Association of Diet Quality and Sleep Duration with IgG Levels and Serum Lipids in Two-Dose COVID-19 Vaccinated Volunteers*

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Abstract

Aim: This study aimed to investigate the associations of sleep duration, diet quality, and body fat classification with IgG levels, biochemical parameters, and anthropometric measurements in volunteers who received two doses of the COVID-19 vaccine.

Method: A total of 61 volunteers participated in the study. Biomarkers, anthropometric measurements, physical activity, sleep duration, and serum IgG levels were assessed. Dietary Quality Index-2015 (DQI-2015) and nutrient intake were calculated using the CeviCal program based on food frequency data.

Results: Individuals with short sleep duration had significantly higher fasting blood sugar levels compared to those with normal sleep duration ($p<0.05$). Individuals with long sleep duration had higher serum IgG levels compared to those with normal sleep duration ($p=0.029$). LDL cholesterol levels were lower in individuals who consumed alcohol, while T3 levels were lower in smokers ($p<0.05$). Total cholesterol, non-HDL cholesterol, and waist circumference values were higher in individuals with poor diet quality ($p<0.05$). Total cholesterol and triglyceride levels were found to be higher in obese individuals ($p<0.05$). The increase in IgG levels was found to be associated with an increase in fasting serum glucose levels, and a moderate positive correlation was found between these parameters ($p<0.001$, $r=0.445$). IgG levels were significantly lower in individuals with high daily vitamin C intake ($p=0.037$). 25(OH)D levels were lower in individuals with active physical activity levels compared to inactive individuals ($p<0.05$).

Conclusion: Short sleep duration, poor diet quality, and obesity have been associated with adverse changes in glucose, lipid profile, and anthropometric measurements. Long sleep duration has been associated with higher IgG levels, while high vitamin C intake has been associated with lower IgG levels. Additionally, increased IgG levels have been associated with higher glucose levels. Larger sample studies are needed to confirm these findings.

Keywords: Diet quality, COVID-19 vaccine, serum IgG, sleep duration.

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ETHICAL STATEMENT: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethical Committee of Avrasya University number 2022-52. Written informed consent was obtained from all subjects.

İki Doz COVID-19 Aşısı Yapılan Gönüllülerde Diyet Kalitesi ve Uyku Süresinin IgG Düzeyleri ve Serum Lipidleri ile İlişkisi

Öz

Amaç: Bu çalışma, iki doz COVID-19 aşısı alan gönüllülerde uyku süresi, beslenme kalitesi ve vücut yağ sınıflandırması ile IgG düzeyleri, biyokimyasal parametreler ve antropometrik ölçümler arasındaki ilişkileri araştırmayı amaçlamıştır.

Yöntem: Çalışmaya toplam 61 gönüllü katılmıştır. Biyobelirteçler, antropometrik ölçümler, fiziksel aktivite, uyku süresi ve serum IgG seviyeleri değerlendirilmiştir. Besin tüketim sıklıkları kullanılarak CeviCal programı aracılığıyla Diyet Kalite İndeksi-2015 (DQI-2015) ve besin öğeleri hesaplanmıştır.

Bulgular: Kısa uyku süresine sahip bireylerin açlık kan şekeri seviyeleri, normal uyuyanlara kıyasla anlamlı derecede daha yüksek bulunmuştur ($p<0,05$). Uzun uyku süresine sahip bireylerin serum IgG seviyeleri, normal uyuyanlara kıyasla daha yüksek tespit edilmiştir ($p=0,029$). Alkol kullanan bireylerde LDL kolesterol düzeyleri daha düşük, sigara içenlerde ise T3 düzeyleri daha düşük bulunmuştur ($p<0,05$). Diyet kalitesi düşük bireylerde toplam kolesterol, non-HDL kolesterol ve bel çevresi değerleri daha yüksek bulunmuştur ($p<0,05$). Obez bireylerde toplam kolesterol ve trigliserit düzeyleri daha yüksek tespit edilmiştir ($p<0,05$). IgG seviyelerindeki artış, açlık serum glukoz seviyelerinde artış ile ilişkili bulunmuş ve bu parametreler arasında orta düzeyde pozitif korelasyon saptanmıştır ($p<0,001$, $r=0,445$). Günlük C vitamini alımı yüksek olan bireylerin IgG seviyeleri anlamlı şekilde daha düşük bulunmuştur ($p=0,037$). Aktif fiziksel aktivite düzeyine sahip bireylerde, pasif bireylere kıyasla 25(OH)D düzeyleri daha düşük bulunmuştur ($p<0,05$).

Sonuç: Kısa uyku süresi, düşük diyet kalitesi ve obezite; glukoz, lipid profili ve antropometrik ölçümlerde olumsuz değişiklikler ile ilişkilendirilmiştir. Uzun uyku süresi daha yüksek IgG düzeyleri ile ilişkili bulunurken, yüksek C vitamini alımı daha düşük IgG düzeyleri ile ilişkilendirilmiştir. Ayrıca, artmış IgG düzeyleri daha yüksek glukoz seviyeleri ile ilişkili bulunmuştur. Bulguların doğrulanması için daha geniş örneklemli çalışmalara ihtiyaç vardır.

Anahtar Sözcükler: Diyet kalitesi, COVID-19 aşısı, serum IgG, uyku süresi.

Introduction

Type 2 diabetes (T2DM) and cardiovascular diseases are increasingly common public health problems. In addition to genetics, modifiable environmental factors such as diet style and physical activity play an important role in these diseases. The best strategy to slow the development of chronic diseases is to adopt healthy lifestyle factors, regular physical activity, and an adequately balanced diet[1].

In addition to type 2 diabetes and cardiovascular diseases, disorders of thyroid function are also quite common. It is known that changes in thyroid function will also affect several health problems. Therefore, it becomes important to know the associations between thyroid hormones and lifestyle[2].

During the COVID-19 pandemic, individuals with diabetes and cardiovascular disease may have had a weaker immune response to the vaccine. Serum IgA, IgG, and IgM levels have been measured to assess immunity post-vaccination[3].

High fasting blood sugar and serum lipids may be associated with a suppressed immune response[4]. Additionally, lifestyle factors like smoking and alcohol use are known to affect serum IgG levels[5].

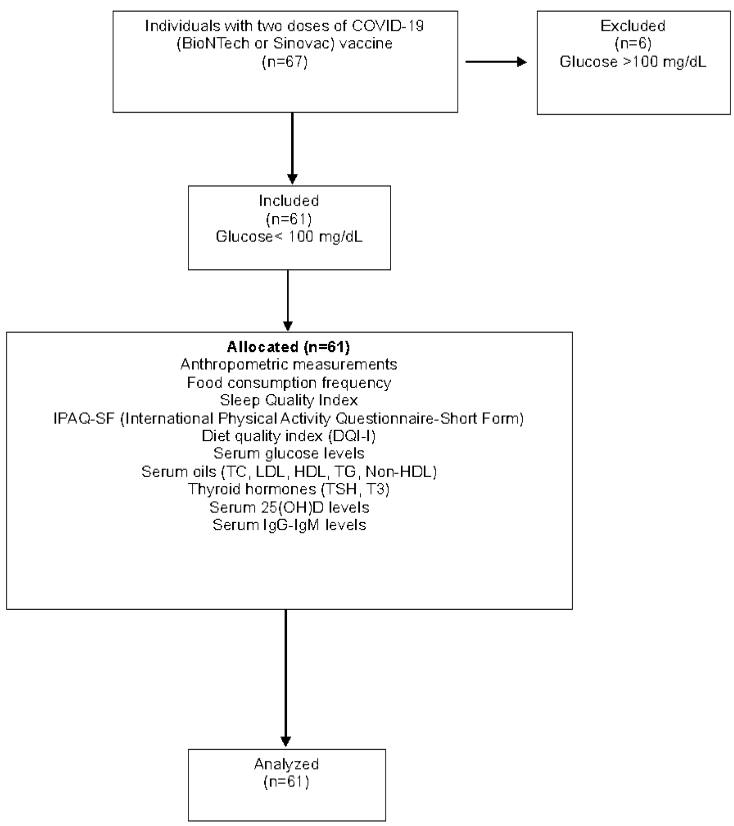
To our knowledge, while several studies have examined the relationship between lifestyle factors and biochemical findings, the association between lifestyle factors and the humoral immune response to COVID-19 vaccination, assessed by serum IgG levels, has not been sufficiently investigated. This study aimed to investigate the associations of sleep duration, diet quality, body fat percentage, smoking, alcohol consumption, physical activity, and selected nutrient intakes with serum IgG levels and metabolic parameters in individuals who received two doses of the COVID-19 vaccine.

Material and Methods

Study Population

This cross-sectional observational study included 61 healthy volunteers (49 women, 12 men, aged 19-32) in Trabzon, all having received two doses of the COVID-19 vaccine (BioNTech and Sinovac).

Figure 1. Flow chart of study



Participants with health issues were excluded. Anthropometric measurements, a food consumption frequency questionnaire, sleep hours, and the International Physical

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Activity Questionnaire-Short Form (IPAQ-SF) were collected. The Diet Quality Index (DQI-I) was calculated from the food frequency forms. Biochemical data, including thyroid hormones, serum 25(OH)D, and IgG levels, were measured. All data were then analyzed (Figure 1).

In the G*Power analysis conducted on 61 people, the power was 96%. The time interval between the second vaccine dose and blood sampling was recorded and evaluated as a potential confounder.

Measurement of Serum IgG Levels

All samples were stored in serum form at -80 degrees, and then the serums were thawed, and IgG levels were measured with the SD Biosensor F200 Analyzer device's Fluorescent Immunological (FIA) method[6]. If IgG levels are less than 1, it is considered negative. Also IgG; was classified as low (0-2.99 COI), medium (3.00-3.99 COI), medium-high (4.00-4.25 COI), and high (4.26-4.75 COI), and this planning was considered according to the research reviewed[7–10]. The antibodies measured give IgG levels of the COVID-19 vaccine. It does not show the total IgG level. In addition, the SD F200 device expresses the measured IgG levels in COI ("cut off") units[6,11]. IgG kits are manufactured by SD Biosensor and originate from South Korea.

Determination of Serum 25-hydroxy D Vitamin Level

SD Biosensor F200 Analyzer device was completed with the Fluorescent Immunological (FIA) method to determine the serum 25(OH)D levels of individuals[11]. The measurement of these two parameters is identical to the method used in a previous study[12].

Measurement of Fasting Serum Glucose Level

It was noted that the individuals were fasting for at least 8-12 hours before measurement. Accu-Chek Performa Nano device was used to measure fasting serum glucose[13].

Measurement of Serum Lipid Level

Total cholesterol (TC), triglyceride (TG), low-density lipoprotein (LDL), high-density lipoprotein (HDL), and non-HDL cholesterol (non-HDL) values of the individuals were measured. For this measurement, the Standard LipidoCare Analyzer device and Lipid Profile Test Strip were used[14,15]. The measurement of these two parameters is identical to the method used in a previous study[12].

Serum Thyroid Stimulating Hormone (TSH) Level Measurement

SD F200 Biosensor Analyzer device was used to determine serum TSH (thyroid stimulating hormone) and T3 (triiodothyronine) levels. The measurement of these two parameters is identical to the method used in a previous study[12].

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Anthropometric Measurements

Using the TANITA MC-780MA device, based on the bioelectric impedance analysis (BIA) method, individuals' weight, body fat, waist circumference, waist-hip ratio, internal fat level, basal metabolic rate, protein, muscle, and mineral levels were measured. TANITA brand stadiometer was used for height measurement.

Calculation of Diet Quality and Duration of Sleep

Dietitians collected annual food consumption frequency data, and diet quality was assessed using the Diet Quality Index-2015 (DQI-I). Sleep duration was classified as low (<7 hours), normal (7-8 hours), and high (>8 hours)[16].

Ethical Statements

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethical Committee of Avrasya University number E-69268593-050-14073 date 02.08.2022. Written informed consent was obtained from all subjects.

Statistical Analysis

Statistical analysis was performed using R language in RStudio version 0.98.501, and figures were created in Microsoft 365 Excel. The Shapiro-Wilk/Kolmogorov-Smirnov tests were used to check normality. Continuous variables are presented as mean ± SD. For normally distributed data, the independent t-test was used for independent groups, and the dependent t-test for dependent groups. For non-normally distributed data, the Wilcoxon Signed Ranks Test was used for dependent groups and the Mann-Whitney U test for independent groups. A p-value <0.05 was considered statistically significant. Post hoc power analysis was performed using G*Power (v3.1.9.7) for the primary outcome based on a two-tailed correlation test, with an effect size of 0.45, an alpha level of 0.05, and a total sample size of 61, yielding a statistical power of 0.96. The CeviCal software is a nutrition analysis program based on the Turkish food composition database and calculates energy and nutrient intake from food frequency data. Diet quality scores (DQI-I) are generated using standard scoring algorithms. The program is widely used in dietary assessment studies in adults[17].

Results

This study included 61 healthy individuals (49 women, 12 men) aged 21.80±2.56 years, all vaccinated with two doses of COVID-19 (BioNTech or Sinovac). No significant difference was found in vaccination times ($p>0.05$). Socio-demographic data, anthropometric measurements, food consumption frequency, sleep duration, and IPAQ-SF were recorded. The Diet Quality Index (DQI-I) was calculated, and biochemical measures (fasting serum glucose, TC, LDL, HDL, Non-HDL, TG), thyroid hormones (TSH, T3), serum 25(OH)D, and IgG levels were assessed.

Table 1. Comparison of alcohol and cigarette use in healthy volunteers with parameters

	Alcohol Classification			Smoking Classification		
	Drinking (n=30)	**Non-Drinking (n=31)**	**p**	**Smoking (n=21)**	**Non-Smoking (n=40)**	**p**
Fasting serum glucose (mg/dL)	87.79±8.58	87.98±10.78	0.947*	89.95±9.12	86.93±10.47	0.275*
LDL (mg/dL)	76.18±17.05	92.80±29.67	**0.038***	82.05±28.70	89.55±26.37	0.366*
HDL (mg/dL)	50.88±12.50	48.37±12.56	0.490*	46.58±12.90	50.33±12.26	0.286*
Non-HDL (mg/dL)	91.18±15.90	100.33±32.27	0.273*	93.78±28.10	99.34±28.86	0.500*
TC (mg/dL)	148.68±27.1	149.95±31.77	0.882*	144.11±29.45	152.13±30.43	0.343*
TG (mg/dL)	96.17±82.51	80.89±68.05	0.185**	71.82±18.80	92.81±87.05	0.668**
TSH (mg/dL)	1.52±0.70	1.53±0.95	0.638**	1.66±0.91	1.47±0.87	0.391**
T3 (mg/dL)	2.26±0.52	2.34±0.84	0.910**	2.03±0.40	2.45±0.84	**0.039****
25(OH)D (mg/dL)	11.38±1.46	15.89±11.29	0.116**	16.62±13.08	13.44±7.32	0.957**
IgG (COI)	3.63±1.03	3.80±0.73	0.573**	3.65±1.01	3.79±0.73	0.967**
Weight (kg)	69.29±12.07	62.49±11.74	**0.042***	67.488±12.64	63.21±11.83	0.201*
Height (cm)	167.47±7.28	164.05±7.22	0.092*	167.65±7.36	163.88±7.12	0.059*
BMI (kg/cm2)	24.64±3.57	23.21±4.06	0.190*	23.95±3.79	23.51±4.05	0.688*
Waist (cm)	81.11±10.75	75.26±16.59	0.165*	79.75±11.36	75.77±16.69	0.341*
Waist/Hip (cm)	0.82±0.06	0.79±0.07	0.172*	0.82±0.07	0.79±0.06	0.227*
Mineral (%)	5.12±0.91	5.08±0.94	0.874*	5.26±0.89	5.02±0.94	0.341*
Protein (%)	15.58±1.69	16.06±1.71	0.308*	15.91±1.85	15.92±1.66	0.983*
PBF (%)	24.14±7.91	23.64±7.71	0.817*	22.41±7.91	24.46±7.62	0.333*
BMR (kcal)	1603.42±263.45	1456.26±210.04	**0.023***	1594.46±290.31	1457.05±192.76	**0.032***

LDL: Low density lipoprotein, HDL: High density lipoprotein, TC: Total cholesterol, TG: Triglyceride, TSH: Thyroid stimulating hormone, T3: Triiodothyronine, Immunoglobulin G: IgG, (25 (OH)) D vitamin: 25 (OH) D, Body mass index: BMI, Body fat percentage: PBF, Basal metabolic rate: BMR,

[a] Data are expressed as mean ± SD.

* Independent sample t-test was used to determine p values in parametric cases, ** Mann Whitney U test was used in nonparametric cases.

While weight and BMR (Basal metabolic rate) values of alcohol users were higher than those who did not use alcohol, LDL levels were found to be lower. In smokers, the T3 level was lower than in non-smokers, but the BMR value was higher in smokers. No significant difference was observed in terms of other parameters (Table 1).

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Table 2. Comparison of the diet quality index (DQI-I) of healthy volunteers with the parameters[a]

DQI-I CLASSIFICATION	Low-quality nutrition (n=33)	Medium-quality nutrition (n=28)	p
Fasting serum glucose (mg/dL)	89.52±10.15	86.04±9.82	0.181*
LDL (mg/dL)	94.05±28.18	79.67±24.21	0.060*
HDL (mg/dL)	50.07±12.97	48.07±12.09	0.548*
Non-HDL (mg/dL)	105.10±30.19	89.44±24.55	**0.039***
TC (mg/dL)	158.91±31.16	138.44±25.07	**0.008***
TG (mg/dL)	99.29±96.91	71.28±22.38	0.250**
TSH (mg/dL)	1.41±0.82	1.65±0.94	0.487**
T3 (mg/dL)	2.44±0.83	2.19±0.66	0.149**
25(OH)D (mg/dL)	16.45±12.56	12.17±2.72	0.373**
IgG (COI)	3.91±0.56	3.55±1.05	0.354**
Weight (kg)	67.36±12.58	61.37±11.01	0.055*
Height (cm)	165.39±7.34	164.79±7.50	0.751*
BMI (kg/cm2)	24.56±3.96	22.60±3.72	0.052*
Waist (cm)	81.09±12.11	72.35±17.17	**0.024***
Waist/Hip	0.82±0.07	0.78±0.06	0.061*
Mineral (%)	5.09±0.88	5.11±0.98	0.936*
Protein (%)	15.52±1.57	16.38±1.77	0.051*
PBF (%)	25.23±7.15	22.09±8.13	0.114*
BMR (kcal)	1538.24±243.57	1459.50±223.53	0.197*

LDL: Low density lipoprotein, HDL: High density lipoprotein, TC: Total cholesterol, TG: Triglyceride, TSH: Thyroid stimulating hormone, T3: Triiodothyronine, Immunoglobulin G: IgG, (25 (OH)) D vitamin: 25 (OH) D, Body mass index: BMI, Body fat percentage: PBF, Basal metabolic rate: BMR,

[a] Data are expressed as mean ± SD.

* Independent sample t-test was used to determine p values in parametric cases, ** Mann Whitney U test was used in nonparametric cases.

When looking at diet quality, individuals with low diet quality were determined to have higher TC, Non-HDL levels, and waist circumference than those with normal diet quality (Table 2).

Table 3. Comparison of body fat percentages of healthy volunteers with the parameters[a]

Body fat ratio classification	Obesity (n=26)	Normal-weight (n=32)	P
Fasting serum glucose (mg/dL)	89.23±9.04	86.88±10.67	0.375*
LDL (mg/dL)	87.15±25.64	86.26±27.16	0.909*
HDL (mg/dL)	51.17±12.01	47.81±12.90	0.328*
Non-HDL (mg/dL)	102.58±24.88	92.38±29.06	0.181*
TC (mg/dL)	157.69±23.21	142.10±33.00	**0.049***
TG (mg/dL)	95.30±72.25	80.81±77.41	**0.005****
TSH (mg/dL)	1.63±1.00	1.49±0.80	0.594**

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T3 (mg/dL)	2.40±0.92	2.28±0.65	0.687**
25(OH)D (mg/dL)	16.31±11.74	13.25±7.87	0.208**
IgG (COI)	3.99±0.73	3.76±0.92	0.595**
Weight (kg)	71.19±9.09	58.91±11.12	**<0.001***
Height (cm)	163.58±6.13	166.34±8.38	0.166*
BMI (kg/cm2)	26.59±2.87	21.16±2.68	**<0.001***
Waist (cm)	85.92±8.36	69.40±15.34	**<0.001***
Waist/Hip avg. (cm)	0.84±0.05	0.77±0.06	**<0.001***
Mineral avg. (%)	4.63±0.81	5.54±0.80	**<0.001***
Protein (%)	14.57±0.84	16.99±1.47	**<0.001***
PBF (%)	30.57±4.06	18.12±5.31	**<0.001***
BMR (kcal)	1536.19±162.32	1469.63±275.87	0.282*

LDL: Low density lipoprotein, HDL: High density lipoprotein, TC: Total cholesterol, TG: Triglyceride, TSH: Thyroid stimulating hormone, T3: Triiodothyronine, Immunoglobulin G: IgG, (25 (OH)) D vitamin: 25 (OH) D, Body mass index: BMI, Body fat percentage: PBF, Basal metabolic rate: BMR,

[a] Data are expressed as mean ± SD.

* Independent sample t-test was used to determine p values in parametric cases, ** Mann Whitney U test was used in nonparametric cases.

TC and TG levels were found to be higher in individuals with obesity compared to those with normal body fat percentage. In addition, weight, BMI, waist, waist/hip ratio, and BPF values of obese individuals were determined to be higher than normal individuals. The amount of protein and minerals was higher in individuals with normal fat content. There was no difference in terms of other biochemical findings and anthropometric measurements (Table 3).

Table 4. Comparison of sleep duration of healthy volunteers with parameters[a]

Sleep Duration	Low (n=17)	Normal (n=26)	High (n=17)	p[a]	p[b]	p[c]
FSG (mg/dL)	92.94±11.35	84.19±9.57	89.41±6.68	**0.009***	0.057*	0.277*
LDL (mg/dL)	85.84±28.57	84.93±26.79	92.66±28.08	0.924*	0.418*	0.530*
HDL (mg/dL)	49.19±11.71	52.32±12.09	45.06±12.93	0.418*	0.076*	0.352*
Non-HDL (mg/dL)	92.63±30.79	95.13±27.52	107.20±28.02	0.790*	0.194*	0.180*
TC (mg/dL)	146.53±30.89	149.20±30.04	155.00±30.82	0.781*	0.554*	0.437*
TG (mg/dL)	99.53±90.66	83.70±83.09	76.29±19.03	0.324**	0.227**	0.793**
TSH (mg/dL)	1.68±0.99	1.42±0.77	1.61±0.96	0.394**	0.504**	0.906**
T3 (mg/dL)	2.43±1.10	2.39±0.62	2.13±0.55	0.635**	0.173**	0.649**

25(OH)D (mg/dL)	11.72±1.43	15.96±11.97	15.16±10.34	0.747**	0.833**	0.973**
IgG (COI)	3.89±0.72	3.52±0.82	4.11±0.34	0.140**	**0.029****	0.683**
Weight (kg)	67.01±12.42	62.79±11.65	63.90±12.47	0.264*	0.768*	0.471*
Height (cm)	167.35±8.12	162.50±5.52	166.18±7.93	**0.024***	0.080*	0.672*
BMI (kg/cm2)	23.85±3.59	23.79±4.25	23.11±4.04	0.963*	0.603*	0.577*
Waist (cm)	76.34±22.57	77.35±12.00	76.88±11.09	0.850*	0.899*	0.929*
Waist/Hip(cm)	0.82±0.08	0.79±0.06	0.80±0.07	0.136*	0.625*	0.384*
Mineral (%)	5.23±0.85	4.79±0.86	5.36±1.00	0.110*	0.055*	0.684*
Protein (%)	15.95±1.52	15.78±1.84	16.11±1.80	0.746*	0.563*	0.786*
PBF (%)	23.20±6.59	26.03±7.34	21.47±8.75	0.207*	0.073*	0.519*
BMR (kcal)	1560.82±259.16	1424.04±153.17	1527.35±270.58	**0.031***	0.117*	0.710*

LDL: Low density lipoprotein, HDL: High density lipoprotein, TC: Total cholesterol, TG: Triglyceride, TSH: Thyroid stimulating hormone, T3: Triiodothyronine, Immunoglobulin G: IgG, (25 (OH)) D vitamin: 25 (OH) D, Body mass index: BMI, Body fat percentage: PBF, Basal metabolic rate: BMR,

[a] Data are expressed as mean ± SD.

Differences between low sleep duration and normal sleep duration (p^a), between normal sleep duration and high sleep duration (p^b) and between low sleep duration and high sleep duration (p^c).

$p^{a,b,c}$ *Independent sample t-test was used to determine p values in parametric cases, ** Mann Whitney U test was used in nonparametric cases.

It was determined that individuals with poor sleep had higher fasting blood glucose levels and BMR values than those with normal sleep. When normal sleep and excessive sleep were compared, serum IgG levels were found to be lower in those with normal sleep. No difference was seen in the parameters when comparing low sleep with high sleep (Table 4).

Table 5. Comparison of physical activity levels of healthy volunteers with parameters[a]

Physical Activity	Passive (n=8)	Middle (n=37)	Active (n=15)	p^a	p^b	p^c
Fasting serum glucose (mg/dL)	93.13±10.27	88.16±10.42	85.47±8.18	0.227*	0.375*	0.064*
LDL (mg/dL)	72.17±22.58	94.28±29.31	79.08±18.91	0.071*	0.105*	0.438*

HDL (mg/dL)	43.50±10.50	50.47±13.32	50.13±10.82	0.176*	0.932*	0.172*
Non-HDL (mg/dL)	84.25±22.70	104.24±31.25	89.93±21.47	0.098*	0.126*	0.565*
TC (mg/dL)	127.75±20.19	158.08±31.62	142.00±22.76	**0.013***	0.090*	0.157*
TG (mg/dL)	73.57±16.44	97.25±91.70	66.08±16.51	0.985**	0.254**	0.302**
TSH (mg/dL)	1.59±0.53	1.56±0.94	1.48±0.91	0.628**	0.649**	0.378**
T3 (mg/dL)	2.32±0.64	2.32±0.81	2.34±0.74	0.716**	0.871**	0.672**
25(OH)D (mg/dL)	12.10±1.22	16.69±11.83	10.49±0.74	0.667**	**<0.001****	**0.003****
IgG (COI)	4.21±0.24	3.79±0.73	3.60±0.80	0.217**	0.298**	0.081**
Weight (kg)	72.78±14.33	62.57±10.82	64.05±12.52	**0.028***	0.673*	0.144*
Height (cm)	174.38±6.16	163.19±5.94	164.13±7.23	**<0.001***	0.628*	**0.003***
BMI (kg/cm2)	23.91±4.45	23.52±4.05	23.68±3.74	0.809*	0.898*	0.895*
Waist (cm)	84.25±12.93	75.56±16.99	76.40±10.93	0.181*	0.861*	0.138*
Waist/Hip (cm)	0.85±0.07	0.79±0.07	0.79±0.06	**0.034***	0.824*	**0.046***
Mineral (%)	5.66±1.13	5.01±0.88	4.94±0.84	0.080*	0.793*	0.098*
Protein (%)	16.03±1.55	15.75±1.68	16.29±1.95	0.661*	0.315*	0.747*
PBF (%)	20.28±10.51	24.99±7.15	23.28±7.19	0.128*	0.438*	0.425*
BMR (kcal)	1738.63±277.49	1434.92±169.09	1501.53±238.49	**<0.001***	0.260*	**0.044***

LDL: Low-density lipoprotein, HDL: High-density lipoprotein, TC: Total cholesterol, TG: Triglyceride, TSH: Thyroid stimulating hormone, T3: Triiodothyronine, Immunoglobulin G: IgG, (25 (OH)) D vitamin: 25 (OH) D, Body mass index: BMI, Body fat percentage: PBF, Basal metabolic rate: BMR,

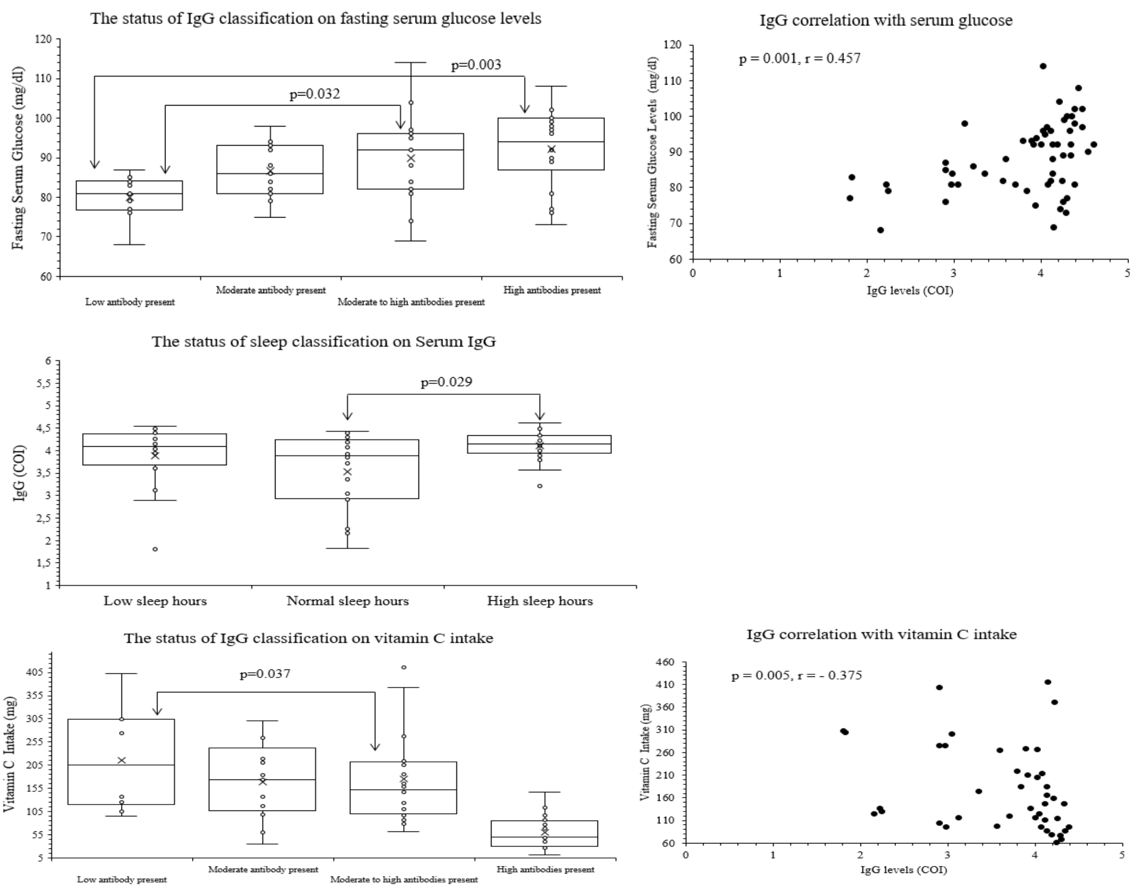
[a] Data are expressed as mean ± SD.

Differences were expressed as passive-middle differences (p^a), middle-active differences (p^b) and passive-active differences (p^c).

$p^{a,b,c}$ *Independent sample t-test was used to determine p values in parametric cases, ** Mann Whitney U test was used in nonparametric cases.

When physical activity levels were examined, individuals with moderate physical activity had significantly higher TC levels than passive individuals. At the same time, 25(OH)D and BMR levels of active individuals were significantly lower than passive individuals. Weight and waist-hip ratio were higher in passive individuals compared to active individuals (Table 5).

Figure 2. Evaluation of IgG and sleep duration



A significant positive moderate correlation was found between fasting serum glucose and serum IgG levels ($p<0.001$, $r=0.445$). Fasting serum glucose levels were found to be progressively higher across low, medium, and high IgG level categories, respectively ($p=0.032$, $p=0.003$). It was found that vitamin C intake from foods was higher at low IgG levels than at medium-high levels ($p = 0.037$). It was analyzed that there was a moderate negative correlation between IgG and vitamin C intake ($p=0.005$, $r=-0.375$) (Figure 2).

Discussion

Information regarding the exact time elapsed since the second vaccine dose, vaccine type distribution, and prior SARS-CoV-2 infection history was limited; therefore, these variables could not be included as covariates in the analyses and were considered as potential confounding factors. This study aimed to investigate the associations between smoking, alcohol, diet quality, body fat, sleep, physical activity, and IgG levels with biochemical and anthropometric parameters in two-dose COVID-19 vaccinated volunteers. Smoking and alcohol are known to affect metabolism both directly and indirectly. A study on Korean men found higher fasting blood glucose, LDL, and TG levels in smokers, increasing the risk of T2DM and lipid abnormalities[18]. Similarly, Cichosz et

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al. observed high LDL and TG and low HDL in smokers, but no effect on fasting blood glucose[19]. In this study, smoking had no impact on fasting blood glucose or lipid profiles.

Regarding alcohol consumption, both moderate and excessive alcohol use were associated with impaired fasting blood glucose. For example, in a study of nondiabetic women, excessive alcohol consumption was associated with increased fasting blood glucose[20]. In a large study by Sung on Korean men, alcohol drinkers were associated with higher fasting blood glucose, TG, HDL, and lower LDL levels than non-drinkers[21]. Similarly, in this study, LDL levels of those who consumed alcohol were found to be lower than those who did not consume alcohol, and there was no significant difference in fasting blood glucose, TG, HDL, and other parameters.

Alcohol and cigarette use have long been known to negatively affect vitamin D levels, with studies showing significantly lower serum 25(OH)D levels in smokers and alcohol users[22]. Contrary to existing literature, this study found no significant difference between smoking, alcohol consumption, and vitamin D levels.

The impact of alcohol and cigarette consumption on thyroid function remains unclear. A study by Gruppen et al. found smokers had higher T3 and lower TSH levels, while alcohol consumption >30g/day was linked to higher TSH and T3[2]. However, contrary to the literature, this study showed decreased T3 levels in smokers, with no significant effect on TSH from alcohol or cigarette consumption

Another important issue affected by smoking and alcohol consumption is serum IgG values, which are immune biomarkers in the body. It has been observed that smokers have lower IgG, and IgG levels decrease as a result of increased alcohol consumption[23]. Additionally, serum IgG levels of smokers were found to be lower than those of non-smokers, but no significant difference was detected with alcohol use[24]. In this study involving healthy individuals, no significant difference was observed between alcohol/cigarette consumption and serum IgG levels.

Dietary intake is known to affect body parameters in terms of both quantity and quality, and the DQI-I scale was used in this study. Daneshzad et al. found that individuals with high diet quality had lower fasting blood glucose, but no significant difference in HDL, LDL, TG, or TC[1]. Another study showed that better diet quality lowered fasting glucose and reduced LDL, TG, and TC[25]. Diet quality was also linked to waist circumference, with improvements correlating to smaller waist sizes in Mexican women[26]. In contrast, Murakami's study found a positive association between lower diet quality and waist circumference[27]. This study confirmed that poor diet quality is associated with higher non-HDL, TC levels, and larger waist circumference.

Quality and duration of sleep are crucial for normal function. Recent studies show that sleep disorders decrease insulin sensitivity, leading to higher blood sugar levels. This also affects lipid profiles. A study on diabetes patients found higher total cholesterol (TC) and fasting blood glucose levels in those with shorter sleep duration compared to those with longer or medium sleep duration. Thus, improving sleep quality may enhance glucose control and other parameters[28]. In one study, participants with poor sleep quality were associated with higher TC and lower HDL levels compared to those with good sleep quality[29]. Poor sleep quality has also been associated with higher TG levels[30]. In this study, the fasting blood glucose of those who slept poorly was found to be higher compared to those who slept normally, but no significant difference was observed in TC, TG, LDL, and HDL values.

The relationship between sleep quality and hormones has been known for many years. In a study, it was observed that TSH increased significantly in case of poor sleep[31]. In this study, no significant difference was found between sleep duration and TSH and T3 values.

A recent study found that sleep quality does not affect IgG, and the vaccine does not impact sleep quality[32]. In our research, individuals with longer sleep had higher IgG levels, but no significant difference was found between those with low sleep and those with normal sleep[33]. A study on stroke patients showed that 200 mg of daily vitamin C supplementation increased IgG levels, while another study with higher doses (1-3 g) found no effect[34]. The recommended daily intake of vitamin C is 75-90 mg[35]. In this study, low IgG levels were associated with high vitamin C intake from foods, while IgG levels were higher in individuals with vitamin C intake within reference values.

The formation of IgG due to the effect of the COVID-19 vaccine in diabetic pregnant women does not hurt glucose[36]. Although it has been stated that IgG values investigated in diabetic patients do not pose a risk to glucose levels[37], there are very few studies on this subject in the literature. Therefore, in this study, a positive moderate correlation was found between fasting serum glucose and IgG levels.

A study on Malaysian adults found that those with low or moderate physical activity had higher fasting blood glucose than active individuals[38]. Another study reported increased HDL levels after five weeks of training but no significant changes in LDL, TG, or TC[39]. Silva et al. found that moderate and high physical activity levels were linked to higher HDL and lower TG[40]. In this study, moderately active individuals had significantly higher TC than passive individuals, while no significant differences were observed in fasting glucose, LDL, HDL, or TG

Physical activity influences vitamin D levels, with studies showing more active individuals having higher 25(OH)D levels. Regular physical activity is associated with higher serum 25(OH)D[41]. However, in this study, moderately active and inactive individuals had higher levels than active ones. This may be due to the low vitamin D levels of most participants and their low sun exposure, but the finding aligns with existing literature.

Limitations of the study include self-reporting and questionnaire-based assessments, while strengths include the use of BIA for anthropometric data, dietitian-analyzed nutrient intake, and FIA for biochemical values.

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Another important limitation is the lack of detailed data on vaccine type distribution, time since the second dose, and previous SARS-CoV-2 infection, which are known to influence post-vaccination IgG levels. Therefore, the observed associations should be interpreted with caution.

Conclusion

This study found that alcohol use and moderate physical activity were associated with higher LDL levels, while smoking was associated with lower T3 levels. Poor diet quality was associated with higher TC and non-HDL levels. Low sleep duration was associated with higher fasting blood glucose, while high sleep duration was associated with higher serum IgG levels. Passive individuals and those with moderate physical activity had higher 25(OH)D levels compared to active ones. Increased IgG levels were associated with higher glucose levels, while high vitamin C intake was associated with lower IgG levels. In conclusion, sleep quality and diet may be associated with vaccine antibody levels, though further research is needed.

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Author Declarations

None of the authors had any conflicts of interest.

Credit Author Statement

Fatih Cesur designed the study and contributed to the performance of the intervention. Fatih Cesur performed the statistical analyses, and dietitians helped to prepare the final draft and analyzed the energy values calculation. Dietitians are mentioned in the acknowledgments section.

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