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Original Article

Adiponectin in spinal cord injury: What is the role of nutrition in serum adiponectin concentration?

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ABSTRACT

Objectives: The study aimed to analyze the relationship between serum adiponectin concentration, Mediterranean diet (MD) adherence, and Dietary Approaches to Stop Hypertension (DASH) diet adherence in patients with spinal cord injury (SCI).

Patients and methods: Thirty-three SCI patients (21 males, 12 females; median age: 33 years; range, 18 to 65 years) and 33 age-, sex-, and body mass index-matched healthy controls (21 males, 12 females; median age: 33 years; range, 18 to 64 years) were included in this cross-sectional study between March 2021 and March 2022. Serum adiponectin concentrations of all participants were measured. Body weight, height, and neck, hip, waist, and mid-upper arm circumferences were measured. Twenty-four-hour dietary records were obtained by the researchers for evaluation of the nutritional status. The DASH diet score and MD score were measured for each participant.

Results: Most of the cases of SCI were due to motor vehicle collisions (n=12, 36.4%) and complete paraplegic. Mid-upper arm circumference, waist circumference, hip circumference, and neck circumference of the patient group were significantly higher than the control group ($p=0.020$, $p=0.002$, $p=0.042$, and $p<0.001$, respectively). Mediterranean diet scores and DASH diet scores of the patient group were significantly higher than the control group ($p<0.001$ and $p=0.031$, respectively). Serum adiponectin concentration of patients was significantly higher than the control group ($p=0.049$). No correlation was detected between adiponectin concentration, MD score, and DASH diet score in both groups.

Conclusion: Although correlation analysis in the current research did not show significant relation between nutrition and adiponectin concentrations, nutrition of patients with SCI, as demonstrated by higher adherence to MD and DASH, may have provided positive effects on adiponectin concentrations. Future studies focused on the effect of a healthy diet intervention on serum adiponectin concentration is warranted.

Keywords: Adiponectin, diet, nutrition, spinal cord injuries.

Patients with chronic spinal cord injury (SCI) are at high risk of metabolic issues, such as type 2 diabetes mellitus, obesity, and cardiovascular diseases.[1] Through appropriate medical management, the life expectancy of these patients has improved, but the rate of mortality is still higher than in the healthy population.[1,2] Therefore, considering the SCI incidence per year, any intervention that will improve the health and quality of life of this patient group would be invaluable.

Adiponectin is a polypeptide hormone that is mainly released from adipocytes.[3] It has extensive regulatory functions on many systems, such as the endocrine, musculoskeletal, and nervous tissues. It can regulate the glucose and fatty acid metabolism.[4] Adiponectin shows its effects in the body mainly through its three main receptors. These receptors are AdipoR1 (adiponectin receptor 1), AdipoR2 (adiponectin receptor 2), and T-cadherin.[5] While AdipoR1 and AdipoR2

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are involved in regulating oxidative stress and inflammation, T-cadherin decreases oxidative stress and protects vascular endothelial cells from oxidative damage.[6]

It is predicted that adiponectin concentrations are relatively higher (about 5 to 10 µg/mL) compared to other hormones in the peripheral blood, thus making it easier to test and can be defined as a potential biomarker.[7] Although it is a hormone released from adipose tissue, particularly studies in obese people reveal that adiponectin concentration is inversely related to the amount of adipose tissue.[8,9] In patients with SCI, such an inverse relationship was also reported between adiponectin concentration, body mass index (BMI), and visceral fat.[10] It is known that after SCI, a decrease in lean body mass and an increase in fatty tissue occurs, and this change in body composition has some negative health consequences on basal metabolic rate and glucose regulation.[11] It is also reported that disorders in the innervation of the sympathetic nervous system may have effects on both adipose tissue composition and adiponectin concentration.[12]

Recent studies on adiponectin concentration in patients with SCI indicated some inconsistent results. Wang et al.[13] reported that patients with SCI have a higher adiponectin concentration than healthy controls, but Liu et al.[14] reported that serum adiponectin concentrations of SCI patients were significantly lower. Additionally, it is well indicated that adiponectin concentration is in close relation to metabolic profile and body composition in patients with SCI.[10,12]

In healthy subjects, it is known that an appropriate dietary pattern can positively affect serum adiponectin concentrations.[15] Diets high in polyunsaturated fatty acids, monounsaturated fatty acids, polyphenols, and fiber can increase adiponectin concentrations, while diets rich in saturated fatty acids, trans fatty acids, red meat, monosaccharides, and disaccharides can show negative effects on serum adiponectin concentrations. The Mediterranean diet (MD) and Dietary Approaches to Stop Hypertension (DASH) diets are well known for their cardiac and vascular protective effects.[16,17] The MD is rich in vegetables, fruits, nonrefined whole grains, nuts, and plants. It includes a low amount of red meat, fish, domestic fowl products, dairy products, fish, sugar, and alcohol.[16] The DASH diet primarily aims to decrease blood pressure and is rich in nutrients such as calcium, fat-free proteins, potassium, fiber, and minerals. In addition to lowering blood pressure, it also decreases oxidative stress and inflammation.[18] However, there is lack of data about the effect of nutrition on adiponectin concentrations in SCI patients. Considering the effects of the MD and DASH diet, we hypothesized that circulating adiponectin would be positively related to MD and DASH diet adherence in patients with SCI.

PATIENTS AND METHODS

Thirty-three SCI patients (21 males, 12 females; median age: 33 years; range, 18 to 65 years) and 33 age-, sex-, and BMI-matched healthy controls (21 males, 12 females; median age: 33 years; range, 18 to 64 years) were included in this cross-sectional study. Patients were recruited from the outpatient clinic of the Ankara Bilkent City Hospital Physical Medicine and Rehabilitation Hospital, and the control group were recruited from healthy caregivers between March 2021 and March 2022 by random sampling. The diagnosis of SCI was based on the revised 2019 American Spinal Cord Injury International Standards for Neurological Classification of Spinal Cord Injury.[19] Patients with a history of SCI for at least six months and injury level above T10 (upper motor neuron lesions) were included. Patients with other chronic diseases or autonomic dysfunction were excluded. Smokers were excluded from both groups. Participant characteristics are given in Table 1.

Peripheral blood samples of participants were collected between 06:00 AM and 07:00 AM after an overnight fasting period. The whole blood samples were centrifuged (3000 g, 10 min), and the serum samples were separated into Eppendorf tubes. Tubes were stored in a refrigerator at −80°C and thawed for use before analysis. Adiponectin was measured by colorimetric enzyme-linked immunosorbent assay (Quickey Adp/Acrp30; Elabscience, Texas, USA). Routine laboratory test results of patients, such as fasting blood glucose and lipid profile, were obtained from hospital records.

Height (cm), body weight (kg), neck circumference (cm), mid-upper arm circumference (MUAC), hip circumference, and waist circumference were measured. A wheelchair scale was used to measure the body weight of the patients (Chinesport Platform Scale XWU003; Chinesport, Udine, Italy). First, the patient was weighed while in a wheelchair. Afterward,

TABLE 1
General characteristics of the participants

	Patient group				Control group				
	n	%	Median	Min-Max	n	%	Median	Min-Max	*p*
Age (year)			33.0	18.0-65.0			33.0	18.0-64.0	0.990
Sex									0.601
Female	12	36.4			12	36.4			
Male	21	63.6			21	63.6			
Marital status									0.325
Married	19	57.6			15	45.5			
Single	14	42.4			18	54.5			
Education level									0.003
Primary school	17	51.5			4	12.1			
Secondary-High School	10	30.3			19	57.6			
University or higher	6	18.2			10	30.3			

the weight of the wheelchair used by the patient was measured when it was empty, and this weight was subtracted from the total weight. Body weight of the control group was also measured via the same scale while standing. These measurements were done when the participants were hungry and wearing light clothes. Self-reported height of the patients was recorded, and height of the control group was measured while standing using a stadiometer. Participants' BMI was determined using the formula body weight divided by height squared (kg/m^2). Waist circumference measurement was done at 2 cm distal to the umbilicus, and hip circumference measurement was done at the widest perimeter. Neck circumference measurement was done with a nonelastic tape from the most protrusive point of thyroid cartilage. Mid-upper arm circumference was measured at the midpoint between the tip of the shoulder and the tip of the elbow.[20]

Twenty-four-hour dietary records were obtained by the researchers to evaluate the nutritional status of the participants. Volumes and portion sizes were assessed using a food catalog with photographs of 120 different foods.[21] The BeBiS pro software version 7.2 (Bebispro for Windows, Stuttgart, Germany; Turkish Version, 2010) was used to calculate the daily intake of macro- and micronutrients and energy.[22]

The DASH diet score was formulated by using eight different components of the diet: vegetables, fruit, legumes, dairy products (low fat), nuts, whole grains, low sodium intake, red and processed meat, and sweetened drinks.[23] For each component, patients were divided into quintiles based on their intake using the 24-hour dietary record. For fruits, vegetables, legumes, low-fat dairy products, nuts, and whole grains, quintile 1 was given 1 point, and quintile 5 was given 5 points. For sweetened drinks, processed and red meat, and sodium due to low intake were grouped in the lowest quintile and given 5 points, and the highest quintile was given 1 point.[24] Scores for each component were summed to yield a total DASH diet score in the range of 8 to 40. Higher scores indicate better DASH diet adherence.

Participants' MD adherence was evaluated via the Mediterranean Diet Adherence Screening Tool.[25] It contains 14 items in total (12 items for habitual preferences of consumption or intake and an additional two items for MD-related dietary routine). According to adherence to MD, if the state in that item is met, 1 point is assigned, and if the state is not met, no point is assigned. A person can have a maximum of 14 points, and higher scores show better MD adherence. The tool has validity for Turkish.[26] Scores of MD were divided into three groups related to adherence: ≤6 low, 7-8 acceptable, and ≥9 high.[27]

Statistical analysis

Sample size was determined using the Stata version 16.0 (StataCorp., College Station, TX, USA) program. The sample size was calculated to be a minimum of 10 in each group, with a 0.05 significance level and a power of 0.95, considering a previous study.[13]

All statistical analysis were done using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous data were shown as median (min.-max.) due to nonparametric distribution, and categorical data were shown as numbers and percentages. The normality of data distribution was evaluated using the Kolmogorov-Smirnov test. The Mann-Whitney U test was used to compare continuous variables between groups, and the Pearson chi-square test was used to compare categorical variables between groups. The Spearman test was used for correlation analysis. A p-value <0.05 was considered statistically significant.

RESULTS

Main characteristics of the participants are given in Table 1. Both groups were similar in age, sex, and marital status (p>0.05). Education level of the control group was higher than the patient group (p=0.003).

Main characteristics about SCI are given in Table 2. Median disease duration was 10 (6-84) months. Most of the cases of SCI were due to motor vehicle collisions (n=12, 36.4%), a fall from elevated height (n=7, 21.2%), and gunshot wounds (n=5, 15.1%). Majority of the patients were paraplegic and completely injured.

In Table 3, anthropometric measurements, nutritional parameters, and biochemical analysis of the participants are demonstrated. There was no significant difference between the patient and control groups in weight, height, BMI, and waist/hip ratio. Mid-upper arm circumference, waist circumference, hip circumference, and neck circumference of the patient group were significantly higher than the control group (p=0.020, p=0.002, p=0.042, and p<0.001, respectively).

Patient groups' Mediterranean diet scores and DASH diet scores were significantly higher than the control group (p<0.001 and p=0.031, respectively). Serum adiponectin concentration of patients was significantly higher than control group (p=0.049). There was no correlation between serum adiponectin concentration and BMI, MUAC, and waist, hip, and neck circumferences (p>0.05, Table 4). Similarly, no correlation was detected between adiponectin, MD score, and DASH diet score in both groups (patient group rs=−0.102, p=0.573; rs=−0.205, p=0.252, respectively) (control group Spearman's rank correlation coefficient [rs]=−0.075, p=0.680; rs=−0.255, p=0.153, respectively; Figures 1a, 1b, 2a, 2b).

When the patients and controls were grouped according to MD adherence, there was no difference between low, moderate, and high score groups in serum adiponectin concentrations (p=0.861 and p=0.050, respectively).

TABLE 2
Main patient characteristics

	Patient group			
	n	%	Median	Min-Max
Months since injury			10.0	6.0-84.0
Etiology				
Motor vehicle collisions	12	36.4		
Fall from elevated height	7	21.2		
Gunshot wound	5	15.1		
Diving into shallow water	3	9.1		
Crush under heavy load	2	6.1		
Other (disc herniation)	4	12.1		
ASIA injury classification				
A	10	30.4		
B	8	24.2		
C	8	24.2		
D	7	21.2		
Neurological level of injury				
Tetraplegia	7	21.2		
Paraplegia	26	78.8		
Need for caregiver				
Yes	25	75.8		
No	8	24.2		

TABLE 3
Anthropometric measurements of the participants

	Patient group		Control group		
	Median	Min-max	Median	Min-max	*p*
Weight (kg)	76.0	46.0-95.0	75.0	50.0-95.0	0.918
Height (cm)	172.0	153.0-196.0	172.0	154.0-180.0	0.723
Body mass index (kg/m^2)	24.7	17.8-34.1	25.5	18.3-38.2	0.817
MUAC (cm)	28.5	19.0-37.0	16.0	12.0-40.0	0.020
Waist circumference (cm)	94.0	70.0-121.0	88.0	60.0-108.0	0.002
Hip circumference (cm)	104.0	82.0-156.0	98.0	70.0-125.0	0.042
Waist/hip ratio	0.9	0.71-1.12	0.8	0.64-1.17	0.649
Neck circumference (cm)	37.0	28.0-44.0	30.0	20.0-45.0	<0.001
Mediterranean diet score	5.0	2.0-12.0	3.0	0.0-7.0	<0.001
DASH diet score	24.0	15.0-33.0	20.0	13.0-30.0	0.031
Serum adiponectin (pg/mL)	5.7	0.8-8.1	5.1	0.7-9.8	0.049
Fasting blood glucose (mg/dL)	86.0	74.0-115.0	NA	NA	
Total cholesterol (mg/dL)	169.0	83.0-260.0	NA	NA	
Triglyceride (mg/dL)	121.0	51.0-394.0	NA	NA	
Low density lipoprotein (mg/dL)	105.0	43.0-184.0	NA	NA	
High density lipoprotein (mg/dL)	38.0	26.0-60.0	NA	NA	
Very low density lipoprotein (mg/dL)	24.0	10.0-79.0	NA	NA	
Systolic blood pressure (mmHg)	110.0	80.0-130.0	NA	NA	
Diastolic blood pressure (mmHg)	70.0	50.0-80.0	NA	NA	

MUAC: Mid upper arm circumference; DASH: Dietary Approaches to Stop Hypertension; NA: Not applicable.

TABLE 4
Correlation between serum adiponectin level and anthropometric measurements

	Patient group		Control group	
	Serum adiponectin		Serum adiponectin	
	rs	*p*	rs	*p*
Body mass index (kg/m^2)	−0.120	0.507	0.027	0.883
MUAC (cm)	0.243	0.173	0.158	0.381
Waist circumference (cm)	0.043	0.813	0.176	0.327
Hip circumference (cm)	−0.029	0.873	0.003	0.985
Neck circumference (cm)	0.075	0.678	0.142	0.429

MUAC: Mid upper arm circumference.

DISCUSSION

In this study, the investigated topics were the comparison of serum adiponectin concentration of patients with SCI and healthy subjects and correlation between serum adiponectin concentration and healthy nutrition parameters. Briefly, patients with SCI had higher serum adiponectin concentrations, MD scores, and DASH diet scores than the healthy subjects, but serum adiponectin concentrations were not in correlation with these diet scores. As expected, anthropometric measurements of the patients with SCI showed some differences compared to healthy subjects.

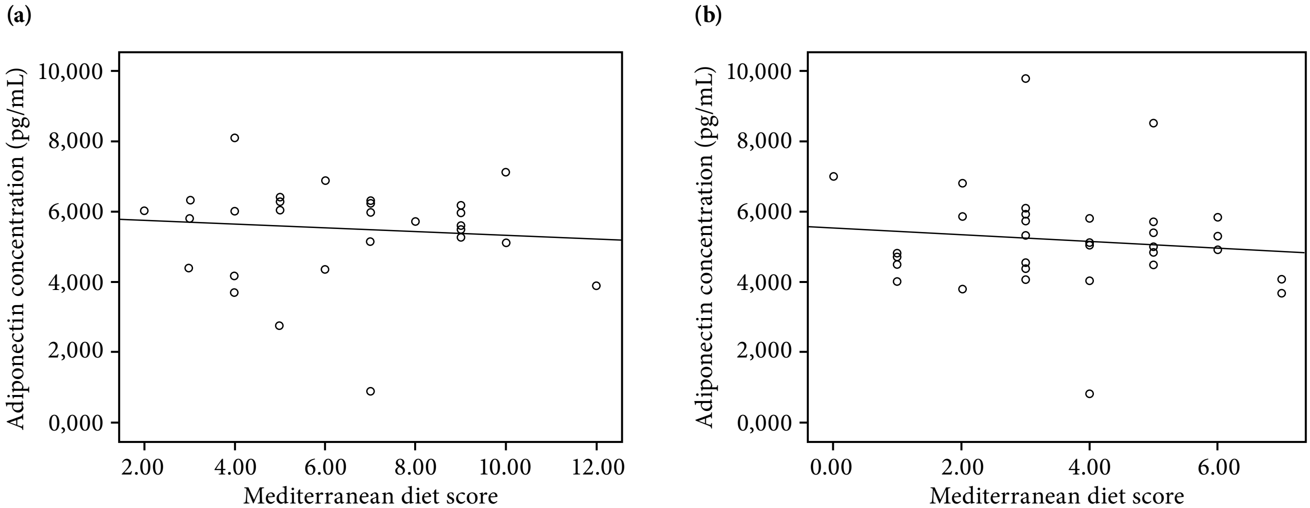

Figure 1. (a) Correlation between serum adiponectin concentration and Mediterranean diet score in patient group. **(b)** Correlation between serum adiponectin concentration and Mediterranean diet score in control group.

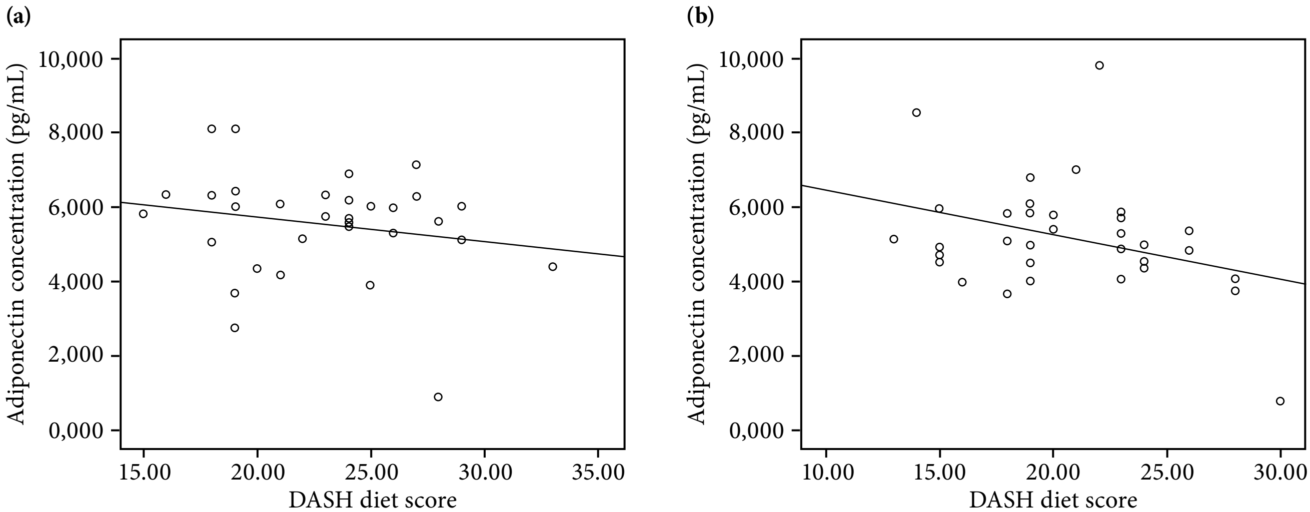

Figure 2. (a) Correlation between serum adiponectin concentration and DASH diet score in patient group. **(b)** Correlation between serum adiponectin concentration DASH diet score in control group.

DASH: Dietary Approaches to Stop Hypertension.

The role of adiponectin in SCI has not been accurately reported yet. There are studies indicating close relation between adiponectin and metabolic profile in SCI patients, and there are also studies indicating that serum adiponectin can be used as one potential marker for the risk of osteoporosis in SCI patients.[12,28] There is an inconsistency regarding serum adiponectin concentrations in these patients and how these serum concentrations differ from healthy individuals. Liu et al.[14] reported that mean serum adiponectin concentration of patients with SCI (6.1±1.1 µg/mL) was significantly lower than healthy subjects (6.7±0.9 µg/mL). In contrast, Wang et al.[13] found that the mean serum concentration of patients with SCI (7.1±0.5 ng/mL) was higher than healthy subjects (5.6±0.5 ng/mL); however, the difference was not significant. In the current study, serum adiponectin concentration was found to be significantly higher in favor of the patients with SCI (p=0.049). In addition, there is heterogeneity in the minimum and maximum concentrations of adiponectin between studies. In a patient group with chronic SCI, Maruyama et al.[10] reported that serum adiponectin concentrations ranged from 2.91 µg/mL to 37.2 µg/mL. Both the differences between groups in the studies and the differences in serum adiponectin ranges may be due to the differences in the characteristics of the patients included, as well as the methods used to determine the serum adiponectin concentration.

Higher scores of MD and DASH diet indicate better dietary habits related to cardioprotective effects and better metabolic profile.[29] In the current study, the patient group showed better scores than the healthy group regarding adherence to MD and DASH diet. Better dietary quality scores of patients may suggest that they are likely to follow healthy eating habits for spinal cord recovery. Previously, it was mentioned that healthy eating habits can positively affect serum adiponectin concentrations. In addition, due to dietary fatty acid pattern and western type eating habits, lower serum adiponectin concentrations may occur.[15] In the current study, no relationship was found between diet scores and serum adiponectin concentrations, nor was there a difference in serum adiponectin concentrations between participants grouped according to MD (low, acceptable, and high score group) scores. It is known that in SCI, particularly in acute and subacute periods of injury, an inflammatory process is present.[30] Due to this inflammatory process, positive systematic effects of healthy nutrition on serum adiponectin concentrations may not be fully reflected.

After SCI, marked changes in body composition occur due to the level of injury and severity of injury. Due to high level of physical inactivity, patients with SCI have a lower lean mass and higher fat mass than the healthy population.[31] The location of the fat mass also changes in this patient group. In a study, it was reported that compared to healthy subjects, patients with SCI had greater fat mass at the arm, leg, and the whole body.[32] In the current study, statistically significant differences were found in body composition. Mid-upper arm circumference, waist circumference, hip circumference, and neck circumference were significantly increased compared to healthy controls. Previously, an inverse relationship between adiposity and serum adiponectin concentrations was reported.[8,9] In this study, increased serum adiponectin concentration despite increased adipose tissue in the mentioned body regions was inconsistent with previous reports.[8,9] It can be supposed that high adherence to MD and DASH diet would have prevented a decrease in serum adiponectin concentration as in obesity. In addition, the patient group's lipid profile being between normal ranges could also be due to high adherence to MD and DASH diet.

Data about the effect of nutrition on serum adiponectin concentration is mostly on the healthy population. Fargnoli et al.[33] included 1922 women in their study and reported that total serum adiponectin concentrations were 24% higher with adherence to the Alternate Healthy Eating Index in participants in the highest quartile compared to participants in the lowest quartile. Additionally, in an epidemiologic study regarding MD adherence, adiponectin concentrations were 41% higher in participants of the highest tertile compared to those in the lowest tertile.[34] Sureda et al.[35] observed higher serum adiponectin concentrations in adult men with high adherence to MD, but same high concentrations were not detected in women. The DASH diet also showed similar effects on serum adiponectin concentrations. According to results of a study that included 122 women, serum adiponectin concentration of participants in highest tertile of adherence scores was 20% higher.[36] The beneficial effect of both diets on serum adiponectin is due to the presence of bioactive elements and components such as polyphenols, omega-3 fatty acids, fiber, and vitamins.[15,37] In the current study, the patient group's MD scores and DASH diet scores were higher than the control group. In addition, serum adiponectin concentrations were higher than the control group. However, the correlation analysis between diet scores and adiponectin concentrations was under the border of statistical significance.

The current study has some limitations. Body composition analysis would be valuable to assess total body fat and whole-body composition despite local anthropometric measurements. Although the patient group was physically inactive, considering the potential effects of physical activity on serum adiponectin concentration, data collection about the physical activity of the control group would provide this comparison. Despite these limitations, the comparison of the results of the patient group with an age-, sex-, and BMI-matched control group was a strength of the current study. In most of the studies on SCI, only BMI was used to assess body composition. However, it is known that BMI may not be a sensitive indicator in this patient group.[38] In the current study, to assess body composition, additional measurements were made from multiple sites in addition to BMI.

To the best of our knowledge, this study is the first about the relationship between serum adiponectin concentrations and nutrition in SCI patients. Although correlation analysis in the current research did not show significant relation between nutrition and adiponectin concentrations, nutrition of patients with SCI may have provided positive effects on adiponectin concentrations, as demonstrated by higher adherence to MD and DASH. Future work focused on the effect of a healthy diet intervention on serum adiponectin concentration is warranted.

Ethics Committee Approval: The study protocol was approved by the Ankara Bilkent City Hospital Ethics Committee (date: 24.02.2021, no: 2021-E2-21-89). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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