronic diseases may help to reduce unnecessary morbidity and mortality. Using a Seemingly Unrelated probit approach for unobserved heterogeneity and probable endogeneity, this study investigates the empirical connection between obesity and chronic diseases in the elderly. Data from the Turkish Health Survey collected by the Turkish Statistical Institute in 2014, 2016, and 2019 were used for the analysis. The empirical results indicate that there are unmeasurable common factors that influence both overweight/obesity and chronic diseases, with overweight/obesity being an important determinant of chronic diseases along with some socioeconomic factors such as gender, physical inactivity, smoking, age, depression, etc. The findings suggest that health policies to reduce preventable morbidity and mortality should take into account unmeasurable genetic factors as well as psychological support to activate sedentary lifestyles in older people and prevent depression and feelings of worthlessness.

Keywords *: Chronic Disease, Seemingly Unrelated Probit Regression Analysis, Elderly Obesity*

JEL Classification *: C01, C24*

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YAŞLILARDA OBEZİTE PREVALANSI Ve KRONİK HASTALIK RİSKİ: TÜRKİYE ÖRNEĞİ

Öz

Obezite, kronik hastalıkların gelişiminde önemli bir faktördür ve genetik yatkınlığın yanı sıra bazı gözlemlenemeyen faktörlerden de etkilenebilir. Obez yaşlıların kronik hastalıklara yakalanma olasılığı daha yüksek olduğundan, aşırı kilo ve kronik hastalıklar arasındaki ilişkinin daha iyi anlaşılması, önlenebilir hastalık ve ölüm oranının azaltılmasına yardımcı olacaktır. Bu çalışma, gözlemlenemeyen dışsallık ve olası içsellik için görünüşte ilişkisiz probit (Seemingly Unrelated Probit) yöntemini kullanarak, yaşlılarda obezite ve kronik hastalıklar arasındaki ampirik bağlantıyı araştırmaktadır. Analiz için Türkiye İstatistik Kurumu tarafından 2014, 2016 ve 2019 yıllarında toplanan Türkiye Sağlık Araştırması anketi verileri kullanılmıştır. Ampirik sonuçlar, hem aşırı kilo/obezite hem de kronik hastalıkları etkileyen ölçülemeyen ortak faktörler olduğunu ve aşırı kilo/obezitenin cinsiyet, fiziksel hareketsizlik, sigara, yaş, depresyon gibi bazı sosyoekonomik faktörlerle birlikte kronik hastalıkların önemli bir belirleyicisi olduğunu göstermektedir. Bulgular, önlenebilir hastalık ve ölüm oranının azaltılmasına yönelik sağlık politikalarının, genetik faktörlerin yanı sıra yaşlılarda hareketsiz yaşam tarzlarını değiştirmek ve depresyon ile değersiz hissetmek gibi duyguları önlemek için psikolojik desteğin de dikkate alması gerektiğini göstermektedir.

Anahtar Kelimeler ***:*** *Kronik Hastalıklar, Görünürde İlişkisiz Probit Modeli, Yaşlılarda Obezite*

JEL Sınıflandırması ***:*** *C01, C24*

INTRODUCTION

Obesity has become a major public health problem in post-industrial societies. It has reached epidemic proportions and continues to grow, especially during the last century when an important part of the world faced starvation. In addition, obesity-related mortality has increased significantly in both developed and developing countries. In 1975, 4.3% of adults worldwide were obese; by 2016, this percentage rose to more than 13%. In 1990, 2.19 million people died due to obesity. In 2019, this number rose to 5 million. The latest statistics also show that obesity-related deaths rank fifth, after hypertension, smoking, air pollution, and diabetes (Our World in Data, 2022). The prevalence of obesity and obesity-related deaths has shown a similar trend in Turkey as in the world. The average BMI of adults in Turkey was 24.71 in 1975; with an increase of 17%, the average BMI was 28.94 in 2016. During the same period, the percentage of the obese population increased from 7.60% to 32.20% (Turkish Statistical Institute, 2019). As the country's population ages, obesity has become a major health problem for the elderly, as well as for children and adults. While the proportion of the elderly population in Turkey was 8.5% in 2017, it increased to 9.9% by 2022, which is slightly higher than the global average of 9.8% (United Nations, 2019), and according to population projections, the proportion of the elderly population in Turkey is expected to be 12.9% in 2030. The obesity rate of the population aged 65 years and older was 22.9% in 2010 and 29.0% in 2019 (Turkish Statistical Institute, 2023).

Obesity manifests as a perilous health condition and stands as a prominent risk determinant for enduring ailments, including type 2 diabetes, cardiovascular maladies, hypertension, stroke, and specific forms of cancer. Its impact extends beyond the realm of personal well-being, adversely affecting the quality of life and precipitating substantial financial burdens on healthcare systems due to the constricted scope of daily activities, particularly impeding mobility (World Health Organization, 2022). The dynamics of obesity depend on social norms, daily activities, dietary habits, and health status in addition to genetic susceptibility. Besides, at the individual level, there is heterogeneity in observable characteristics such as age and gender, education level, etc. All these factors, including genetic factors, influence body mass index (BMI) and thus obesity. Among other factors, health status such as diabetes, hypertension, and heart disease has much more complex effects on BMI due to mutual affinity. In this context, obesity and chronic diseases are high risk factors that negatively affect the life quality. The prevalence of diabetes, hypertension, and heart disease may promote obesity, while it is also possible

that the prevalence of obesity promotes diabetes, hypertension, and heart disease, especially in older people (Erem et al., 2001; Wang et al. 2007; Zhao et al. 2008; Gökler et al., 2015; Hu et al. 2020; Vanzo & Basello 2021; Jana &Chattopadhyay, 2022). Therefore, elderly people who are overweight and obese should be at increased risk of diabetes, heart disease, and hypertension. Understanding the relationships between socioeconomic factors as well as variables such as obesity and chronic diseases can help health authorities develop more specific programs and combat obesity and chronic diseases among the elderly (Chun et al., 2014; Bonilla-Sierra, 2020; Dorner and Rieder, 2012; Kim et al., 2011; Keramat et al., 2021). Healthy aging has become a very important goal for the elderly in Turkey, as in most countries. Due to increasing life expectancy, the elderly often suffers from obesity and chronic diseases such as diabetes, heart disease and hypertension have become more prevalent. The effects of chronic diseases and obesity lead to reduced quality of life, shorter life expectancy and increased demand for healthcare resources. Therefore, the quality of life of the elderly is an important public health issue (Chen et al, 2024).

Accurately identifying the socioeconomic factors leading to obesity and recommending effective policy interventions is valuable not only for controlling the disease, but also for preventing obesity-related diseases in old age, potentially allowing governments transfer potential health expenditures to other areas such as education, technology, or infrastructure. (OECD, 2019). Despite the indisputable evidence demonstrating an association between obesity and chronic diseases, studies comprehensively investigating the collective effects of obesity and other contributing factors on the prevalence of chronic diseases in the elderly are limited in both national and international literature. In this paper, we aim to investigate the association between obesity and chronic diseases such as diabetes, cardiovascular disease, and hypertension in the elderly. For this purpose, we used data from the Turkish Health Survey of 2014, 2016, and 2019 collected by the Turkish Statistical Institute (TURKSTAT). A seemingly unrelated probit model augmented with control variables was used to determine the collective influence of individual and socioeconomic factors on the likelihood of being overweight or obese and having chronic diseases. The use of the apparently unrelated probit model offers notable advantages over alternative models, as it facilitates the identification of correlations between the error terms of two equations while mitigating potential problems associated with reverse causality. This analytical approach enables a comprehensive examination of the shared determinants influencing both overweight or obesity and chronic diseases, thereby offering insights instrumental for devising health promotion interventions within an "obesogenic environment."

I. LITERATURE

Obesity is a treatable disease caused by many economic, environmental, and genetic factors. Differences in awareness between countries and individuals, as well as differences in socioeconomic conditions, are important factors in the prevalence of obesity (Gupta et al., 2012; Gil & Takourabt, 2017; Yang et al., 2019; Sengul et al., 2020). Moreover, many variables such as education level, income level, gender, quality of work, depression, and chronic diseases of the individual are among the most important factors affecting obesity (Çakmur & Ardıç, 2015; Egemen, 2019). Many researchers suggest that socioeconomic factors rather than genetic susceptibility influence the prevalence of obesity. These studies suggest an inverse relationship between education and obesity in general. As individuals or society become more educated, awareness about obesity also increases. Therefore, the prevalence or rate of obesity decreases as the level of education increases (Kim, 2016; Ogden et al., 2018; Santas & Santas, 2018; Hsieh et al., 2020).

The effects of income on obesity are inconsistent compared with the effects of educational attainment on obesity. Thus, obesity rates increase with income in underdeveloped or developing countries, whereas the relationship is reversed in developed countries. In other words, the impact of income on obesity is not stable and may vary over time or between different groups of countries. Income level is an indicator of social status, especially in developing or underdeveloped countries. Because people with high household income or social status are more likely to have a healthy diet, the incidence of obesity should decrease with income or social status (Poobalan & Aucott, 2016; Ogden et al., 2018;

Nobari et al., 2018; Ball et al., 2019). Gender and cultural differences are also important parameters influencing obesity. In patriarchal societies, women are more likely to have a higher BMI or to be obese because they have lower levels of education and participation in the labour force and therefore lead more sedentary lifestyles. However, as countries develop, obesity among women decreases (Ameye & Swinnen, 2019; Aitsi-Selmi et al. 2014).

The prevalence of obesity in Turkey and the increase in the number of obesity-related deaths have led to numerous scientific studies on this issue. These studies mostly examined the relationship between obesity and predetermined variables such as education, household income, daily physical activity, smoking or alcohol consumption, marital status, gender, etc. The results show that women in Turkey have higher BMI and are more obese than men (Güven et al., 2008; Karaoğlan and Tansel, 2017; Yılmaz et al., 2019; Şengül et al., 2020; Er et al., 2021). However, in low- and middle-income countries such as Turkey, education level is a critical factor that increases social awareness about obesity, and an inverse relationship is expected between education level and obesity prevalence in adults (Erem, 2015; Sipahi, 2020). However, studies show that there is a positive relationship between income and obesity prevalence in developing or underdeveloped countries and that obesity prevalence is high (Popkin & Slining, 2013; Templin et al., 2019; Ameye & Swinnen, 2019; Demir et al., 2019; Pirinçci et al., 2010; Santas & Santas, 2018)

As in many other countries, obesity studies in Turkey have focused on obesity in adults and children rather than obesity in the elderly. Therefore, it is perhaps surprising that the problem of obesity in the elderly has not received more attention, especially since it appears that obesity in the elderly has quantitatively different effects on morbidity and mortality than in younger people. To understand these complex relationships, the changes in weight, body mass index (BMI) and body composition associated with aging need to be considered. Older individuals tend to have a higher fat percentage than younger individuals with the same BMI, especially men (Launer et al., 1994). Many studies have shown that BMI and fat mass are positively related to disability and disease, such as limitations in activities of daily living, heart and lung disease, diabetes, hypertension, etc. There is a wealth of clinical experience that clearly shows that weight loss benefits people with diabetes, respiratory disease and other conditions (Launer et al, 1994; Galonos et al, 1994; Visser et al 1998 Elia, 2001; Hsieh et al 2020; Bosello & Vanzo 2021).

The relationship between obesity and the occurrence of chronic diseases such as heart disease, diabetes, hypertension, and cholesterol has been investigated in numerous international studies (Marbaniang et al. 2021, Al-Sumaih 2020; Perez-Ferrer et al., 2019; Costa et al., 2005). On the other hand, although there are many studies on obesity in Turkey (Özdirenç et al., 2005; Pekkurnaz, 2021; Baygutalp et al., 2023; Yavuz, 2023), there is a gap in studies focusing on obesity in the elderly. In this context, all existing studies show the importance of the topic, as the elderly are at higher risk of chronic diseases than young people and obesity-related diseases pose a greater risk to individuals and the nation's healthcare system. In terms of causality, the potential chronic diseases of the elderly may be a trigger for obesity or vice versa (Rippe, Crossley & Ringer, 1998; Clark & Brancati, 2000; Dietz et al., 2015). Consequently, the increasing prevalence of obesity in the elderly requires a paradigm shift in healthcare systems to curb this growing public health problem (Salihu et al., 2009). Establishing a robust link between chronic disease and obesity in the elderly is of paramount importance, as this link is relevant to both individual well-being and the long-term sustainability of national health systems. Therefore, there is a compelling case for comprehensive research that addresses the complex interplay between obesity and the development of chronic diseases in the elderly. In addition, research on the influence of socioeconomic factors on the relationship between obesity and chronic diseases in the elderly is limited, especially in the Turkish population (İşeri & Arslan, 2009; Akın et al., 2010). This gap emphasises the need for the present study, which attempts to fill this critical knowledge gap. By carefully examining the above relationships, the present study has the potential to lay the foundation for future efforts in this area.

II. MATERIAL AND METHOD

II.I. Seemingly Unrelated Probit Model

Econometric models treat some phenomena, such as obesity and chronic diseases, as unrelated and estimate them separately, although they are influenced by common factors. The error terms of the separately estimated regression models may have correlations. If so, the estimated coefficient is not unbiased. Seemingly unrelated regression models serve to alleviate bias in regression coefficients when error terms exhibit correlation, and the dependent variable in one equation assumes the role of an independent variable in another. The identification of a statistically significant nonzero correlation among the error terms in the estimated regressions signifies the applicability of the seemingly unrelated model, indicative of the presence of unobservable variables linking the propensity for obesity and the occurrence of chronic diseases. Employing the seemingly unrelated probit model for coefficient estimation and to comprehend the collective impact of age and socioeconomic factors on the determination of obesity and chronic diseases represents a simultaneous joint estimation approach, adept at addressing concerns related to endogeneity and unobserved heterogeneity. This modeling approach offers a notable advantage over alternative methods by enabling the observation of correlations between the error terms of two equations and facilitating control over potential issues associated with reverse causality. In the analysis, we used overweight or obesity and diabetes, heart disease, hypertension, and all three chronic diseases together as dependent variables of the seemingly unrelated probit regressions. The dependent variables used in the regressions are binary and have a value of 1 if the participant's response is "yes" and 0 if not. The explanatory variables consist of some dummy variables for the years and the socioeconomic variables such as gender, education, income, age, and so on. Because the common risks cannot be observed directly, the risk of suffering from obesity (1) and a chronic disease (2) is given by the following equations[3]:

$$Y_{1i}^{*} = \beta_1 X_{1i} + \mu_{1i} \tag{1}$$

β_1 is the regression coefficient. X_{1i} is the matrix of explanatory variables including socio-economic factors including education, marital status, age of individuals, etc. and μ_{1i} is the error term. In addition, $i = 1, 2, \ldots, n$ represents the individuals who participated in the survey.

$$Y_{2i}^{*} = \beta_2 X_{2i} + \mu_{2i} \tag{2}$$

β_2 is the regression coefficient. X_{2i} is the matrix of explanatory variables of chronic diseases including hypertension, heart disease and diabetes and μ_{2i} is the error term. If the covariance of the error terms is statistically[4] nonzero, the models in equation (1) and equation (2) should be estimated jointly (Costa-Font and Gil, 2005; Marbaniang et al., 2021). In the case of nonzero covariance, the dependent variable (obesity) in the first equation becomes the risk factor for chronic diseases, as shown in the second equation. Therefore, the equations should be estimated with the seemingly unrelated probit model constructed as follows.

$$Y_{1i}^{*} = \beta_1 X_{1i} + \varepsilon_{1i} \tag{3}$$

$$Y_{2i}^{*} = \delta_1 Y_{1i} + \delta_2 Z_{2i} + \varepsilon_{2i} \tag{4}$$

Here Y_{1i}^{*} and Y_{2i}^{*} are latent dependent variables from equation (1) and equation (2). X_{1i} is the explanatory variable of the first equation. Y_{1i} is the potentially endogenous binary variable (obesity). Z_{2i} are explanatory variables including risk factors of chronic diseases. β_1, δ_1 and δ_2 are the estimated coefficients. If ε_{1i} and ε_{2i} are uncorrelated, this implies for the system that there are no third equation risk factors affecting chronic diseases. If this is the case, the third and fourth equations can be estimated

[3] Here, $Y_{1i} = \begin{cases} 1, if\ Y_{1i}^{*} \geq 0 \\ 0, otherwise \end{cases}$ and $Y_{2i} = \begin{cases} 1, if\ Y_{2i}^{*} \geq 0 \\ 0, otherwise \end{cases}$

[4] Whether the correlation between the error terms is dependent across equations can be determined with the help of the Wald or the Lagrange multiplier test.

separately, but if ε_{1i} and ε_{2i} are correlated, the seemingly unrelated probit model with endogenity would yield more efficient and unbiased coefficients (Fabbri et al., 2004).

II. Data and Variables

We investigated the effects of obesity in the elderly on diabetes, hypertension, and heart disease using data from 2014, 2016, and 2019 Turkish Health Survey collected by the TURKSTAT. Since we intended to investigate the association between obesity and diabetes, hypertension, and heart disease in the elderly, the study included individuals aged 65 years and older. The sample included 7395 individuals aged 65 years and older, of whom 55.9% were men and 44.1% were women. Of this sample, 32.8% were interviewed in 2014, 32% in 2016, and 33.2% in 2019. Obesity or overweight of individuals was calculated using BMI and utilized as one of the dependent variables in probit regressions. Hypertension, diabetes, and heart disease were other dependent variables in the estimation process. Considering existing studies, socioeconomic variables affecting obesity were determined as age, gender, income level, education level, and marital status. Besides, some physical activities (sedentary, moderate physical activity, heavy physical activity, walking time, exercising or not) and smoking, alcohol consumption, and dietary habits (fruits and vegetables) were assessed as behavioral habits. Dummy variables for help in the household, feelings of worthlessness, and depression (e.g., help with housework or caring for children in the family) were used as additional explanatory variables in seemingly unrelated regression models.

Table 1. Definition Variables and Descriptive Statistics

Variable	Definition	1	2	3	4	5
		$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$	$\bar{X}$
BMI	*Body Mass Index*	27.566	30.07	28.44	28.87	27.97
Normal	*BMI<25*	0.330		0.220	0.232	0.315
Overweight	*24.99<BMI<29.99*	0.392	0.585	0.386	0.395	0.367
Obese	*BMI>29.99(If the elderly person is obese 1, otherwise 0)*	0.278	0.415	0.394	0.372	0.318
Hyper.	*If the elderly person has hypertension 1, otherwise 0*	0.545	0.593		0.709	0.724
Diabetes	*If the elderly person is diabetic 1, otherwise 0*	0.276	0.316	0.359		0.359
Heart	*If the elderly person has heart disease 1, otherwise 0*	0.206	0.211	0.274	0.269	
Depression	*If the elderly person had depression within the last 12 months 1, otherwise 0*	0.110	0.121	0.142	0.144	0.180
Worthless	*If the elderly person has felt worthless within the last two weeks 1, otherwise 0*	0.637	0.165	0.139	0.147	0.146
Age	*Age*	73.266	72.54	73.66	72.59	74.03
Gender	*If the elderly person is male 1, otherwise 0*	0.559	0.398	0.340	0.349	0.408
SSI	*If health care costs are covered by social security 1, otherwise 0*	0.258	0.249	0.245	0.250	0.257
Education1	*If primary school was not completed or if the elderly person is illiterate 1, otherwise 0 (reference)*	0.448	0.437	0.498	0.468	0.522
Education2	*If the elderly person is a primary school graduate 1, otherwise 0*	0.405	0.423	0.372	0.403	0.363
Education3	*Secondary school, vocational secondary school and high school graduates are 1, others 0*	0.094	0.091	0.084	0.089	0.070
Education4	*University graduates are 1, others 0*	0.053	0.049	0.046	0.040	0.045
Income1	*If the elderly person is in the lowest income group 1, otherwise 0 (reference)*	0.595	0.579	0.605	0.586	0.617
Income2	*If the elderly person is in the middle-income group 1, otherwise 0*	0.185	0.193	0.176	0.185	0.185
Income3	*If the elderly person is in the highest income group 1, otherwise 0*	0.220	0.229	0.218	0.229	0.198
Single	*If the elderly person has never married 1, otherwise 0(reference)*	0.011	0.009	0.008	0.007	0.007
Married	*If the elderly person is married 1, otherwise 0*	0.630	0.626	0.577	0.600	0.600
Widow	*If the elderly person is divorced or widowed 1, otherwise 0*	0.359	0.365	0.415	0.394	0.393
Sedentary	*If the elderly person is mostly sitting or standing 1, otherwise 0*	0.738	0.746	0.794	0.797	0.820
Moderated	*If the elderly person is mostly walking and doing moderate physical activity 1, otherwise 0*	0.252	0.247	0.200	0.198	0.174
Heavy physical activity	*If the elderly person does mostly heavy physical activity 1, otherwise 0*	0.09	0.008	0.006	0.005	0.006
Walk	*If the elderly person walks 30 minutes or more per day 1, otherwise 0*	0.295	0.015	0.021	0.018	0.028
Sport	*If the elderly person performs at least 10 minutes of sports, fitness, or leisure activities in a week 1, otherwise 0*	0.656	0.296	0.335	0.331	0.375
Help	*If the elderly person participates in housework and/or care of children, sick, etc. in the family 1, otherwise 0*	0.123	0.296	0.335	0.331	0.375
Fruit	*If the elderly person eats fruit 1, otherwise 0*	0.739	0.646	0.656	0.650	0.678
Vegetable	*If the elderly person eats vegetables 1, otherwise 0*	0.815	0.761	0.729	0.751	0.691
Smoking	*If the elderly person smokes 1, otherwise 0*	0.104	0.828	0.806	0.817	0.782
Alcohol	*If the elderly person drinks alcohol 1, otherwise 0*	0.172	0.101	0.103	0.103	0.105
Year2014	*If the elderly person participated in the 2014 survey 1, otherwise 0*	0.328	0.866	0.850	0.839	0.836
Year2016	*If the elderly person participated in the 2014 survey 1, otherwise 0*	0.320	0.341	0.328	0.320	0.352
Year2019	*If the elderly person participated in the 2016 survey 1, otherwise 0*	0.332	0.342	0.337	0.337	0.332
Sample Size	*The number of observations*	7395	4955	4030	2041	1523

Note: 1, 2, 3, 4 and 5 show all sample, obese and overweight, hypertension, diabetes and heart diseases, respectively.
$\bar{X}$ is the mean of each variable.

Table 1 indicates that the mean BMI of the elderly was 27.56 kg/(m)^2 for all the sample, while it was 27.30 kg/(m)^2 in 2014, 27.55 kg/(m)^2 in 2016, and 27.84 kg/(m)^2 in 2019, respectively. The average age of the elderly in the entire sample was 73.26 years. The figures show that 33.0% of the elderly in Turkey were in the underweight or normal weight group, 39.2% of the elderly were in the overweight group, and 27.80% were in the obese group. Of all the elderly participants, 27.6 % had chronic diabetes, 11% suffered from depression, 54.5% suffered from hypertension, and 20.6% had heart disease. In addition, 63.7% of the elderly felt worthless, 35.9% were divorced or widowed, 44.8% did not complete elementary school or were illiterate, and 40% did not attend elementary school. Besides, 59.5% were in the low-income group and 12.3% helped the family with home care, childcare, and nursing. Less than 30% of the total sample walked 30 minutes or less per day, 73.9% ate fruits and 81.5% ate vegetables, 10.4% smoked and 17.2% drank alcohol. It was also found that 67% of the elderly with an average BMI of 30.07 kg/(m)2 were in the obese or overweight group, while the percentage of chronic diseases in obese and overweight elderly was hypertension with 59.3%, diabetes with 31.6%, and heart disease with 21.1%.

Table 2. Descriptive Statistics for Interaction Samples

	Obese Female		Obese Male		Obese-Heart		Obese-Diabetic		Obese-Hyper.		Obese-Chronic	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
BMI	30.73	4.34	29.08	5.13	30.47	4.28	30.73	4.38	30.62	5.34	31.23	4.56
Obese	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Hyper	0.68	0.47	0.46	0.50	0.75	0.43	0.73	0.45	1.00	0.00	1.00	0.00
Diabetes	0.35	0.48	0.26	0.44	0.39	0.49	1.00	0.00	0.39	0.49	1.00	0.00
Heart	0.22	0.41	0.20	0.40	1.00	0.00	0.26	0.44	0.27	0.44	1.00	0.00
Depression	0.15	0.36	0.07	0.26	0.19	0.39	0.16	0.36	0.15	0.36	0.25	0.43
Worth	0.86	0.35	0.88	0.32	0.85	0.36	0.84	0.36	0.86	0.35	0.79	0.41
Age	72.72	6.39	72.28	6.19	73.38	6.37	72.19	6.11	72.92	6.34	73.04	5.85
Gender	1.00	0.00	1.00	0.00	0.37	0.48	0.33	0.47	0.31	0.46	0.26	0.44
SSI	0.18	0.39	0.35	0.48	0.24	0.43	0.24	0.43	0.24	0.42	0.23	0.42
Education1	0.59	0.49	0.21	0.40	0.52	0.50	0.46	0.50	0.48	0.50	0.55	0.50
Education2	0.33	0.47	0.57	0.50	0.38	0.49	0.42	0.49	0.39	0.49	0.37	0.48
Education3	0.06	0.24	0.14	0.35	0.07	0.25	0.09	0.28	0.08	0.28	0.05	0.22
Education4	0.02	0.15	0.09	0.28	0.04	0.19	0.03	0.18	0.04	0.20	0.02	0.15
Income1	0.61	0.49	0.54	0.50	0.60	0.49	0.57	0.50	0.58	0.49	0.59	0.49
Income2	0.17	0.38	0.23	0.42	0.19	0.39	0.19	0.39	0.19	0.39	0.18	0.38
Income3	0.22	0.42	0.24	0.43	0.21	0.41	0.24	0.43	0.23	0.42	0.23	0.42
Single	0.01	0.09	0.01	0.10	0.00	0.07	0.01	0.08	0.01	0.09	0.01	0.08
Married	0.48	0.50	0.84	0.36	0.59	0.49	0.59	0.49	0.58	0.49	0.54	0.50
Widow	0.51	0.50	0.15	0.35	0.41	0.49	0.40	0.49	0.41	0.49	0.46	0.50
Sedentary	0.80	0.40	0.66	0.47	0.81	0.39	0.80	0.40	0.80	0.40	0.87	0.34
Walk	0.38	0.48	0.17	0.38	0.37	0.48	0.33	0.47	0.34	0.47	0.41	0.49
No Sport	0.66	0.47	0.63	0.48	0.67	0.47	0.64	0.48	0.65	0.48	0.66	0.48
Fruit	0.75	0.44	0.78	0.41	0.70	0.46	0.76	0.43	0.75	0.43	0.72	0.45
Vegetable	0.81	0.39	0.85	0.36	0.79	0.41	0.82	0.38	0.82	0.39	0.79	0.41
Smoking	0.10	0.30	0.10	0.30	0.09	0.29	0.10	0.31	0.10	0.30	0.12	0.32
Alcohol	0.03	0.17	0.37	0.48	0.13	0.34	0.14	0.35	0.14	0.34	0.11	0.32
Year2014	0.32	0.47	0.30	0.46	0.34	0.47	0.31	0.46	0.32	0.47	0.33	0.47
Year2016	0.34	0.47	0.34	0.47	0.34	0.47	0.34	0.47	0.34	0.48	0.33	0.47
Year2019	0.33	0.47	0.36	0.48	0.32	0.47	0.35	0.48	0.34	0.47	0.34	0.47
Sample	**2983**		**1972**		**1045**		**1565**		**2939**		**340**	

Table 2 presents descriptive statistics for obese older women, obese older men, older people who are obese and have hypertension, older people who are obese and have diabetes, older people who are obese and have heart disease, and older people who are obese and have all chronic diseases. The average BMI of obese women was calculated to be 30.73. Of the obese women, 68% suffered from hypertension, 35% from diabetes, and 22% from heart disease. While 15% of the obese elderly women were depressed, 86% felt worthless. The rates of chronic disease were 46%, 26%, and 20%, respectively among obese

men. Compared to obese women, obese men were significantly less likely to have hypertension or diabetes. The prevalence of obesity decreased while income increased in both women and men. The mean age of the obese elderly with heart disease was calculated 73.38 years. Of the obese elderly with heart disease, 60% were in the low-income group, 37% were men, and 52% had low education levels. The obese elderly with heart disease also had hypertension, and 39% of them were diabetic. The average BMI in the obese diabetic group was 30.73, 80% of the participants in the obese diabetic group lived a sedentary life, 73% also had hypertension, and 57% of the elderly did not have a primary school diploma or were illiterate. Similarly, 39% of the obese hypertensive elderly people also had diabetes, and their average age was 72.92 years. While 80% of the elderly in this group lived a sedentary life, 58% were in the low-income group. The last column of Table 2 provides summary statistics of the elderly individuals who are obese and have all chronic diseases (diabetes, hypertension, and heart disease). The percentage of the elderly who are obese and have all chronic diseases was 4.6%. According to these statistics, both obese and chronically ill elderly individuals had an average BMI of 31.23kg/m2 and an average age of 73.04 years; 59% belonged to the middle-income group; and 79% reported that they felt worthless. Finally, 2% of them were university graduates and 66% of the obese and chronically ill elderly participants did not exercise daily.

III. EMPIRICAL RESULTS AND DISCUSSIONS

The outcomes of the seemingly unrelated probit models involving five distinct dependent variables are succinctly presented in Table 3. Within the model framework, the coefficient rho (ρ) serves as an indicator of the correlation among the residuals (error terms) of the system equations. This coefficient assumes significance as it encapsulates the interdependence of the latent components within the equations pertaining to overweight or obesity and chronic diseases. The calculated rho values were 0.182 for diabetes, 0.09 for heart disease, 0.204 for hypertension, and 0.086 for the composite measure of all three chronic diseases, all of which demonstrated statistical significance distinct from zero. These findings suggest the presence of one or more unobservable factors exerting influence on the prevalence of overweight or obesity and the occurrence of a chronic disease (specifically, diabetes, heart disease, hypertension, and the combination of all three chronic diseases). In other words, unobserved factors that influence the likelihood of being overweight would also simultaneously influence the likelihood of having a chronic disease. Because data on the marital status of the elderly were incomplete, this variable was excluded from the chronic disease equations. According to the estimated coefficients, aging in the elderly had negative effects on overweight or obesity and diabetes but positive effects on heart disease and hypertension. The effects of aging on obesity or chronic disease are consistent with the findings of the existing literature (Kan & Tsai, 2004; Baum & Ruhm, 2009; Costa-Font et al., 2010; Bonanno et al., 2018; Karaoglan &Tansel, 2018; Caglayan et al., 2022). Older men in Turkey were less likely to be overweight or obese than older women and they are less likely to have diabetes, hypertension, or all three of these chronic diseases. In other words, older women were more likely to suffer from overweight or obesity and chronic diseases than older men. These findings are also consistent with previous studies (Sengul et al., 2020; Karthika et al., 2023). Middle-income and high-income elderly were more likely to be overweight or obese than low-income elderly. The effect of high-income elderly on diabetes was positive and statistically significant. Elderly people with primary education and lower levels of education (no high school diploma or illiterate) were more likely to be overweight or obese than elderly people with high school diplomas, yet the effect of education level on all chronic diseases was not statistically significant. While fruit consumption reduced the likelihood of hypertension, elderly people who consumed fruit had a higher risk of developing diabetes or obesity. The effect of alcohol and vegetables on obesity and chronic diseases was not statistically significant. Smokers had a lower risk of overweight and obesity than nonsmokers because smokers have a higher metabolism and consume fewer calories than nonsmokers. Feeling worthless in old age increased the likelihood of being overweight or obese, but decreased the likelihood of diabetes, heart disease, hypertension, and all three chronic diseases combined. Another important finding of this study was that a sedentary lifestyle and depression increased the likelihood of being overweight or obese, diabetes, heart disease, hypertension, and all three chronic diseases combined. When older people exercised at least 10 minutes a week or engaged in

leisure-time physical activities, they reduced both their risk of obesity and their likelihood of developing a chronic disease.

Table 3. The Coefficients of Seemingly Unrelated Probit Models

Model	Obese		Diabetes		Heart		Hypertension		Chronic	
Variables	**Coef.**	**Z stat.**	**Coef.**	**Z stat**	**Coef.**	**Z stat**	**Coef.**	**Z stat**	**Coef.**	**Z stat**
Age	-0.031	-12.34*	-0.018	-7.33*	0.007	2.70*	0.007	2.92*	-0.005	-1.51
Gender	-0.340	-8.88*	-0.267	-7.95*	0.037	0.96	-0.499	-16.13*	-0.253	-4.90*
Income2	0.182	3.98*	0.063	1.36	-0.002	-0.004	0.006	0.14	0.026	0.38
Income3	0.213	4.67*	0.108	2.44*	-0.070	-1.47	0.048	1.13	0.029	0.45
Education1	0.146	1.80***	0.151	1.83***	0.066	0.77	0.019	0.25	0.178	1.29
Education2	0.297	3.93*	0.187	2.30**	-0.049	-0.59	-0.013	-0.19	0.117	0.87
Education3	0.102	1.10	0.134	1.51	0.154	-1.59	-0.026	-0.32	-0.038	-0.24
Fruit	0.174	4.26*	0.084	2.09**	-0.115	-2.61*	-0.003	-0.09	0.015	0.25
Vegetable	0.027	0.56	-0.014	-0.31	-0.034	-0.69	-0.017	-0.34	-0.089	-1.28
Alcohol	0.040	0.88	0.015	0.32	-0.870	-1.71***	0.006	0.13	-0.008	-0.11
Smoking	-0.094	-1.98**	-0.025	-0.48	0.015	2.10**	-0.020	-0.41	0.056	0.75
Depression	0.156	3.04*	0.195	3.99*	0.430	8.68*	0.382	7.69*	0.424	6.75*
Worthless	0.113	2.32*	-0.111	-2.24**	-0.089	-1.73***	-0.011	-2.09**	-0.188	-2.77*
Sedentary	0.124	3.25*	0.242	6.08*	0.254	5.86*	0.266	7.24*	0.361	5.31*
Sport	-0.076	-1.92***	-0.066	-1.65***	-0.157	-3.80*	-0.074	-2.00**	-0.126	-2.20**
Walk	-0.017	-0.09	0.330	1.07	0.381	1.07	0.044	0.31	0.584	1.43
Year2016	0.067	1.76***	0.020	0.51	-0.046	-1.13	0.010	0.27	0.041	0.71
Year2019	0.242	1.59	0.386	2.24**	0.291	1.48	0.041	0.29	0.540	1.32
Married	0.258	2.27**								
Widow	0.342	4.39*								
Constant	2.408	9.74*	0.393	1.61	-1.880	-7.04*	-0.455	-2.15**	-1.901	-3.89*
Rho			0.182	8.54*	0.090	2.79*	0.204	10.24	0.086	2.68*
LR			73.78	0.001	3.20	0.07	106.43	0.001	7.20	0.007
(*), (**) and (***) represent significant level at 1%, 5% and 10%, respectively.										

Table 4 includes the estimations derived from the seemingly unrelated probit model incorporating endogenous obesity, as delineated. Across all four chronic diseases, both the Wald test and the likelihood ratio test yielded indications of endogeneity. Notably, the correlation coefficient, characterized by a negative sign, diverged from the values observed in the preceding table. Nonetheless, the coefficients associated with the remaining variables exhibited a comparable sign and magnitude. The negative correlation coefficient was statistically significant (-0.405 for diabetes, -0.480 for heart disease, -0.462 for hypertension, and -0.507 for all chronic diseases). The correlation coefficients suggest that there are one or more unobserved factors that are positively related to overweight or obesity but negatively related to chronic diseases (or vice versa).

Table 4. The Coefficients of Seemingly Unrelated Probit Models with Endogeneity

Model	Obese		Diabetes		Heart Disease		Hypertension		Chronic	
Variables	**Coef.**	**Z stat.**	**Coef.**	**Z stat**	**Coef.**	**Z stat**	**Coef.**	**Z stat**	**Coef.**	**Z stat.**
Obese			0.918	3.62*	0.656	2.93*	0.150	4.45*	0.68	3.61*
Age	-0.031	-12.44*	-0.004	-1.55	0.0007	-0.20	0.008	5.38*	-0.001	-0.25
Gender	-0.340	-8.90*	-0.126	-2.90*	-0.060	-1.86***	-0.487	-5.90*	-0.212	-3.10*
Income2	0.182	3.98*	0.051	0.10	-0.039	-0.64	-0.037	-0.72	-0.014	-0.19
Income3	0.209	4.62*	0.056	0.90	-0.096	-1.55	0.001	0.09	-0.008	-0.01
Education2	0.165	2.24**	0.105	1.81**	0.016	0.17	-0.012	0.16	0.129	0.96
Education3	0.122	4.44*	0.094	0.93	0.137	-1.40	-0.084	-1.01	0.023	0.16
Education4	0.101	1.52	0.100	1.08	-0.175	-1.89***	-0.051	-0.62	-0.066	-0.45
Fruit	0.183	4.65*	0.028	0.50	-0.153	-3.02	-0.054	-1.11	-0.040	-0.60
Vegetable	0.027	0.45	-0.026	-0.56	-0.034	-0.71	-0.024	-0.53	-0.091	-1.37
Alcohol	0.042	0.96	0.004	0.05	0.067	-1.34	0.007	-0.17	0.009	0.12
Smoking	-0.098	-2.04**	0.007	0.15	0.026	0.46	0.006	0.13	0.084	1.15
Depression	0.155	2.94*	0.128	2.68*	0.444	8.86*	0.373	7.32*	0.403	5.90*
Worthless	0.113	2.33**	-0.150	-3.02*	0.057	1.82**	-0.054	-1.09	-0.205	-2.97*
Sedentary	0.121	3.17*	0.190	4.60*	0.264	5.78*	0.264	7.05*	0.348	4.95*
Sport	-0.012	-0.15	0.292	1.90**	0.348	2.74*	0.047	0.34	0.587	1.45
Walk	0.075	1.90***	0.037	1.09	0.159	1.89**	0.064	1.67***	0.119	2.05*
Year2016	0.067	1.86***	-0.003	-0.08	-0.090	-2.51*	-0.031	-0.84	0.030	0.25
Year2019	0.236	1.55	0.284	1.64***	0.115	0.70	-0.030	-0.21	0.523	1.32
Married	0.273	2.08								
Widow	0.361	2.57								
Constant	2.402	9.75	-0.891	-2.68	-0.837	-2.32*	-0.634	-4.47*	-2.284	-3.47*
Rho			-0.405	-3.22	-0.480	-2.79	-0.462	-2.46*	-0.507	-2.43*
LR			4.40	0.036	6.98	0.008	5.41	0.020	4.63	0.03
Wald Test			864.41		706.77		898.86		579.86	
(*), (**) and (***) represent significant level at 1%, 5% and 10%, respectively.										

Apart from the results in Table 3, the estimates of Seemingly Unrelated Probit regressions with endogeneity suggest that the effects of depression and physical inactivity tended to increase the risk of diabetes, heart disease, hypertension, and the combination of all chronic diseases in the case of endogeneity. Income level and education level also had no statistically significant coefficients on all diseases. At older ages, women had higher odds of diabetes, heart disease, hypertension, and all chronic diseases than older men. Only the prevalence of hypertension increased with age in the elderly.

Table 5. Marginal Effects*

Variables	Diabetes	Heart Diseases	Hypertension	All Chronic Diseases
Obese	0.316	0.205	0.059	0.036
Age	-0.002	0.010	-0.004	0.003
Gender	-0.041	-0.017	-0.190	-0.022
Fruit	0.010	-0.046	-0.021	-0.005
Vegetable	-0.008	-0.010	-0.010	-0.012
Alcohol	0.002	-0.019	-0.003	0.001
Smoking	0.003	0.008	0.003	0.011
Depression	0.045	0.144	0.143	0.056
Worthless	0.054	-0.017	0.021	-0.025
Sedentary	0.065	0.073	0.105	0.033
Walk	0.013	0.048	0.013	0.011
Sport	-0.096	0.095	0.056	0.019
Year2016	-0.002	-0.012	0.004	0.001
Year2019	0.081	0.079	0.006	0.064
Pr(chronic diseases /obese)	0.251	0.241	0.047	0.032

* Marginal effects are calculated for the statistically significant coefficients in Table 4

Table 5 shows the marginal effects of obesity or overweight and each of the examined chronic diseases, employing the seemingly unrelated probit model that accommodates endogeneity. The average marginal effect delineates that a 10% escalation in overweight or obesity yields a 31.6% increase in diabetes, a 20.5% increase in heart disease, a 5.97% increase in hypertension, and a 3.6% increase in the composite measure of all chronic diseases. When considering elderly individuals classified as overweight or obese, the odds of experiencing diabetes, heart disease, hypertension, and all chronic diseases were 0.251, 0.241, 0.047, and 0.032, respectively. Notably, the impact of overweight and obesity appeared to be comparatively less pronounced for heart disease in comparison to the other chronic diseases under investigation. The influence of age on chronic diseases among the elderly was not prominent, but gender exhibited statistically significant effects. Specifically, older men exhibited a 4.1% lower likelihood of having diabetes compared to older women. Additionally, men were 1.7% and 19% less likely to have heart disease, hypertension, and all chronic diseases, respectively. Furthermore, men demonstrated a 2.2% reduced likelihood of diabetes compared to their older female counterparts.

CONCLUSION

It is of great importance to study the causes of obesity, because it can trigger common chronic diseases in the elderly. Considering obesity and chronic diseases separately can lead to biased results in econometric analyzes because there are some potential common factors that influence both obesity and diseases. To avoid the problems of bias in estimation, we considered the potential unobserved heterogeneity between obesity and chronic diseases such as heart disease, hypertension, diabetes, and all chronic diseases in the elderly together by using a SURE probit model with and without endogeneity utilizing data from 2014, 2016, and 2019 Turkish Statistical Institute Health Surveys. Consequently, the incorporation of overweight or obesity as an endogenous variable yielded a substantial impact on the determinants of chronic diseases. The empirical findings underscore the critical importance of accounting for unobserved factors in the investigation of the determinants of both obesity and chronic diseases. The conducted tests within the models reveal a statistically significant correlation among

unobserved factors influencing both overweight/obesity and all chronic diseases. The correlation coefficients substantiate that, beyond the recognized measurable factors, non-measurable elements such as genetic factors, psychological aspects, and addictive behaviors exert a discernible influence on both overweight/obesity and chronic diseases. The findings suggest a bidirectional relationship between the prevalence of chronic diseases and obesity. Not only may the presence of chronic diseases contribute to the onset of obesity, but conversely, the prevalence of obesity might also enhance the likelihood of developing specific chronic conditions, particularly in the elderly. In this context, the results align with prior research indicating a positive association between overweight/obesity and various chronic diseases (Katz et al., 2000; Costa-Font and Gil, 2005; Kearns et al., 2014; Au, 2016; Al-Sumai, 2020; Marbaniang, 2021). Hence, reducing obesity could have a simultaneous effect on reducing several chronic diseases. Moreover, overweight/obesity is a critical factor that increases the risk of diabetes, heart disease, hypertension, and all chronic diseases in old age. The results show that women are more prone to overweight/obesity and chronic diseases. This could be due to hormonal changes in ageing that make women more likely to be overweight or obese and have chronic diseases than men. Education and income are not determinants of overweight/obesity and chronic diseases. Income levels of older people also negatively affect healthy eating and thus overweight and chronic diseases. In addition, overweight/obesity is associated with a sedentary lifestyle, depression, and worthlessness. Finally, mental health is as important to a healthy life as physical health. Therefore, they receive special attention when we recommend interventions to improve the physical and mental health of older people. Consequently, introducing measures to promote healthier lifestyles for older people is considered to reduce obesity and thus chronic diseases. In conclusion, obesity and obesity-related chronic diseases are a major problem in the elderly, as in all age groups. The results of this study suggest that reducing obesity also reduces the risk of developing chronic diseases in the elderly. Therefore, physicians and nutritionists should work together to reduce obesity and develop nutrition counseling strategies for the elderly population to curb the obesity epidemic. Special attention should be paid to socioeconomic factors for effective intervention in obesity-related chronic diseases.

LIMITATIONS

This study uses data from health surveys conducted by the Turkish Statistical Institute in 2014, 2016 and 2019 to draw conclusions about obesity and chronic diseases in the elderly population of Turkey. The empirical findings derived from these surveys reflect the health status of the participating individuals. These findings are then generalized to elderly in Turkey. It is worth noting that different survey replicates can lead to variations in the observed relationships between the variables studied, which is a recognized limitation of empirical studies. In contrast to panel studies, the surveys used in this study interview different participants in each cycle of data collection. This methodological feature precludes the possibility of tracking the health status of the same individuals over time, further limiting the study's ability to draw definitive longitudinal conclusions.

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