Original Article

Role of Branched and Aromatic Amino Acids, Diet Inflammatory Index, and Anthropometric Indices on Mental Health

Abstract

Background: Mental health disorders are one of the most important and increasing health problems in the youth of today's societies. Some dietary intake and body mass status are factors that affect mental health. This study aimed to investigate the relationship between the intake of branched-chain amino acids (BCAAs) and aromatic amino acids (AAAs) and anthropometric and dietary inflammatory indices with mental health, including depression, anxiety, and stress. **Methods:** In this case-control study, the data of 138 teenage girls aged 13–18 years were collected. Three-day 24-hour food recall and standard anthropometric methods were used to calculate the dietary inflammation intake score of normal and energy-adjusted diets. Mental health disorders were diagnosed by the DASS-21 questionnaire. Statistical analysis used Student's *t*-test, correlation, and multiple regression were used to analyze the data based on the study's statistical requirements. **Results:** Based on the findings, 59 (42%) of the girls had mental disorders, and 79 (58%) were healthy. The average weight of stressed people was significantly higher than that of healthy people, and the BMI of anxious people was significantly higher than that of nonanxious people ($P < 0.05$). A significant positive correlation was found between stress and weight and energy intake. Additionally, there was a significant negative correlation between BCAAs and mental health. The average intake of BCAAs was significantly lower in patients ($P = 0.01$). The trend analysis showed significantly lower BCAA levels among the 4th quartile of mental disorders. No significant relationship was observed between DII, AAA, and anthropometric indices. After adjustment of the results, no relationship was observed between mental health and the studied factors. **Conclusions:** BCAA might be related to mental health. Further studies in different age and sex groups are highly recommended.

Keywords: *Adolescents, aromatic amino acids, branched-chain amino acids, mental health*

Golnaz Majdizadeh, Mina Beytollahi, Abolghasem Djazayery[1], Ariyo Movahedi

Department of Nutrition, Science and Research Branch Islamic Azad University, Tehran, Iran, [1]Department of Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran

Introduction

Mental diseases include a large proportion of diseases in adolescents of all societies and are diagnosed after a long period of life.[1] Mental health disorders are related to other aspects of health in young people. It is very important to carry out more effective interventions and comprehensive and potential support for mental health diseases to treat a wide spectrum of these diseases. It seems that mental health disorders are more common in Iranian adolescent girls than boys.[2] Although some studies have stated that age has a linear relationship with mental health disorders, depression is one of the most important brain problems in adolescents around the world, occurring with a probability of 20–25% in a lifetime.[3] Depression is the third most common disease in Iran,[4] and its prevalence is generally estimated to be between 6 and 73% in different populations.[5,6] Additionally, the prevalence of depression among Iranian teenagers varies between 14.77% and 72%,[7] which, in addition to extensive personal, social, and economic effects, requires individual care, the healthcare system, and the intervention of the whole society.[8] Previous studies have shown a direct relationship between nutrition and mental health.[9,10] Some of them have shown a possible relationship between some proteins, branched and aromatic amino acids (BCAAs, AAAs), and obesity and insulin resistance in humans.[11-13] It seems that changes in the concentration and intake of BCAAs and AAAs may be associated with behavioral disorders.[14,15] Since tryptophan is a precursor of serotonin,[16] reducing its transport through the blood–brain barrier leads to a decrease in serotonin synthesis

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Address for correspondence:
Dr. Ariyo Movahedi,
Science and Research Branch,
Daneshgah Blvd, Simon Bulivar Blvd, Tehran, Iran.
E-mail: amm35@mail.aub.edu

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and causes various functional disorders, including boredom and appetite regulation,[17,18] and as a result, different foods and amino acids in the diet lead to behavioral changes by changing blood serotonin levels.[18,19]

Moreover, in general, studies that have examined the relationship between dietary patterns and the risk of depression have found an inverse relationship between depression and diets rich in fruits, vegetables, olive oil, legumes, and other anti-inflammatory foods.[20,21] An increase in the risk of all three mood disorders has been seen in preinflammatory (Western) dietary patterns,[22,23] and thus far, only very few cohort studies have measured the relationship between inflammatory dietary patterns and the risk of depression.[24] The possible role of inflammation in depression is through mechanisms such as stimulation of the hypothalamic–pituitary–adrenal axis, depletion of tryptophan reserves, and reduction of brain-derived neurotrophic factor.[25-28]

In recent years, connections between other inflammatory factors, such as heart diseases, type 2 diabetes, metabolic syndrome, obesity, and mental health disorders, have been observed.[29-31] In obesity, hyperleptinemia and insulin resistance are associated with inflammatory processes[30] and are also associated with high levels of cortisol secretion and excessive stimulation of the hypothalamic–pituitary–adrenal axis.[32] More recent studies have addressed the role of oxidative and nitrosative stress (reaction of oxygen and active nitrogen) in addition to inflammatory-immune pathways (which lead to serotonin reduction, melatonin circadian rhythm disorder, neurogenesis, neuron destruction processes, and brain volume reduction).[33] It is also possible that depression has a common inflammatory etiology through a disorder caused by cytokines in the kynurenine cycle. This cycle provides the primary way to eliminate tryptophan and has a fundamental role in maintaining serotonin and a very important balance between toxic and protective metabolites of neurons.[34]

Considering the high prevalence of obesity and mood disorders, it seems that eating too much has a direct relationship with improper brain function.[17] The main disorders of depression and obesity are related to each other, although the mechanism and the directness of the relationship have not yet been determined.[34] Due to the lack of sufficient studies on the effect of the mentioned factors, such as BCAAs and AAAs, the inflammatory index of the diet (DII)[35] and obesity and overweight and the resulting inflammation, especially during adolescence, the purpose of the present study is to determine the relationship between the intake of BCAAs, AAAs, DII, and anthropometric indicators and the mental health of teenage girls in Tehran.

Methods

This descriptive-analytical cross-sectional study was conducted by a random sampling method on 138 teenage girls aged 13 to 18 years selected from three schools in District 4 of the eastern area of Tehran. Sample sizes were calculated using the valid software GPower (version 3.1.9.7, Germany)[36] and PASS (version 15.0.5) based on a correlation point biserial model and linear multiple regression.[37,38] The required data for this calculation were based on previous studies.[39] The inclusion criteria included the age of 13–18 years, consent to participate in the study, not having mental disorders other than stress, anxiety, and depression, and willingness to cooperate in the study.

After explaining the project to the volunteers, an informed consent form was taken from all the participants in this research at the beginning of the study. Information related to the basic characteristics of people, including age, class and academic average, economic status, educational status of parents, and household rank, was obtained using a general questionnaire. Anthropometric indices, including height, weight, and BMI, were measured using standard methods. The DASS-21 questionnaire[40] was used to diagnose mental disorders (depression, anxiety, and stress) and divide adolescents into healthy and sick groups. Food intake was measured using a valid and reliable 24-hour recall questionnaire[41] for 2 casual days and 1 holiday.[42] Then, average food intake was measured, and dietary micro- and macronutrients, including vitamins, minerals, and amino acids, were analyzed by using Nutritionist IV (The Hearst Corporation, San Bruno, CA, USA). Then, DII was measured using Hébert *et al*.'s method.[43]

The mean and standard deviation were compared using Welch's independent sample *t*-test.[44] The correlation of independent and dependent variables was performed using Pearson's correlation coefficient. Linear regression analysis was used to measure the relationship between the main variables and the role of confounding variables. The Newman–Keuls *post hoc* ANOVA test was used to see the differences between the quartiles.[45] A P value of less than 0.05 was considered significant.

This study was approved by the Research Ethics Committee of the Faculty of Medical Sciences and Technology of the University of Sciences and Research with the code of ethics approved under the number IR.IAU.SRB.REC.1398.030 of the Islamic Azad University of Science and Research.

Results

Based on the present findings, 138 teenage girls with an average age of 15.43 ± 1.26 years old were included in the study. Approximately 80% of the students had a good economic situation, and less than 2.2% had a weak economic status. More than 52% of parents (both fathers and mothers) had an academic degree, and the rest had a high school diploma. More than 76% of the students were living in their own houses, while less than 24% were living in renting houses.

As shown in Table 1, no significant difference was observed between healthy students and students with mental disorders in anthropometric indices ($P > 0.05$). Surprisingly, anxious students had a significantly lower waist circumference than healthy students ($P < 0.05$). Moreover, stressed students showed significantly higher weight than healthy students ($P < 0.05$).

As shown in Table 2, no significant difference in daily energy intake, fat, carbohydrate, protein, BCAA, AAA, or DII was observed between healthy students and students with mental disorders in nutritional intake ($P < 0.05$). Daily energy intake was significantly higher among anxious students ($P = 0.03$). Moreover, both carbohydrate and BCAA intake were higher among healthy students than among anxious students ($P < 0.05$).

As shown in Table 3, except for BCAA daily dietary intake, there was no significant difference in the *P* trend for other nutritional variables between quartiles of mental health degree. Based on this table, students in the 4th quartile who had a higher grade of mental disorders had lower daily BCAA intake than the other groups ($P = 0.046$). Although the *P* trend of the protein intake was not significant, students in the 4th quartile showed lower daily protein intake by performing a *post hoc* test. Surprisingly, students in the 2nd quartile showed significantly higher waist circumference than those in the other quartiles. No more differences were observed between the quartiles after performing ANOVA *post hoc* tests.

Based on the Pearson correlation test, which is shown in Table 4, there was a negative significant relationship between BCAA dietary intake and mental health ($P = 0.008$). Likewise, a significant negative relationship between height and mental health was noticed ($P = 0.019$). Moreover, a significant positive relationship was noticed between dietary fat intake and weight with stress ($P < 0.05$). A similar relationship was found between energy intake and carbohydrate intake and anxiety ($P < 0.05$).

Finally, based on Table 5, a significant relationship was observed between DII, BCAA, and AAA dietary intake and the mental health of the students (Model 1) ($P = 0.044$). After adjusting these results by energy intake (Model 2), adjusting for energy intake, carbohydrate, and fat (Model 3), and adjusting for energy intake, carbohydrate, fat, weight, and BMI (Model 4), no significant relationship was observed ($P > 0.05$).

Discussion

Based on the present findings, no significant difference was observed between mental disorders and anthropometric indices. Although weight was different between stressed students and healthy students, as the WAZ between these groups was not significantly different, such a difference might not be effective. As shown in Table 1, the average WAZ of the students was on the normal track. Surprisingly, anxious students had a significantly lower waist circumference than healthy students. The present finding was similar to that of Ahmadi *et al*.[46] On the other hand, in Gariepy's study, cross-sectional evidence of

Table 1: Comparison of mean and standard deviation of anthropometric indices in healthy people and those suffering from different mental health disorders*

Variable	Mental Health Disorders			Depression			Anxiety			Stress		
	Healthy (n=79)	Patient (n=59)	*P*	Healthy (n=110)	Patient (n=28)	*P*	Healthy (n=107)	Patient (n=21)	*P*	Healthy (n=117)	Patient (n=21)	*P*
	Mean±SD			Mean±SD			Mean±SD			Mean±SD		
Weight (kg)	62.84±13.28	62.09±17.14	0.772	63.15±15.47	59.92±12.39	0.325	63.26±14.98	60.13±14.99	0.314	61.59±13.81	70.47±22.65	0.033
Height (Cm)	163.28±6.10	160.32±22.45	0.259	163.08±5.96	157.00±32.66	0.067	163.64±6.16	156.80±30.09	0.029	161.68±16.19	165.47±7.47	0.375
BMI (kg/m^2)	24.03±5.28	22.56±5.02	0.103	23.21±5.13	24.38±5.70	0.309	23.86±5.42	21.81±4.15	0.057	23.59±5.42	21.75±3.72	0.204
WC (Cm)	73.06±8.94	70.63±10.58	0.147	72.40±10.01	69.96±7.72	0.247	72.93±9.59	68.93±9.71	0.046	71.73±9.40	75.80±12.75	0.133
WAZ	0.72±0.92	0.47±1.22	0.169	0.62±0.99	0.59±1.35	0.892	0.69±1.03	0.30±1.12	0.076	0.63±1.09	0.50±0.92	0.663
HAZ	0.22±0.84	0.30±0.96	0.622	0.19±0.86	0.49±0.98	0.119	0.29±0.88	0.16±0.96	0.494	0.24±0.93	0.20±0.68	0.855
BAZ	0.68±1.35	0.62±1.39	0.794	0.66±1.37	0.58±1.40	0.780	0.66±1.36	0.66±1.43	0.989	0.72±1.37	0.40±1.27	0.396

*$P \leq 0.05$ is considered significant based on Welch's independent sample t-test. WC: Waist circumference. WAZ: Weight for Age Z Score, HAZ: Height for Age Z Score, BAZ: BMI for Age Z Score

Table 2: Comparison of the assessed nutritional variables between adolescents with mental health disorders and healthy controls

Variable	Mental Health			Stress			Anxiety			Depression		
	Healthy (79)	Patient (59)	*P**	Healthy (110)	Patient (28)	*P**	Healthy (107)	Patient (31)	*P**	Healthy (110)	Patient (28)	*P**
	Mean±SD			Mean±SD			Mean±SD			Mean±SD		
Energy (Kcal)	2195.28±86.46	2176.48±128.73	0.30	2194.71±99.58	2157.30±130.66	0.10	2222.65±116.09	2176.52±101.04	0.03	2194.71±99.58	2157.30±130.66	0.10
Fat (g)	76.17±5.57	76.91±7.17	0.49	76.82±5.90	75.60±7.59	0.37	76.23±7.05	76.63±6.03	0.75	76.82±5.90	75.60±7.59	0.37
Carbohydrate (g)	288.15±11.64	285.53±16.74	0.28	288.17±13.25	282.20±16.56	0.06	292.16±14.29	285.49±13.58	0.02	288.17±13.25	282.20±16.56	0.06
Protein (g)	89.28±16.57	85.54±23.54	0.27	87.66±19.10	87.03±23.07	0.88	91.98±21.14	86.21±19.05	0.15	87.66±19.10	87.03±23.07	0.22
BCAA (g)	19.01±3.70	19.72±6.01	0.39	19.16±4.44	19.88±6.04	0.48	21.28±6.44	18.74±4.10	0.01	19.16±4.44	19.88±6.04	0.48
AAA (g)	9.39±3.16	9.27±2.70	0.80	9.41±2.96	8.71±2.84	0.27	9.25±2.70	9.40±3.04	0.80	9.41±2.96	8.71±2.84	0.27
DII	-0.05±0.86	-0.05±0.84	0.09	-0.07±0.88	0.02±0.75	0.63	0.10±0.93	-0.09±0.83	0.28	-0.07±0.88	0.02±0.75	0.63

**P*≤0.05 is considered significant, BCAA: Branch Chain Amino Acids; AAA: Aromatic Amino Acids, DII: Dietary Inflammatory Index

a positive relationship between obesity and anxiety disorder in women was reported.[47] The findings of Moghimi *et al*'s study on 300 people living in Tehran[48] showed that underweight, overweight, and obesity disorders in women with each of the three mental health disorders were 1 to 4 times more common than in healthy people. However, in some other studies, such as Askari *et al*.'s[49] study in 2013 on 800 people aged 16–50 and in phase 3 of the CASPIAN study on 5570 Iranian students aged 10–18,[50] although the percentage of girls with stress was higher among underweight, overweight, and obese groups than in healthy people, no significant correlation was reported between mental disorders and body mass index. The findings of Ho *et al.* showed no significant associations between WC and depressive symptoms.[51] However, in a study by Zhao *et al*., it was concluded that high waist circumference increases major depressive symptoms.[52] These differences could be due to the difference in the sample size and different measurement tools for measuring mental health disorders as well as the age groups.

Despite some studies that have shown the relationship between anthropometric indices and body weight with mental disorders,[53] the present study failed to find such a relation, which was in line with the Fowler-Brown *et al*. study.[54] One of the main issues for such a result might be the Z score of the weight for age of the studied population. These findings eliminate the effect of anthropometric indices on the effects of BCAAs and AAAs on the mental state of the studied population.

As illustrated in the present study, daily energy intake, fat, carbohydrate, protein, BCAA, AAA, and DII were significantly different between healthy students and students with mental disorders. The present results are in line with previous studies in the USA and South Korea. As Oh *et al*.[55] showed, no significant difference exists between energy intake and depression. Maddahi *et al*.[56] also found no significant difference in this regard. Despite the similar results, it should be noted that the age group and number of the studied population in these studies are totally different. Even social effects are different in each country, especially between eastern and western Asia as well as Asia compared to the USA.[57,58] Recently, some studies have shown a relationship between BCAAs and depression.[16,59] Baranyi *et al*. found that BCAAs were significantly reduced in patients with major depression compared with healthy subjects. Decreased mTor activation due to decreased BCAAs may play an important and unrecognized role in the etiology of depression and induce depressive symptoms and lower energy metabolism in patients with major depression.[16] Some studies, such as Correi and Vale, observed a significant relationship between the tryptophan amino acid and the enhancement of depression symptoms. This amino acid can be metabolized via two important pathways in the setting of depression: serotonin and kynurenine pathways. These tryptophan metabolic pathways are important in several processes involved in depression.[60]

Table 3: Comparison of assessed variables to mental health quartiles

Variable	1st Quarter ≤14 (*n*=34)	2nd Quarter 15 – 30 (*n*=33)	3rd Quarter 31 – 48 (*n*=32)	4th Quarter 49+ (*n*=31)	P Trend
Energy (Kcal)	2182.38±95.20	2186.48±112.94	2223.25±88.88	2157.46±114.08	0.093
Fat (g)	75.33±6.29	75.97±7.17	76.44±5.53	78.01±5.45	0.351
Carbohydrate (g)	286.03±13.41	287.25±13.65	292.22±10.91	283.23±15.67	0.066
Protein (g)	90.07±16.08[a]	88.43±21.93[a]	91.61±17.79[a]	80.60±20.54[b]	0.111
BCAA (g)	20.38±4.37[a]	20.14±5.76[a]	19.81±4.24[a]	17.38±4.29[b]	0.046
AAA (g)	9.21±2.63	9.40±2.81	9.56±3.31	9.08±3.36	0.927
DII	-0.09±0.87	0.04±0.77	0.01±0.93	-0.07±0.87	0.914
Weight (kg)	63.82±13.50	59.39±11.99	62.38±14.08	63.97±17.90	0.550
Height (cm)	163.21±5.44	164.21±6.06	162.09±6.45	158.26±30.15	0.452
BMI (kg/m^2)	24.98±5.71	22.21±4.50	23.69±4.97	23.39±5.56	0.193
WC (Cm)	72.74±7.91[a]	69.15±8.13[b]	72.44±9.98[a]	74.32±11.55[a]	0.170
WAZ	0.67±1.12	0.47±1.35	0.73±0.91	0.46±0.76	0.642
HAZ	0.40±1.06	0.34±0.91	0.20±0.72	0.05±0.92	0.427
BAZ	0.74±1.47	0.76±1.46	0.63±1.43	0.61±1.18	0.963

[a,b]Columns with different superscripts in each row show significant differences between groups based on the Newman–Keuls post hoc ANOVA test. $P<0.05$. BCAA: Branch Chain Amino Acids; AAA: Aromatic Amino Acids, DII: Dietary Inflammatory Index, BMI: Body Mass Index, WC: Waist Circumference, WAZ: Weight for Age Z Score, HAZ: Height for Age Z Score, BAZ: BMI for Age Z Score

Table 4: Correlation between different mental disorders and assessed variables

Variables	Mental Health		Stress		Anxiety		Depression	
	*R**	*P***	*R**	*P***	*R**	*P***	*R**	*P***
Age	-0.088	0.320	-0.140	0.108	-0.022	0.799	0.121	0.162
Energy	-0.065	0.462	-0.019	0.827	0.214	0.012	-0.129	0.135
Fat	0.095	0.280	0.18	0.039	-0.030	0.725	-0.078	0.365
Carbohydrate	-0.044	0.615	-0.043	0.625	0.21	0.014	-0.166	0.053
Protein	-0.124	0.159	-0.124	0.158	0.161	0.061	0.000	0.998
BCAA	-0.233	0.008	-0.102	0.244	0.128	0.135	0.044	0.611
AAA	-0.002	0.984	0.034	0.697	-0.012	0.889	-0.135	0.117
DII	0.045	0.612	-0.098	0.264	0.004	0.965	0.022	0.803
Weight	0.025	0.781	0.21	0.016	-0.043	0.621	-0.067	0.441
Height	-0.205	0.019	0.087	0.323	-0.097	0.258	-0.178	0.038
BMI	-0.081	0.358	-0.122	0.165	-0.128	0.135	0.116	0.179
Waist Circumference	0.094	0.290	0.149	0.089	-0.107	0.211	-0.083	0.339
WAZ	-0.051	0.563	-0.054	0.536	-0.108	0.208	-0.015	0.861
HAZ	-0.118	0.183	-0.034	0.697	-0.032	0.706	0.098	0.257
BAZ	-0.101	0.253	-0.036	0.679	-0.032	0.714	-0.078	0.368

**R*: Correlation coefficient, ***P*≤0.05 is considered significant, BCAA: Branch chain amino acids; AAA: Aromatic amino acids, DII: Dietary inflammatory index, BMI: Body mass index, WAZ: Weight for age Z score, HAZ: Height for age Z score, BAZ: BMI for age Z score

Table 5: Investigating mental health relationship with DII, BCAA, AAA based on linear regulation results in candidates

Models	*R*	*R* Square	Adjusted R Square	Std. Error of the Estimate	CI*	*P***
Model 1	0.273	0.075	0.045	25.641	42.53-101.43	0.044
Model 2	0.280	0.078	0.041	25.693	-84.19-148.33	0.484
Model 3	0.283	0.080	0.035	25.773	-86.43-147.23	0.630
Model 4	0.313	0.098	0.038	25.731	-74.25-169.01	0.304

*CI: Confidence interval, ***P*≤0.05 is considered significant, Model 1: Crude model, Model 2: Adjusted based on energy intake, Model 3: Adjusted based on energy intake, carbohydrates, and fat, Model 4: Adjusted based on energy intake, carbohydrate, fat, weight, and BMI

In the present study, there was a significant negative relationship between BCAA dietary intake and mental health [Table 3]. Students in the 4th quartile who had a higher grade of mental disorders had lower daily BCAA intake compared to the other groups. In confirmation of this issue, the present study showed a significant negative relationship between daily BCAA intake and mental disorders [Table 4]. These findings are similar to those of some previous studies.[16,59,61] Additionally, based on Table 5, a significant relationship was observed between BCAAs and the mental health of the students. In some studies, such as Anderson *et al*. and Koochakpoor *et al*., it was reported that an inverse association between dietary intake of BCAAs and odds of depression and anxiety was found, and the serum levels of BCAAs were reduced in patients with major depression.[59,62] Aquilani *et al*. reported in their former study that changes in Krebs cycle intermediates due to oxidative BCAA degradation may influence neurotransmitter synthesis. These findings suggest that increased BCAA levels may influence synaptic transmission.[63] In addition, the large neural amino acids and the serotonin precursor tryptophan make use of the same transport system across the blood–brain barrier. Hence, competition among these amino acids for the carrier protein might be the result.[64] Thus, increased concentrations of large neural amino acids might be linked with reduced tryptophan availability in the brain for serotonin synthesis. However, the clinical impact of the competitive effect of BCAAs is polemically discussed,[65] and the decrease in BCAAs in mental patients could lead to the alternative hypothesis that the mTor pathway might be dysregulated due to a lack of BCAAs, especially leucine, during depressive episodes.[16]

In the present study, a negative significant relationship between height and mental health was noticed. In Gunnell's study, it was already shown that a taller height is associated with a decrease in the likelihood of suicide and depression.[66] Additionally, Rees *et al*. showed that height is associated with fewer symptoms of depression among females 17–19 years of age. Despite all these findings, the R value was -0.205, which means that the R^2 would be less than 0.04, which is a statistically weak relationship.[67] In other words, the present study failed to find strong results in this regard.

Moreover, a significant positive relationship was noticed between dietary fat intake and weight with stress. A similar relationship was found between energy intake and carbohydrate with anxiety. Additionally, the study conducted by Kouvonen *et al*. showed that the effect of stress reduces food consumption by people in such a way that BMI remains unchanged or decreases with increasing stress.[68] Paying too much attention to thinness and a negative attitude toward obesity may put pressure on obese teenagers and make them suffer from depression.

Additionally, in line with our findings, Heath *et al*.,[69] in a study on shift-working nurses, found that higher levels of stress are associated with higher energy intake.[70] Under stressful conditions, humans desire palatable foods that are energy-dense, especially elevated eating of high-sugar, high-fat foods, and processed foods[71-74] and a decrease in consumption of main meals, fruits, and vegetables.[72,74,75] The preference for highly palatable, energy-dense food items is attributed to hormones secreted in the stress response, such as cortisol.[76] Behaviorally, during stress, people have less energy and time to devote to the preparation of foods; thus, they have an elevated dependence on preprocessed convenience food items, which are frequently rich in energy.[77,78] The "comfort food hypothesis" proposes that chronic stress could endorse a coping strategy resulting in a preference toward food comprising more carbohydrates and saturated fats,[75] which have higher energy density.

Additionally, recent studies have reported that stress increases levels of cortisol among individuals, inducing an increase in the intake of high-fat foods to control this stress.[72,79,80] A previous study enrolling 40 women reported that high-stressed females preferred sweet, high-fat food more than low-stressed women.[81] Additionally, a cross-sectional study with young and middle-aged adults reported a positive association between refined grain intake and anxiety.[82] A scoping review concluded that refined carbohydrate intake was linked to an increased prevalence or severity of anxiety[83] In turn, studies have reported the influence of sugars on inflammation, gut microbiome dysbiosis, and brain insulin resistance, which are well-established as mechanisms underlying anxiety disorders.[84] Furthermore, certain gut microbes are directly involved in the production of neurotransmitters such as dopamine and can impact host production of serotonin,[85] which could affect anxiety status.

In the present study, a significant relationship was observed between DII, AAA dietary intake, and the mental health of the students. After adjusting these results, no significant relationship was observed. Although this outcome shows the importance of the confounders on the final results, it should be noted that perhaps with a higher rate of mental disorders among the subjects, different results could be seen. In some studies, such as Wang *et al*. and Haghighatdoost *et al*., a direct association was reported between the proinflammatory properties of the diet and an increased risk of a higher mental health disorders profile score.[86,87] Phillips *et al*. showed a positive relationship between higher DII scores and depression.[88] Additionally, Bergmans and Malecki reported that a higher DII score causes over twofold odds of depression, although the association between DII and anxiety was not significant in their study.[89] However, in the Adjibade *et al*. study, DII was not associated with incident depressive symptoms in any of the participants.[90] Depression, anxiety, and other common mental health symptoms or disorders have a high comorbidity, and it is well documented that these disorders share genetic determinants as well as underlying neurobiological mechanisms.[91,92] Several potential mechanisms have been proposed to explain the observed association. First, a proinflammatory diet is associated with high levels of circulating inflammatory markers.[88,93] It has been shown that inflammatory markers, such as cytokines, could regulate neurotransmitter metabolism and neural plasticity, which in turn induce the development of neuropsychiatric diseases.[94] Second, oxidative stress is implicated as an important determinant relevant to mental health disorders.[95] It has been indicated that a proinflammatory diet can modulate oxidative processes, and oxidant–antioxidant imbalance is associated with elevated levels of reactive oxygen and nitrogen species, which increase DNA damage. Such damage may underlie the demonstrated association between DII and mental health.[96] Apart from the rule of confounders in the present study, it should be noted that age and sex group as well as ethnicity and cultural differences in the previous studies might have affected the outcomes.

Conclusions

BCAA might have an important effect on mental health. Further studies in different age and sex groups are highly recommended.

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Conflicts of interest

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