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ORIGINAL ARTICLE

EVALUATION OF DIETARY ADVANCED GLYCATION END PRODUCTS IN OLDER ADULTS: RESULTS OF THE TÜRKİYE NUTRITION AND HEALTH SURVEY 2010–2017

Abstract

Introduction: With aging, advanced glycation end products accumulate on nucleotides, lipids, and proteins. Reducing dietary advanced glycation end products intake is important, as advanced glycation end products are known to be associated with chronic diseases. This study was designed to determine the dietary advanced glycation end products intake of older adults in Türkiye, assess the contribution of foods to dietary advanced glycation end products intake, and evaluate the relationship between dietary advanced glycation end products content and energy and nutrient intake.

Materials and Method: Data on 24-hour dietary recalls of the older adults were obtained from the 2010 and 2017 Türkiye Nutrition and Health Survey databases, which are based on nationally representative sample.

Results: According to Türkiye Nutrition and Health Survey 2017 data, dietary advanced glycation end products intake and daily estimated dietary intake values in the older adults were 12193.73±8773.86 kilounits/day and 168.30±126.40 kilounits/(kg·day), respectively. These values were higher than those reported in the Türkiye Nutrition and Health Survey 2010 data, which were 10391.59±7310.56 kilounits/day and 148.41±110.40 kilounits/(kg·day), respectively ($p<0.001$). The food groups contributing most to advanced glycation end products intake were fats, meat/meat products, and milk and dairy products.

Conclusion: To reduce dietary advanced glycation end products intake, it is recommended that older adults decrease total fat consumption, prefer low-fat dairy products to full-fat dairy products, use moist heat cooking methods for meat/meat products, and marinate meats with ingredients like lemon juice or vinegar.

Keywords: Aged; Glycation End Products, Advanced; Nutrition Survey.

INTRODUCTION

In recent years, the consumption of high-energy, low-nutrient ready-to-eat and processed foods has increased in Türkiye and globally. Heat treatment is a common food processing method used to enhance flavor, extend shelf life, and reduce the risk of food-borne illnesses. However, non-enzymatic biochemical reactions also occur during heat treatment. Among these reactions, the Maillard reaction occurring between the hydroxyl group of carbohydrates and the amino group of proteins at high temperatures is the most significant. Advanced glycation end products (AGEs) are formed during advanced stages of the Maillard reaction (1).

AGEs are a heterogeneous class of glycated proteins and lipoproteins that are produced endogenously in the body or ingested exogenously through food. Most endogenous AGEs are formed spontaneously and accumulate in the body throughout life. Diet, radiation, and smoking are among the exogenous causes (1, 2). AGEs are naturally present in most foods and can also form during food processing, packaging, and storage. Dry heat processing methods such as frying, grilling, and barbecuing lead to more AGEs formation compared to moist heat methods like boiling or steaming (3). The two most common types of AGEs found in foods are N-epsilon-carboxymethyllysine (CML) and N-epsilon-carboxyethyllysine (CEL). CML is the first identified and most studied (2).

Chronic diseases associated with aging are one of the most significant health problems of the 21st century. The incidence rates of non-communicable diseases, such as cardiovascular diseases, type 2 diabetes, and osteoporosis are increasing particularly in Western countries (2, 4). AGEs negatively impact health due to their known effects on proinflammatory and prooxidant pathways involved in the pathogenesis of chronic diseases (5, 6). Therefore, exposure to AGEs is crucial from a clinical perspective. The negative effects of high dietary AGEs accumulate over the years due to the glycation of proteins and their deposition in tissues (4). The most effective way to reduce AGEs formation in the body is to limit AGEs intake through diet. As a result, the number of studies focused on reducing AGEs formation has increased in recent years (7, 8). There is no study in Türkiye that has evaluated dietary AGE intake in older adults. To the best of our knowledge, this is the first study to assess dietary AGE intake in older adults using data from the 2010 and 2017 national nutrition and health surveys and to compare AGE exposure over the years.

This study was conducted to assess dietary AGEs intake in older adults in Türkiye, examine the contribution of foods to AGEs intake, and evaluate the relationship between the diet AGEs content and energy and nutrient intake.

MATERIALS AND METHOD

Study design

The study utilized data from the 'Türkiye Nutrition and Health Survey (TNHS)' conducted nationally in Türkiye in 2010 and 2017. TNHS 2010 and TNHS 2017 are comprehensive nutrition and health surveys conducted by the Ministry of Health of the Republic of Türkiye (T.C.), with sample sizes that represent the national population (9, 10). A total of 1374 individuals aged 65 years or over in the TNHS 2010 database and 1913 in the TNHS 2017 database were included in the study. Older adults with low (<500 kcal/day) or excessive (>5000 kcal/day) energy intake were excluded. Official permission for the use of the data was obtained from the T.C. Ministry of Health, and ethics committee approval (GO 21/344) was obtained from Hacettepe University Noninterventional Clinical Research.

Dietary intake and anthropometric measurement

In the TNHS 2010 and TNHS 2017 studies, individual food consumption records of older adults were obtained using 24-hour dietary recalls (9, 10). The program Nutrition Information System (BeBIS) 8.1 was used to calculate the daily energy and nutrient intake. Anthropometric measurements of the older adults were taken by trained personnel following measurement techniques (9, 10) and evaluated by sex (11). Body mass index (BMI) was calculated by dividing body weight (kg) by height squared (m^2), and the World Health Organization (WHO) classification was used to assess its compliance with the standard (11). A waist-to-hip ratio greater than 0.90 in men and 0.85 in women was considered a high risk for metabolic complications, while a waist-to-height ratio greater than 0.5 was considered the cut-off point for cardiovascular and metabolic risk (12).

Determination of dietary advanced glycation end products

The AGEs content of the diet was calculated based on the food consumption amounts in the 24-hour dietary recalls in the TNHS 2010 and 2017 databases. The CML database, prepared by Uribarri et al. (13), was used for the calculation. For foods not included in the database, the CML value of the food most similar in terms of content, preparation, and cooking methods was used. The dietary AGEs intake of the older adults was evaluated according to energy intake and divided into tertiles. Estimated dietary intake (EDI), which expresses the estimated daily AGEs exposure, was calculated by dividing the daily AGEs intake of the older adults by their body weight (14).

Statistical analysis

The data were analyzed with the SPSS 23.0 package program. Categorical data are presented as numbers (n) and percentages (%), while quantitative data are expressed as means ($\bar{x}$) and standard deviations (SD). The mean dietary AGEs intake was adjusted for daily energy intake using the residuals method. For comparisons between two independent groups, the Mann-Whitney U test was used for continuous variables, while the linear trend Chi-square test was applied for categorical variables. For comparisons of more than two independent groups, the Kruskal-Wallis test was applied. Bonferroni correction was performed post hoc when the difference between groups was statistically significant. Correlation between variables were evaluated by Spearman's correlation. Values of $p<0.05$ were considered statistically significant.

RESULTS

Table 1 presents the general characteristics of the older adults according to dietary AGEs tertiles. No significant difference was found in age or sex distribution across dietary AGEs tertiles ($p>0.05$). In the TNHS 2010 study, the percentage of older adults with chronic diseases was higher in the T3 tertile ($p=0.034$). Although similar results were observed in the TNHS 2017 study, no significant difference was found ($p=0.082$). The differences in BMI, waist-hip ratio, and waist-height ratio averages between dietary AGEs tertiles were not significant ($p>0.05$). In the TNHS 2017 study, the percentage of older adults in the high-risk group according to waist-hip ratio and waist-height ratio classifications was higher in the T3 tertile compared to the T1 tertile ($p=0.048$, $p=0.047$, respectively).

The dietary AGEs intake and EDI averages of the older adults by year are shown in Figure 1. In the TNHS 2017 study, the dietary AGEs intake and daily EDI values of the older adults were 12193.73±8773.86 kU/day and 168.30±126.40 kU/(kg·day), respectively. These values were found to be higher than those in the TNHS 2010 study, which were 10391.59±7310.56 kU/day and 148.41±110.40 kU/(kg·day), respectively ($p<0.001$).

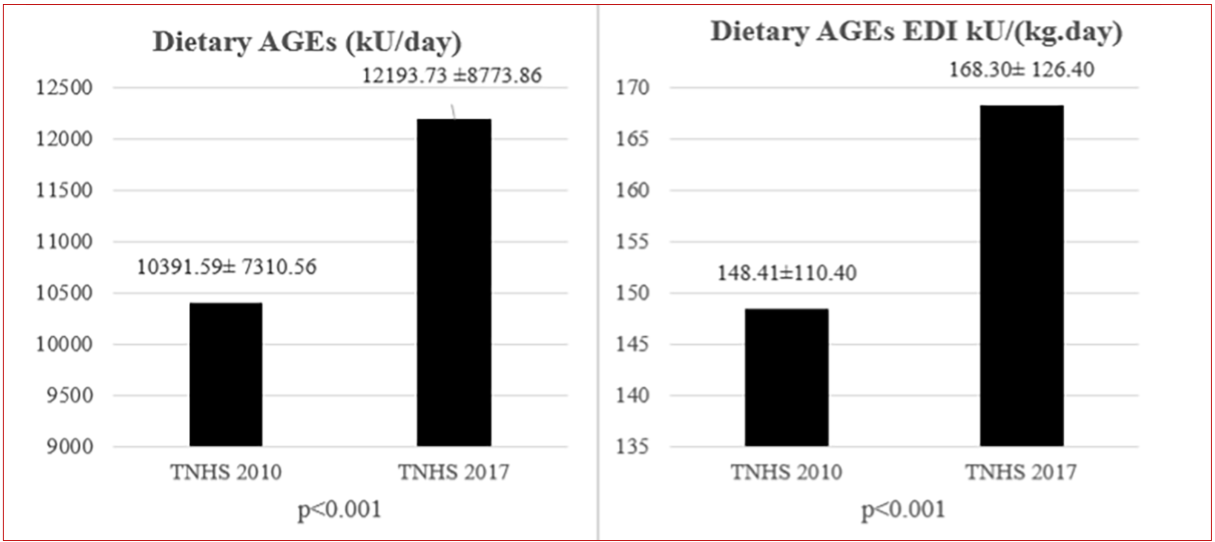
The contribution of foods to dietary AGEs intake is shown in Figure 2. In the TNHS 2010 and TNHS 2017 studies, the food groups that contributed

Table 1. General characteristics of older adults according to dietary AGEs tertiles.

	Dietary AGEs tertiles (KU/day)									
	TNHS 2010					TNHS 2017				
	n	T_1	T_2	T_3	p_1	n	T_1	T_2	T_3	P_2
Cut-off	1374	≤6365.38	6365.38-11659.71	≥11659.72		1913	≤8506.28	8506.29-12955.40	≥12955.41	
Characteristics N (%)										
Age (year) §	1374	73.8±6.27	73.8±6.08	72.7±6.07	0.985	1913	73.7±6.94	72.9±6.50	73.1±6.28	0.120
Sex	1374					1913				
Male		170 (37.1)	175 (38.2)	176 (38.4)	0.909		248 (38.9)	284 (44.5)	270 (42.3)	0.126
Female		288 (62.9)	283 (61.8)	282 (61.6)			389 (61.1)	354 (55.5)	368 (57.7)	
Chronic disease	1290					1891				
Yes		321 (73.5)	331 (77.2)	343 (80.9)	0.034		530 (83.9)	531 (84.3)	553 (87.9)	0.082
No		116 (26.5)	98 (22.8)	81 (19.1)			102 (16.1)	99 (15.7)	76 (12.1)	
Anthropometric measurements										
BMI (kg/m2) §	1235	28.95±5.67	29.28±5.65	29.19±5.40	0.660	1759	30.5±6.3	30.4±6.2	29.7±5.5	0.660
BMI classification	1233					1759				
Underweight		5 (1.2)	9 (2.2)	5 (1.2)	0.405		20 (3.4)	17 (2.8)	9 (1.6)	0.347
Normal		99 (23.6)	73 (18.0)	80 (19.7)			102 (17.5)	86 (14.4)	90 (15.5)	
Overweight		154 (36.7)	154 (37.9)	149 (36.6)			189 (32.5)	201 (33.6)	198 (34.2)	
Obese		162 (38.6)	170 (41.9)	173 (42.5)			271 (46.6)	294 (49.2)	282 (48.7)	
Waist-height ratio §	1238	0.62±0.10	0.63±0.09	0.62±0.08	0.394	1735	0.65±0.10	0.65±0.09	0.65±0.09	0.394
Waist-height ratio classification	1276					1735				
Normal		40 (9.5)	33 (8.1)	29 (7.1)	0.349		29 (5.1)	19 (3.2)	14 (2.4)	**0.048**
High risk		382 (90.5)	374 (91.9)	380 (92.9)			542 (94.9)	511 (96.8)	588 (97.6)	
Waist-hip ratio §	1292	0.92±0.10	0.92±0.09	0.92±0.08	0.190	1735	0.94±0.08	0.95±0.08	0.94±0.09	0.190
Waist-hip ratio classification	1292					1735				
Normal		117 (27.0)	116 (27.6)	101 (23.9)	0.926		107 (18.7)	81 (13.7)	85 (14.9)	**0.047**
High risk		317 (73.0)	304 (72.4)	321 (76.1)			464 (81.3)	511 (86.3)	487 (85.1)	

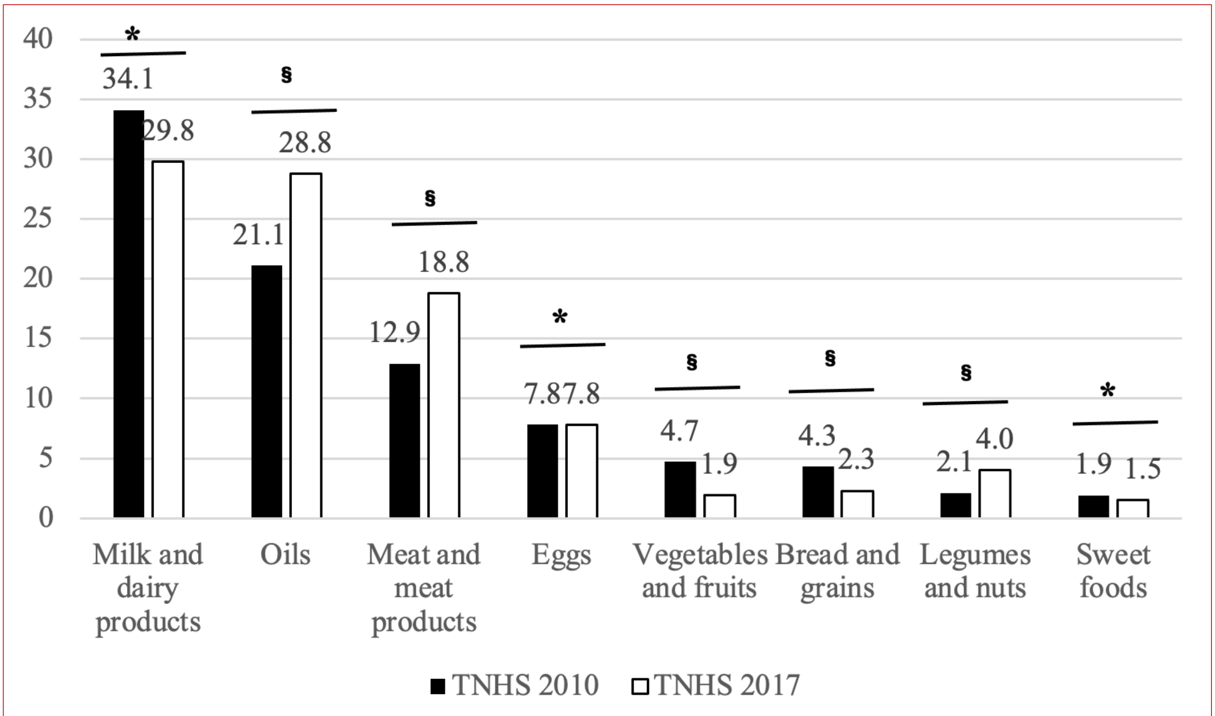
§ Values are means ± SD. Dietary AGEs adjusted for energy intake by using the residual method before calculating tertiles p values calculated with the Kruskal-Wallis test (continuous variables) or linear trend Chi-square test (categorical variables).(p_1:TNHS 2010, p2:TNHS 2017). Abbreviations: TNHS:Türkiye Nutrition and Health Survey, T:Tertile (T_1 the lowest and T_3 the highest), BMI: Body mass index

Figure 1. Dietary AGEs intake and EDI values according to TNHS 2010 and TNHS 2017.



Dietary AGEs adjusted for energy intake by using the residual method. (AGEs: Advanced glycation end products, EDI: Estimated dietary intake, TNHS: Türkiye Nutrition and Health Survey). Values are means ± SD. p -values calculated with Mann Whitney U test.

Figure 2. Contribution of food sources on dietary AGEs (%)



(TNHS: Türkiye Nutrition and Health Survey). p -values calculated with Mann Whitney U test.

§ p<0.001, * p>0.05

Table 2. Daily energy and nutrient intakes of older adults according to dietary AGEs tertiles.

	Dietary AGE tertiles (KU/day)							
	TNSH 2010 (n=1374)				TNSH 2017 (n=1913)			
	T1 (n=458)	T2 (n=458)	T3 (n=458)	P1	T1 (n=637)	T2 (n=638)	T3 (n=638)	P2
Energy (kcal)	1525.93±668.68	1456.75±549.34	1890.01±647.69	0.190	1520.27±611.28[a]	1627.45±635.06[bc]	1608.18±619.18[b]	**0.001**
Protein (%)	13.26±3.47[a]	13.39±3.87[a]	14.39±3.81[c]	**<0.001**	13.94±3.57[a]	14.83±3.89 [b]	15.34±4.00[c]	**<0.001**
Carbohydrate (%)	60.82±9.02[a]	52.45±8.81[b]	44.83±9.92 [c]	**<0.001**	57.45±10.33[a]	50.66±9.73[b]	47.80±11.04[c]	**<0.001**
Fiber (g)	22.29±11.90[a]	19.59±10.21[b]	16.55±9.59 [c]	**<0.001**	21.29±10.82[a]	22.04±11.37[a]	20.53±10.51[b]	**0.027**
Total Fat (%)	25.88±9.18[a]	34.60±9.09[b]	40.20±9.88[c]	**<0.001**	28.42±9.58 [a]	34.43±8.90[b]	36.70±10.09[c]	**<0.001**
Saturated fat (%)	6.99±3.38[a]	11.18±3.36[b]	15.37±5.3[c]	**<0.001**	8.83±3.97[a]	11.41±3.46[b]	13.50±4.73[c]	**<0.001**
Cholesterol (mg)	97.62±108.50[a]	167.08±147.20[b]	215.65±152.70[c]	**<0.001**	145.08±133.47[a]	203.10±155.42[b]	227.92±164.09[c]	**<0.001**
Vitamin B6 (mg)	1.30±0.68	1. 24±.0.59	1.18±0.58	0.050	1.01±0.57[a]	1.08±0.48[b]	1.31±0.68[b]	**<0.001**
Vitamin B12 (mg)	1.51±1.75[a]	2.37±4.14[b]	3.06±5.51[c]	**<0.001**	2.33±2.59 [a]	4.05±10.43[b]	5.07±12.72[c]	**<0.001**
Folic acid (µg)	329.09 ±173.67	317.41±145.64	292.16±143.60	0.092	289.99±159.15[a]	310.09±150.60[b]	358.61±195.12[b]	**<0.001**
Calcium (mg)	549.53±297.21[a]	567.31±282.82[a]	581.22±318.99[b]	**<0.001**	666.39±325.72[a]	710.44±302.19[b]	741.56±338.49[b]	**<0.001**
Iron (mg)	10.22±5.34[a]	9.54±4.54[a]	9.05±4.53[c]	**0.006**	8.30±4.22[a]	9.46±4.65[b]	9.21±4.93[b]	**<0.001**
Zinc (mg)	7.72±3.45	7.71±3.62	7.92±3.58	0.484	6.89±3.41[a]	8.30±3.85 [b]	8.47±4.38 [b]	**<0.001**

Values are means ± SD. Dietary AGEs adjusted for energy intake by using the residual method before calculating tertiles . p_1 and p_2 values calculated with Kruskal-Wallis test . (p_1:TNHS 2010, p_2:TNHS 2017). Bonferroni correction was performed as post hoc. Abbreviations: TNHS: Türkiye Nutrition and Health Survey, T:Tertile (T_1 the lowest and T_3 the highest)

Table 3. Correlation between food sources and dietary AGEs.

	Dietary AGEs (kU/day)			
	TNHS 2010 (n=1374)		TNHS 2017 (n=1913)	
Food sources	r	p_1	r	p_2
Milk and dairy products	0.584	**<0.001**	0.611	**<0.001**
Meat and meat products	0.474	**<0.001**	0.475	**<0.001**
Eggs	0.217	**<0.001**	0.212	**<0.001**
Legumes and nuts	0.119	**<0.001**	0.110	**0.018**
Bread and grains	0.067	**0.014**	0.014	0.535
Vegetables and fruits	0.144	**<0.001**	0.190	**<0.001**
Oils	0.401	**<0.001**	0.408	**<0.001**
Sweet foods	0.156	**<0.001**	0.132	**<0.001**

p values calculated with Spearman correlation. ($p_{1:}$TNHS 2010, $p_{2:}$TNHS 2017). Abbreviations: TNHS:Türkiye Nutrition and Health Survey

most to dietary AGEs intake were meat and meat products, oils, and milk/dairy products. In terms of food consumption, the contribution of oils, meat/meat products, legumes and seeds to dietary AGEs intake increased over the years, while the contribution of vegetables and fruits decreased (p<0.001). The contribution of milk/dairy products and sweet foods to dietary AGEs intake did not change (p>0.05).Table 2 presents the daily energy and nutrient intakes of the older adults according to dietary AGE intake tertiles. According to TNHS 2017 and 2010 data, daily energy intake was higher in the T3 tertile than in the T1 tertile (p=0.001, p>0.05, respectively). In both studies, the intakes of protein (%), fat (%), saturated fat (%), cholesterol, vitamin B6 (TNHS 2017), vitamin B12, folic acid (TNHS 2017), calcium, iron, and zinc (TNHS 2017) were higher in the T3 tertile (p<0.05), while carbohydrate (%) and fiber intakes were lower (p<0.001).

The relationship between the amount of food consumed by the older adults and dietary AGEs intake is presented in Table 3. A moderate (r=0.584) and a high (r=0.611) significant relationship were found between dietary AGEs intake and milk/dairy products consumption in the TNHS 2010 and TNHS 2017 studies, respectively (p<0.001). In both studies, a moderate relationship was found between dietary AGEs intake and meat/meat product consumption (r=0.474, r=0.475, respectively; p<0.001), and fat consumption (r=0.401, r=0.408, respectively; p<0.001). A weak relationship was found with egg consumption (r=0.217, r=0.212, respectively; p<0.001). A low level of relationship was found between the consumption of legumes and seeds, bread and cereals (TNHS 2010), vegetables and fruits, and sugary foods and dietary AGEs intake (p<0.05). In the TNHS 2017 study, no association was found between the consumption of bread and cereals and dietary AGEs intake (p>0.05).

DISCUSSION

As life expectancy increases worldwide, the prevalence of chronic diseases in later life has also risen (15). It is well-established that environmental factors and lifestyle habits, alongside the genetic structure of older adults, play a significant role in the development of these diseases (16). Among lifestyle habits, dietary factors hold particular importance. Numerous studies have highlighted a strong association between the adoption of healthy eating patterns (e.g., Dietary Approaches to Stop Hypertension (DASH) diet, Mediterranean diet) and the prevention or development of chronic diseases (17, 18). However, it is believed that factors closely associated with consumed foods, such as acrylamide intake (19) and AGEs intake (6), are related to aging and the development of chronic diseases. This study assessed the dietary AGEs intake of the older adults, evaluated the contributions of different food sources to AGEs intake, and investigated its association with various parameters. This study is the first to evaluate dietary AGEs intake in the older adults using data from the 2010 and 2017 national nutrition and health surveys conducted in Türkiye. As aging progresses, AGE accumulation in the body increases, while AGEs excretion decreases. Consequently, exogenous AGEs become the primary source of AGEs in the body (6). In the TNHS 2010 and TNHS 2017 studies, no significant differences were observed in sex, age, and anthropometric measurements across dietary AGEs intake tertiles ($p>0.05$). According to TNHS 2010 data, the percentage of older adults with chronic diseases was lower in the T3 tertile ($p=0.034$), whereas no significant difference was observed in the TNHS 2017 study ($p=0.082$) (Table 1). This may be attributed to older adults adopting healthier diets as a response to the increased prevalence of chronic diseases with aging (20, 21). With aging, the metabolism of dietary AGEs absorption and excretion changes, leading to an increase in the accumulation of AGEs in tissues. Therefore, assessing dietary AGEs intake and developing nutritional recommendations to reduce intake are essential for protecting the health of older adults (6).

Obesity is defined as abnormal and excessive fat accumulation, and according to the WHO, the waist-hip ratio reflects the distribution of body fat. An increase in the waist-hip ratio elevates the risk of chronic diseases, such as type 2 diabetes and cardiovascular diseases, as well as obesity-related morbidities (11). In this study, the mean waist-height ratio values of older adults according to dietary AGEs tertiles were found to be above 0.5 in all tertiles. In the TNHS 2017 study, the proportion of older adults at risk for metabolic diseases, as determined by waist-hip and waist-height ratio classifications, was significantly higher in the T3 tertile ($p<0.001$) (Table 2). During the aging process, the reduction in total energy expenditure, resulting from decreases in both basal metabolic rate and physical activity, affects nutrition and overall health, leading to an increase in body fat mass and a decrease in muscle mass (16). Therefore, interpreting the relationship between dietary AGEs intake and anthropometric measurements in the older adults can be challenging.

The dietary AGEs intake and daily EDI values in the older adults were found to be higher in the TBSA 2017 compared to the TBSA 2010 ($p<0.001$) (Figure 1). This indicates that the dietary AGEs intake among the older adults increased over the seven-year period. In a study conducted by Almajwal et al. (6), dietary AGEs intake in the older adults was reported to be 13121±6785.1 kU/day in male and 14712±6122.8 kU/day in female. Urribarri et al. (14) classified dietary AGEs intake exceeding 15000 kU/day as high AGEs intake. The average dietary AGE intake among older adults in Türkiye is lower compared to findings from other studies. In Türkiye, the Mediterranean diet is the traditional dietary pattern that is, rich in vegetables, fruits, legumes, whole grains, and oilseeds, and low in red meat, processed meat and refined sugar (22). For this reason, the Mediterranean diet, which is also widely followed in Türkiye, contains low amounts of AGEs (3). According to the NOVA classification, processed and ultra-processed foods are the primary sources of AGEs (3, 14). Limited access to processed foods among the older adults can also contribute to their low dietary AGEs intake (7). However, considering the negative effects of AGEs on health, the increasing dietary AGEs intake and exposure in Türkiye over the years is a concerning trend.

Dietary AGEs are known to be high in processed foods and meat products, particularly those with high protein and fat content (3, 14). According to national data, the contribution of oils, meat/meat products, legumes, and oilseeds to dietary AGEs intake in the older adults has increased over the years ($p<0.001$), while the contribution of milk/dairy products and sweet foods has remained unchanged ($p>0.05$) (Figure 2). Additionally, diets high in AGEs are characterized by higher levels of saturated fat and cholesterol, which are associated with the consumption of meat/meat products, as well as milk/dairy products (5). In the study, energy, protein (%), fat (%), saturated fat (%), and cholesterol intake were higher in the high T3 tertile (Table 2). However, in the TNHS 2010 study, no significant difference in energy intake was observed between dietary AGEs tertiles. The results of studies examining the relationship between dietary AGEs content and energy intake are quite heterogeneous (20, 23). This variability is likely due to the differing energy contributions of the nutrients that contribute to dietary AGEs intake. In fact, the TNHS 2010 study showed that the contribution of meat/meat products, as well as fats, to dietary AGE intake was lower compared to the TNHS 2017 study (Figure 2). In the T3 tertile, carbohydrates (%) was lower, in contrast to the higher protein and fat (%) ($p<0.001$) (Table 2). The AGEs contents of a diet rich in protein and fat may differ from those of a diet rich in carbohydrates, even if the energy intake is the same (24). Similar results have been reported in other studies, which attribute this to the high water and antioxidant content of complex carbohydrates and fiber-rich foods (5, 23). However, in the T1 tertile, protein (%), carbohydrates (%), fat (%), and fiber intake align with the nutritional recommendations for the older adults (Table 2). When consumed with adequate liquid, the fiber from legumes, whole grains, vegetables, and fruits can help prevent common age-related conditions such as constipation and diverticulosis. Additionally, high-fiber diets play a key role in the prevention and management of diabetes, cardiovascular diseases, and obesity (16). Since meat/meat products, which are high in dietary AGEs, are also rich in vitamin B6, vitamin B12, iron, and zinc, and milk/dairy products are sources of vitamin B12 and calcium, the intake of these nutrients was found to be higher in the T3 tertile compared to the T1 tertile in our study (Table 2). Due to decreased energy requirements and changes in nutrient absorption in the older adults, it is important to prioritize foods that are low in energy but rich in micronutrients (16). However, to avoid increasing AGEs intake, cooking methods that minimize AGEs formation should be preferred. Moist heat cooking methods are effective alternatives to dry heat cooking methods, as they reduce AGEs formation in foods (1). In Turkish cuisine, the use of local spices, herbs, and plants is quite common. The frequent use of spices and herbs in food preparation not only enhances flavor but also reduces the formation of AGEs due to their antioxidant properties (7). One study reported that spices, such as cloves, allspice, cinnamon, tarragon, rosemary, ginger, black pepper, and bay leaf, possess antiglycation properties. The results of the study highlight the potential of natural plant extracts and spices as a strategy to reduce AGE formation in foods (25). Additionally, for older adults, adding spices to low-salt or salt-free meals enhances the flavor and makes them easier to eat (22).

A moderate significant relationship was found between milk/dairy product consumption and dietary AGEs intake in the TNHS 2010 study, and a strong significant relationship was found in the TNHS 2017 study ($p<0.001$). In both studies, there was a moderate relationship between meat/meat product consumption, fat consumption, and dietary AGEs intake, and a weak relationship with egg consumption ($p<0.001$) (Table 3). To reduce dietary AGEs intake, it is recommended to limit the consumption of fatty meats, full-fat milk/dairy products, and processed foods. Additionally, cooking methods should involve short cooking times at low temperatures and moist heat, such as boiling and steaming, and meats should be marinated (3, 13). To reduce dietary AGE intake, attention should be paid to the variety of vegetables and fruits in the diet, as well as the use of herbal products such as spices with high antioxidant content (7, 25). These recommendations are in line with general healthy eating guidelines and it is suggested that an individual's preference for healthy food groups and the consumption of foods prepared using healthy cooking methods will positively contribute to reducing the AGE load in the body (1, 3). Dietary guidelines should include sample menus of traditional Turkish recipes with low-AGE content for all age groups. Due to the high prevalence of chronic diseases in older adults, it is recommended to develop personalized dietary guidelines (22).

This study has limitations. As a cross-sectional study, it is not suitable for establishing a cause-and-effect relationship. The database used to calculate dietary AGEs intake consists of 549 foods and, is commonly employed in studies. However, this database does not include AGEs values for foods specific to each culture. As a result, analogy was used to determine the AGEs content of some foods. The study also has several strengths. The use of TNHS 2010 and 2017 data, which represent a national sample of Türkiye, is one of its strengths. Additionally, this is the first study to evaluate dietary AGEs intake in the older adults on a national scale. Given the rising prevalence of chronic diseases associated with aging, reducing dietary AGEs intake is crucial for maintaining health. This study evaluated the dietary AGEs intake among the older adults in Türkiye and the contribution of various nutrients to AGEs intake. The findings may contribute to the development of dietary recommendations aimed at reducing AGEs intake in older adults.

CONCLUSIONS

This study is the first in Türkiye to calculate dietary AGEs intake using the National Nutrition and Health Survey database of the older adults. Dietary AGEs intake and exposure were found to be higher in the TNHS 2017 study compared to the TNHS 2010 study. The food groups that contribute the most to dietary AGEs intake were meat/meat products, fats, and milk/dairy products. The results show a correlation between dietary AGEs intake and the consumption of meat/meat products, milk/dairy products, fats, and eggs. Given the increase in dietary AGEs intake and exposure over the years in Türkiye, nutritional recommendations and dietary models should be developed to reduce dietary AGEs intake. Additionally, laboratory studies are needed to determine the AGEs content of foods in Türkiye.

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