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The role of fatty acids in the emotional well-being of young adults: associations between fatty acid levels and symptoms of depression, anxiety, stress, and sleep disturbances

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Abstract

Purpose: Young adults experience high stress levels, leading to mood disorders. This study investigates the associations between specific fatty acid levels, lipid profiles, inflammatory markers, and emotional well-being among young adults.

Methods: Seventy-two young adults aged 18-35 participated in this study. Participants completed self-assessments of depression severity (PHQ-9), stress (PSS-10), insomnia (ISI), and anxiety (GAD-7). Blood samples were collected and analyzed for plasma fatty acid profiles, lipid profiles, C-reactive protein (CRP) and kynurenine pathway metabolites. Classification and Regression Tree (C&RT) and multivariate stepwise regression analyses were employed to identify potential predictors of mental health outcomes.

Results: The analyses revealed significant associations between certain fatty acids, lipid markers, and mental health conditions. Lauric acid, myristic acid, and eicosatrienoic acid were identified as potential indicators of mental health issues. Higher levels of palmitoleic acid were linked to increased depressive symptoms, while higher oleic acid levels were associated with reduced depression. Anxiety was influenced by myristoleic acid and docosahexaenoic acid. Stress and sleep disturbances correlated with specific fatty acids. The models explained a significant percentage of variability in mental health outcomes, accounting for 25% in both depressive symptoms and anxiety, 23% in stress, and 43% in sleep disturbances.

Conclusions: Specific fatty acids, associated with lipid profiles, kynurenic acid, and CRP, significantly impact the mental health of young adults. Monitoring biomarkers may assist in managing mental health disorders. Personalized dietary interventions could improve well-being and sleep quality. Further research is needed to confirm these findings and establish causal relationships.

Key words: young adults, sleep disturbances, mental health, fatty acids, KYNA.

INTRODUCTION

Emotional well-being of young adults

Young adults are exposed to higher levels of stress and pressure than the general population [1, 2]. Prolonged exposure to severe stress may contribute to an increased incidence of mood disorders, insomnia, depression, and anxiety, as well as early burnout [3]. High levels of anxiety and depression reduce quality of life and might even contribute to suicidal ideation [4, 5]. Stressors impacting young adults' mental health include extensive responsibilities, academic demands, exams, demanding schedules, exposure to illness and death, post-mortem examinations

during coursework, and financial problems [6, 7]. Additionally, young adults rarely seek psychological support due to the of societal stigma [8].

Given these challenges, implementing preventive interventions and psychological support for young adults is essential. One approach is to promote healthy lifestyle and change of diet as these are easily modifiable aspects with significant effects on mental health but are often overlooked [9, 10]. The frequency, type and quantity of food groups consumed have a significant influence on the intake of nutrients crucial for mental well-being [11-13]. Research in nutritional psychiatry suggests that the pathogenesis of mood disorders, depressive-anxiety disorders, and insomnia may be closely linked to dietary quality and nutrient intake [11, 12].

The role of fatty acids profile in the emotional well-being

Essential fatty acids (EFAs) are compounds that must be obtained from diet, as humans cannot to synthesize them. Despite the vast knowledge we have on their importance in human diet, determining the optimal amount and ratios of FAs in the diet remains a challenge. Studies confirm that different FAs exert varied effects on human health. The majority of evidence indicates the protective role of polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA), but the negative impact of saturated fatty acids (SFA) and trans fatty acids (TFA) on mental health. Food contains a complex mixture of various FAs, and the proportions of these in the diet have practical implications for nutritional status, metabolism [14], and, ultimately, health and well-being. Gaining a better understanding of these implications may help formulate dietary guidelines and targeted interventions [15].

Omega-3 and omega-6 PUFAs are essential for brain and central nervous system function. They are integral elements of the cell membrane (neurons) structure that affects membrane fluidity, which is a key factor in neurotransmission. PUFAs are transformed to lipid mediators that regulate pro- and anti-inflammatory processes. Both omega-3 and omega-6 FAs have anti-inflammatory properties. However, the Western diet is typically deficient in omega-3 FAs and usually often presents an excessive omega-6/omega-3 ratio which has significant health implications [16].

Changes in the ratio of PUFAs in the diet show that lipid mediators formed from omega-6 PUFAs are proinflammatory, while those from omega-3 PUFAs are anti-inflammatory [17].

Evidence suggests that supplementation with eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which belong to the omega-3 PUFAs, may alleviate depression and anxiety symptoms [18, 19]. Diets rich in PUFAs, such as the Mediterranean diet which is known for its anti-inflammatory properties has been shown to have positive effect on the quality of sleep and improvement of cognitive functions [10, 20, 21]. In contrast, consuming large amounts of ultra-processed foods can increase symptoms of depressive disorders [22]. The pathogenesis of depression and anxiety disorders is implicated in low-grade inflammation, oxidative stress, and brain neuroplasticity [10, 21]. On the other hand, DHA and EPA reduce arachidonic acid levels, which leads to a decrease in the synthesis of pro-inflammatory cytokines, including interleukin-1β (IL-1β), interleukin-2 (IL-2) and interleukin-6 (IL-6). Consequently, it reduces inflammation in the body. Additionally, EPA influences the production of N-acetyl-aspartate through which it exhibits neuroprotective effects. N-acetyl-aspartate as an indicator of neuronal homeostasis could increase the ratio of brain phosphomonoesters to phosphodiesters and decrease the expression of nuclear factor kappa B (NF-κB). EPA also plays a role in synthesizing dopaminergic and serotonergic neurotransmitters [18]. Intervention with omega-3 in the psychiatric patient population has been extensively studied and shown to be safe and well-tolerated. This assurance, alongside endorsements from scientific societies, supports the use of omega-3 supplementation in managing psychiatric conditions [23, 24].

To the best of our knowledge, there is a definite lack of clinical studies examining the relationship between FA profile and emotional well-being in young adults. Therefore, the purpose of our study was to examine the associations between specific FA levels, lipid profiles, inflammatory markers, and emotional well-being in this population.

METHODS

This study was conducted in accordance with the Helsinki Declaration guidelines. All procedures were approved by the Ethics Committee of the Medical University of Lublin KE-0254/127/04/2023 and informed written consent was obtained from all individuals involved in the study.

Study group

The study involved young adults aged 18-35 who participated in all the procedures on a voluntary basis. Recruitment and data collection took place from August 2023 to January 2024. Prior to the examination all participants were asked to sign informed consent forms. In total, 72 individuals took part in the project. None met the exclusion criteria and both sexes were included in the study. The inclusion criteria were: signed informed consent, age 18-35, proper nutritional status confirmed by two indicators: body mass index (BMI) ≥ 18.0 kg/m^2 or ≤ 30 kg/m^2 and waist circumference < 115 cm [25], no exclusion

criteria met. The exclusion criteria included: refusing to sign informed consent form, pregnancy or breastfeeding, current use of antibiotics, hypolipemic, antihistamine, anti-inflammatory and lipid-altering drugs, use of supplements such as omega-3 FAs within three months prior to the study, presence of conditions affecting vascular tone (e.g. diabetes, vasculitis, chronic hypertension), skin diseases, autoimmune, cancer, cardiovascular diseases, and other somatic diseases in unstable phase or with active inflammation, low-fat diet or major psychiatric disorders according to DSM-5. Clinical symptomatology was self-reported by participants.

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Sociodemographic and health-related data

Information was collected using a custom-designed questionnaire, which included questions about age, sex, field of education, BMI and any diagnosed conditions or medications taken by the participants.

Severity of stress symptoms

Participants' perceived stress exacerbation levels were assessed using the Polish adaptation of the Perceived Stress Symptoms Scale (PSS-10) [26, 27], which provides an assessment of the level of stress perceived by the individual over the past month. It consists of 10 items that measure the extent (0-4) to which an individual considers their life to be unpredictable, uncontrollable and overbearing. The total score (0-40) is the sum of the scores for each question, with higher scores indicating greater levels of stress.

Severity of depressive symptoms

The intensity of depressive symptoms was measured with Patient Health Questionnaire-9 (PHQ-9) [28, 29]. This is a short questionnaire that includes nine questions assessing the severity of depressive symptoms over the past two weeks. Every question responds to one of the diagnostic criteria for depression according to DSM-IV. The final score can range from 0 to 27 points, where a higher score indicates a more severe depression. The PHQ-9 questionnaire is widely used in diagnosing depression, monitoring its severity, and assessing the effectiveness of treatment.

Insomnia intensity

The severity of sleep disorders among the subjects was assessed using the Insomnia Severity Index (ISI), which a tool used to determine the intensity of sleep problems, in particular insomnia. It consists of 7 questions that assess aspects strictly connected with difficulties falling asleep, staying asleep, and waking up too early as well as a subjective assessment of sleep quality and satisfaction [30].

Severity of experienced anxiety

The Generalized Anxiety Disorder-7 (GAD-7) scale was used to evaluate the intensity of anxiety experienced by participants. GAD-7 is a brief diagnostic tool consisting of 7 questions assessing the severity of generalized anxiety symptoms over the past two weeks. The total score can range from 0 to 21 points, where higher scores indicate greater severity of anxiety. The GAD-7 is used to screen for anxiety disorders and monitor changes in anxiety levels during treatment [31].

Anthropometric measurements

Using the electrical bioimpedance method (BIA) we measured the body weight and composition of each individual who participated in the project. Measurements were taken three times at each stage of the study using Impedimed SFB7 device.

Blood assessment

Laboratory tests including complete blood count with differential, lipid panel (total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides [TG]), and CRP were performed by the hospital laboratory. Serum and plasma were obtained by centrifugation, then pipetted and frozen at –80°C for further analysis.

KYNA assessments

The content of tryptophan (TRP), kynurenic acid (KYNA), and L-kynurenine (L-KYN) in the studied samples was measured chromatographically. A volume of 250 µl of serum was analyzed by the Ultra-High-Pressure Liquid Chromatography (UHPLC) system equipped with fluorescence and UV detectors (UltiMate 3000 Analytical Systems, Thermo Fisher Scientific, USA) [32]. The mobile phase consisted of 20 mmol/l sodium acetate, 3 mmol/l zinc acetate and 7% acetonitrile, was run at a flow rate of 0.1 ml/min through Agilent analytical column (C18; 5 µm). KYNA was measured fluorimetrically, with excitation set at 344 nm and emission at 398 nm. UV detection was applied to estimate the content of TRP and L-KYN in analyzed samples and performed at 250 nm and 365 nm wavelength, respectively. The linearity of calibration curves for each of studied substances was no less than $r^2 > 0.999$.

Isolation of fatty acids

Plasma was obtained from blood collected from the clots by centrifugation for 10 minutes at 1200 G. FAs were isolated using the Folch method [24]. 0.5 ml of plasma was saponified in 1 ml of 2 mol/l KOH solution in methanol at 70°C for 20 minutes, followed by methylation with 2 ml of 14% boron trifluoride in methanol

under the same conditions. 2 ml of n-hexane and 10 ml of saturated NaCl solution were then added to the sample. One milliliter of the n-hexane phase was taken for further analysis [33].

Fatty acid analysis by gas chromatography

Gas chromatography was performed on an Agilent Technologies 7890A GC using a SUPELCOWAX™ 10 capillary column (15 mm × 0.10 mm, 0.10 µm) from Supelco, Bellefonte, PA, USA. The following conditions for analysis were established: the initial temperature was 60°C (0 min), and was then increased by 40°C/min to 160°C (0 min), further increased by 30°C/min to 190°C (0.5 min), and then increased by 30°C/min to 230°C for 2.6 min, where it was maintained for 4.9 min. The total analysis time was about 8 minutes, and the flow rate of the carrier gas, which was hydrogen, was set at 0.8 ml/min. FA identification was carried out by comparing retention times with those of commercial standards [33].

Statistical analysis

The statistical analysis was performed using the Statistica 13 package (StatSoft, Inc., Tulsa, OK, USA). The Shapiro-Wilk test was used to determine the distribution of quantitative data. Based on the total scores of the scales used to measure mental-health-related symptoms, we allocated the examined population into groups with or without depressive symptoms (PHQ-9 scale), anxiety symptoms (GAD-7 scale), psychological stress (PSS-10 scale) and sleep disturbances (ISI scale). The specific cut-off point for subgroup allocation was based on earlier studies as follows: PHQ-9 scale ≥ 8 points [34]; GAD-7 ≥ 8 points [35]; PSS-10 ≥ 20 points [36]; ISI scale ≥ 8 points [37].

According to these results, individuals were classified into those experiencing at least one mental health issue and those without any mental health problems. Multiple regression analysis was performed to develop predictive models for mental health-related symptoms by including FA concentrations in the sera of the examined populations. Additionally, Classification and Regression Tree Analysis (CART) analysis was performed to identify potential FAs that may play a significant role in the development or severity of mental health problems. The relationship between FA concentrations potentially related to mental health and other biological markers was tested using Pearson's R and Spearman's rho correlation values.

Table 1. The characteristic of the examined population

Factor	Median (Min-Max)	Individuals upon cut-off (I; %)
Females (%)	51	N/A
Age (years)	24 (19-32)	N/A
BMI (kg/m^2)	22.79 (18.07-35.38)	22; 31
PHQ-9 total score (points)	5 (0-19)	17; 24
GAD-7 total score (points)	5 (0-21)	21; 29
ISI total score (points)	6 (0-24)	28; 39
PSS-10 total score (points)	14 (1-33)	21; 29

BMI – body mass index, PHQ-9 – Patient Health Questionnaire, GAD-7 – General Anxiety Disorder, ISI – Insomnia Severity Index, PSS-10 – Perceived Symptoms Scale, N/A – Not Applicable

RESULTS

Characteristics of the examined population

The characteristics of the examined group are presented in Table 1. According to analysis, 24% of individuals experienced depressive symptoms, 29% reported anxiety symptoms, 39% insomnia, and 29% distress. Thirty-five individuals (49%) had at least one psychological health problem (the total score of PHQ-9, GAD-7, ISI or PSS-10 upon the cut-off point). Nine participants (13%) experienced severe symptoms of 1 psychological health problem, and 10 people (56%) had 2 psychological health problems, 7 (10%) reported 3, and 9 (13%) had severe symptoms of 4 examined areas.

The potential biomarkers of mental health in the examined population

Based on the C&RT analysis, the potential panel of biomarkers that characterized mental health problems was C:12:0, lauric acid > 0.01 mg/l; C20:3n6, eicosatrienoic acid ≤ 0.10 mg/l, and C14:0, myristic acid > 0.25 mg/l.

According to our analysis, the tepwiseioned Fas correlated to some other examined biomarkers: C12:0 to white blood cells (WBC; $R = 0.32$, $p < 0.05$), neutrophils (NEU; $R = 0.30$, $p < 0.05$), eosinophils (EOS; $R = 0.27$, $p < 0.05$), total cholesterol ($R = 0.26$, $p < 0.05$), LDL cholesterol ($R = 0.27$, $p < 0.05$), TG ($R = 0.31$, $p < 0.05$) and NEU to CRP ratio ($R = 0.34$, $p < 0.05$), C20:3n6 to lymphocytes (LYM; $R = 0.24$, $p < 0.05$), procalcitonin (PCT; $R = 0.30$, $p < 0.05$) and mean platelet component (MPC)/platelets (PLT) ratio ($R = –0.25$, $p < 0.05$), total cholesterol ($R = 0.33$, $p < 0.05$), LDL cholesterol ($R = 0.33$, $p < 0.05$), TG ($R = 0.49$, $p < 0.05$), CRP ($R = 0.29$, $p < 0.05$), TG to HDL ratio ($R = 0.33$, $p < 0.05$) and KYNA ($R = –0.24$, $p < 0.05$), C14:0 to KYNA ($R = –0.29$, $p < 0.05$), LKYN to TRP ratio ($R = –0.27$, $p < 0.05$), total cholesterol ($R = 0.29$, $p < 0.05$), TG ($R = 0.56$, $p < 0.05$), TG to HDL ratio ($R = 0.33$, $p < 0.05$).

The stepwise linear regression analyses were performed to predict the severity of experienced symptoms (depression, stress, anxiety and sleep disturbances) based on serum FAs concentrations. The results of the analyses are shown in Tables 2-5.

Table 2. The predictors of depressive symptoms according to regression analysis

PHQ-9 scale	25% variability of depressive symptoms			
	β	SE	*t*	*p*
C16:1, Palmitoleic acid	0.323252	0.150862	2.14269	0.036204*
C12:0, Lauric acid	0.240699	0.146183	1.64656	0.104877
C14:1, Myristoleic acid	0.236996	0.124315	1.90642	0.061388
C18:1n9, Oleic acid	–0.721030	0.280455	–2.57093	0.012641*
C22:1/C20:1, cis-11-Eicosenoic acid	0.441568	0.222106	1.98810	0.051369
C18:4, Stearidonic acid	–0.020181	0.156538	–0.12892	0.897854
C16:0, Palmitic acid	0.590154	0.303010	1.94764	0.056142
C20:3n6, Eicosatrienoic acid	–0.306401	0.239789	–1.27780	0.206243
C22:6n3, Docosahexaenoic acid	–0.231890	0.196471	–1.18028	0.242549

PHQ-9 scale – Patient Health Questionnaire scale, β – beta coefficient, SE – standard error, t – statistic, p-value

Table 3. The predictors of anxiety symptoms according to regression analysis

GAD-7 scale	25% variability of anxiety symptoms			
	β	SE	*t*	*p*
C16:1, Palmitoleic acid	0.231795	0.122295	1.89537	0.062633
C14:1, Myristoleic acid	0.220471	0.109446	2.01444	0.048238*
C22:6n3, Docosahexaenoic acid	0.343550	0.166020	2.06933	0.042623*
C22:0, Behenic acid	–0.362310	0.191031	–1.89660	0.062468
C23:0, Tricosylic acid	0.270533	0.195855	1.38130	0.172068
C20:5n3, Eicosapentaenoic acid	–0.181853	0.155174	–1.17193	0.245637

GAD-7 scale – General Anxiety Disorder scale, β – beta coefficient, SE – standard error, t – statistic, p–value

Table 4. The predictors of stress symptoms according to regression analysis

PSS-10 scale	23% variability of stress symptoms			
	β	SE	*t*	*p*
C20:4n6, Arachidonic acid	0.106147	0.165731	0.64048	0.524222
C21:0, Heneicosylic acid	0.146165	0.116437	1.25532	0.214074
C18:4, Stearidonic acid	0.346516	0.167797	2.06509	0.043103*
C20:3n6, Eicosatrienoic acid	–0.595963	0.241929	–2.46338	0.016553*
C16:0, Palmitic acid	0.705862	0.286744	2.46164	0.016626*
C18:3n3, Linolenic acid	–0.467860	0.236087	–1.98173	0.051948
C18:1, trans-Vaccenic acid	–0.310803	0.199957	–1.55435	0.125191

PSS-10 scale – Perceived Symptoms Scale, β – beta coefficient, SE – standard error, t – statistic, p–value

A relationship was found between depressive symptoms and C16:1 (positive) and C18:1n9 (negative) FAs (see Table 2). These models, adjusted for C12:0, C14:1, C22:1/C20:1, C18:4, C16:0, C20:3n6, and C22:6n3, allow us to explain 25% of the variability of depressive symptoms in the examined population.

C16:1 was inversely related to LKYN to TRP ratio ($R = –0.25$; $p < 0.05$); monocytes (MONO; $R = –0.37$, $p < 0.05$), MPV ($R = –0.45$, $p < 0.05$) and NEU to LYM ratio ($R = –0.33$; $p < 0.05$). C16:1 was positively related to total cholesterol ($R = 0.46$, $p < 0.05$), LDL cholesterol ($R = 0.41$, $p < 0.05$), TG ($R = 0.61$, $p < 0.05$), TG to HDL cholesterol ratio ($R = 0.41$, $p < 0.05$).

C18:1n9 was related to PCT ($R = 0.29$, $p < 0.05$), total cholesterol ($R = 0.43$, $p < 0.05$), LDL cholesterol ($R = 0.47$, $p < 0.05$), TG ($R = 0.71$, $p < 0.05$), TG to HDL ratio ($R = 0.56$, $p < 0.05$).

The anxiety symptoms depended on C14:1 and C22:6n3 concentrations adjusted for C16:1, C22:0, C23:0, and C20:5n3. The following model explained 25% of the variability of anxiety symptoms (Table 3).

C14:1 was inversely associated with KYNA ($R = –0.27$, $p < 0.05$), MPV ($R = –0.25$, $p < 0.05$) and positively related to total cholesterol ($R = 0.25$, $p < 0.05$), TG ($R = 0.50$, $p < 0.05$), and TG to HDL ratio ($R = 0.30$, $p < 0.05$).

Table 5. The predictors of sleep disturbances according to regression analysis

ISI scale	43% variability of sleep disturbances symptoms			
	β	SE	*t*	*p*
C14:0, Myristic acid	0.15046	0.313748	0.47955	0.633600
C20:3n6, Eicosatrienoic acid	–0.77594	0.242684	–3.19733	0.002383*
C22:1/C20:1, cis-11-Eicosanic acid	0.20798	0.244975	0.84898	0.399859
C18:3n3, Linolenic acid	–0.96948	0.285036	–3.40126	0.001311*
C18:4, Stearidonic acid	0.18455	0.212022	0.87044	0.388139
C18:0, Stearic acid	0.12002	0.182834	0.65645	0.514485
C20:0, Arachidic acid	0.79456	0.332568	2.38915	0.020624*
C22:0, Behenic acid	–1.19533	0.354396	–3.37287	0.001427*
C23:0, Tricosylic acid	0.91003	0.315938	2.88040	0.005795*
C18:1, trans-Vaccenic acid	–0.56896	0.246223	–2.31075	0.024926*
C15:0, Pentadecanoic acid	–0.09955	0.237738	–0.41873	0.677170
C16:0, Palmitic acid	0.88540	0.365896	2.41982	0.019131*
C22:1n9, Erucic acid	–0.31616	0.218700	–1.44564	0.154396
C20:4n6, Arachidonic acid	–0.27550	0.197977	–1.39157	0.170092
C12:0, Lauric acid	0.29976	0.169743	1.76597	0.083386
C22:6n3, Docosahexaenoic acid	–0.39505	0.233877	–1.68914	0.097297
C20:5n3, Eicosapentaenoic acid	0.24990	0.229168	1.09049	0.280625

ISI scale – Insomnia Severity Index scale, β – beta coefficient, SE – standard error, t – statistic, p-value

C22:6n3 was related to KYNA (R = –0.28, $p < 0.05$), L-KYN ($R = –0.27$, $p < 0.05$), PCT ($R = 0.27$, $p < 0.05$), total cholesterol ($R = 0.41$, $p < 0.05$), HDL cholesterol ($R = 0.26$, $p < 0.05$), LDL cholesterol ($R = 0.36$, $p < 0.05$), and TG ($R = 0.28$, $p < 0.05$).

The concentration of three FAs: C18:4, C20:3,6 and C16:0, adjusted for C20:4n6, C21:0; C18:3n3 and C18:1 explained the 23% variability of the severity of stress symptoms in the examined population (see Table 4).

C16:0 was related to KYNA ($R = –0.37$, $p < 0.05$), L-KYN ($R = –0.28$, $p < 0.05$), PLT ($R = 0.26$, $p < 0.05$), MPV ($R = 0.26$, $p < 0.05$), PCT ($R = 0.28$, $p < 0.05$) and MPV to PLT ratio ($R = 0.32$, $p < 0.05$). C16:0 was also related to lipids concentration: total cholesterol ($R = 0.46$, $p < 0.05$), LDL cholesterol ($R = 0.41$, $p < 0.05$), TG ($R = 0.61$, $p < 0.05$), TG to HDL ratio ($R = 0.41$, $p < 0.05$).

C18:4 was related to MPV ($R = 0.31$, $p < 0.05$), PCT ($R = 0.27$, $p < 0.05$), HDL cholesterol ($R = 0.24$, $p < 0.05$). C20:3n6 was related to KYNA ($R = –0.24$, $p < 0.05$), LYM ($R = 0.24$, $p < 0.05$), PCT ($R = 0.30$, $p < 0.05$), MPV to PLT ratio ($R = –0.24$, $p < 0.05$), total cholesterol ($R = 0.33$, $p < 0.05$), LDL cholesterol ($R = 0.33$, $p < 0.05$), TG ($R = 0.49$, $p < 0.05$), TG to HDL ratio ($R = 0.33$, $p < 0.05$), and CRP ($R = 0.29$, $p < 0.05$).

A relationship was found between sleep disturbances and C20:3n6, C18:3n3, C20:0, C22:0, C23:0, C18:1, and C16:0. These models, adjusted for other FAs (see Table 5), allow us to explain 43% of the variability of sleep disturbance symptoms in the examined population.

C18:3n3 was related to KYNA ($R = –0.26$, $p < 0.05$), MPV ($R = –0.29$, $p < 0.05$), TG ($R = 0.31$, $p < 0.05$). C20:0 was related to MPV ($R = –0.25$, $p < 0.05$), total cholesterol ($R = 0.29$, $p < 0.05$), LDL cholesterol ($R = 0.37$, $p < 0.05$), and total cholesterol to CRP ratio ($R = 0.31$, $p < 0.05$).

C22:0 was related to PCT ($R = 0.30$, $p < 0.05$), LDL cholesterol ($R = 0.25$, $p < 0.05$). C23:0 was related to PCT ($R = 0.28$, $p < 0.05$), total cholesterol ($R = 0.24$, $p < 0.05$), and LDL cholesterol ($R = 0.28$, $p < 0.05$).

C18:1 was related to KYNA ($R = 0.30$, $p < 0.05$), RBC ($R = 0.27$, $p < 0.05$), HGB ($R = 0.33$, $p < 0.05$), HCT ($R = 0.36$, $p < 0.05$), CRP ($R = –0.31$, $p < 0.05$), total cholesterol to CRP ($R = 0.38$, $p < 0.05$), PLT to CRP ratio ($R = 0.28$, $p < 0.05$), LYM to CRP ratio ($R = 0.26$, $p < 0.05$), and NEU to CRP ratio ($R = 0.24$, $p < 0.05$).

DISCUSSION

Based on our study, which analyzed specific FAs profile and other biological markers within a homogenous group of young adults aged 18-35, significant findings have been obtained that are relevant for both clinical practice and future research directions. The detailed examination of FA profiles in relation to mental health symptoms such as depression, anxiety, stress, and sleep disturbances provided valuable insights that can inform personalized treatment approaches. The present study identified a panel of potential biomarkers indicative of mental health issues, focusing on specific FAs.

The analysis revealed that lauric acid, a SFA was associated with mental health issues when its concentration exceeded 0.01 mg/l. SFA like lauric acid are often linked to metabolic health, and elevated levels in our study suggested that they might have contributed to inflammatory processes that influence mental well-being [38]. On the other hand, lauric acid has been shown to have a potential therapeutic effect on mood disorders, capable of preventing depressive- and anxiety-like behaviors in animal models [39]. However, in a study involving patients with anorexia nervosa, each unit increase of lauric acid was associated with higher anxiety by 0.0005 points. The dietary source of lauric acid may include highly processed foods, and prospective studies have confirmed that a high-saturated-fat diet was linked to with depressive and anxiety symptoms [40, 41].

In the analysis, eicosatrienoic acid, a polyunsaturated omega-6 FA (n-6 PUFA), was found to be associated with mental health issues when its levels were lower (≤ 0.10 mg/l). A lower concentration of eicosatrienoic acid was found in the erythrocyte membrane of individuals with schizophrenia compared to the healthy volunteers [42]. Studies have shown that imbalances in omega-6 FAs, such as reduced levels of eicosatrienoic acid, can disrupt the balance between pro-inflammatory and anti-inflammatory responses in the body, leading to increased neuroinflammation, which is a key factor in mood disorders and other mental health issues [43].

Additionally, myristic acid, another SFA, was linked to mental health problems when its concentration exceeded 0.25 mg/l. The presence of higher levels of myristic acid in the participants of our study suggested that it might have impacted mental health through mechanisms related to inflammation and lipid metabolism, similar to lauric acid. The negative effect of myristic acid on cognitive performance in elderly individuals has been shown in other studies [44].

Several recent studies support our research, which highlighted the significant role of FAs such as myristic acid and eicosatrienoic acid in mental health. For instance, a study analyzing the association of serum FA patterns with depression in U.S. adults found that certain FA profiles, including those rich in SFA, were significantly associated with higher rates of depression. This finding aligns with our observation that elevated levels of lauric and myristic acids may be linked to a heightened risk of mental health challenges [39].

The findings suggested that low levels of the n-6 PUFA (eicosatrienoic acid) combined with elevated levels of SFA (lauric acid and myristic acid) could have indicated a heightened risk of emotional and mental health challenges. Studies have shown that imbalances in omega-6 FAs can disrupt the balance between pro-inflammatory and anti-inflammatory responses in the body, leading to increased neuroinflammation, which is a key factor in mood disorders and other mental health problems [45].

In the next stage of our research, we sought to explore the relationships between the severity of depression, anxiety, and stress symptoms and the concentrations of specific FAs in blood plasma or erythrocytes.

Relationship between depressive symptoms and specific fatty acids and other biological markers

A significant relationship between depressive symptoms and specific FAs has been discovered in the present study – notably, PA (positive correlation) and oleic acid (negative correlation). By adjusting our models for other FAs (e.g., lauric acid, myristoleic acid, cis-11-eicosenoic acid, stearidonic acid, palmitic acid, eicosatrienoic acid, and DHA), we were able to explain 25% of the variability in depressive symptoms within the examined population.

PA showed a positive correlation with depressive symptoms, meaning higher levels of this FA were associated with increased depressive symptoms. This FA was inversely related to several biological markers, including the LKYN to TRP ratio ($R = -0.25$, $p < 0.05$), MONO ($R = -0.37$, $p < 0.05$), MPV ($R = -0.45$, $p < 0.05$), and the NEU to LYM ratio ($R = -0.33$, $p < 0.05$). Additionally, PA was positively associated with total cholesterol ($R = 0.46$, $p < 0.05$), LDL cholesterol ($R = 0.41$, $p < 0.05$), TG ($R = 0.61$, $p < 0.05$), and the TG to HDL cholesterol ratio ($R = 0.41$, $p < 0.05$), suggesting a multiplex relationship between lipid metabolism and mental health. Individuals with diseases involving metabolic dysregulation and inflammation were observed to have high PA serum levels. On the contrary, oleic acid was negatively correlated with depressive symptoms, indicating that higher levels of this FA were associated with lower levels of depression. Oleic acid was related to several lipid markers, including PCT ($R = 0.29$, $p < 0.05$), total cholesterol ($R = 0.43$, $p < 0.05$), LDL cholesterol ($R = 0.47$, $p < 0.05$), TG ($R = 0.71$, $p < 0.05$), and the TG to HDL ratio ($R = 0.56$, $p < 0.05$). These findings suggested that oleic acid might have been protective against depressive symptoms, possibly through its effects on lipid profiles. Similarly, the results of a Mendelian randomization study, published in 2022, suggested that higher levels of oleic acid and ALA may increase the risk of depression [47].

In summary, our study indicated that PA was positively associated, while oleic acid was negatively associated with depressive symptoms, highlighting the probable role of specific FAs in the regulation of emotional well-being and mental health. The possible effect of oleic acid on mental health is ambiguous. A downward trend of these FAs in anxiety patients has been proven [48]. Contrarily, in the study of American adults, oleic acid serum levels were positively associated with depression and cognitive dysfunction in individuals with schizophrenia [49, 50]. Substantial evidence highlights the protective effect of

oleic acid on health [51]. However, these suggestions need clarification in further studies.

Relationship between anxiety symptoms and specific fatty acids and other biological markers

This stage of the study concentrated on the associations between anxiety symptoms and the concentrations of specific FAs in blood plasma. Our findings revealed that the severity of anxiety was influenced by levels of myristoleic acid and DHA, after adjusting for other FAs such as PA, behenic acid, tricosylic acid, and EPA. The model developed was able to explain 25% of the variability in anxiety symptoms among the participants. This type of anxiolytic effect of myristoleic acid has been demonstrated in an animal model [52, 53].

Myristoleic acid was found to have had an inverse relationship with markers such as KYNA ($R = –0.27$, $p < 0.05$) and MPV ($R = –0.25$, $p < 0.05$), suggesting that higher levels of this FA were associated with lower anxiety symptoms. On the other hand, myristoleic acid was positively correlated with lipid markers like total cholesterol ($R = 0.25$, $p < 0.05$), TG ($R = 0.50$, $p < 0.05$), and the TG to HDL ratio ($R = 0.30$, $p < 0.05$), suggesting a complex interplay between lipid metabolism and anxiety. The impact of myristoleic acid on cholesterol levels has been known for many years. Similarly, DHA was linked to various biological markers. It was inversely related to KYNA ($R = –0.28$, $p < 0.05$) and L-KYN ($R = –0.27$, $p < 0.05$), but positively associated with PCT ($R = 0.27$, $p < 0.05$), total cholesterol ($R = 0.41$, $p < 0.05$), HDL cholesterol ($R = 0.26$, $p < 0.05$), LDL cholesterol ($R = 0.36$, $p < 0.05$), and TG ($R = 0.28$, $p < 0.05$). These correlations indicated that DHA might have played a significant role in modulating anxiety symptoms, potentially through its effects on both inflammatory pathways and lipid metabolism. The anxiolytic effects of DHA have been confirmed in numerous studies [55, 56], especially during pregnancy, but a recently published meta-analysis on the anxiolytic effects of omega-3, including DHA, indicates low certainty that omega-3 PUFAs supplementation may greatly improve anxiety symptoms, with the highest improvements observed at a dosage of 2 g/day [57].

Overall, these findings underscored the potential implications of specific FAs, particularly myristoleic acid and DHA, in influencing anxiety levels. The complex relationships observed suggested that both lipid and inflammatory pathways might have been crucial in understanding the biochemical underpinnings of anxiety.

Relationship between stress symptoms and specific fatty acids and other biological markers

In this stage, a relationship between the severity of stress symptoms and the concentrations of specific FAs in blood plasma has been explored. The findings revealed that the levels of stearidonic acid, eicosatrienoic acid, and palmitic acid – adjusted for other FAs, such as arachidonic acid, heneicosylic acid, linolenic acid, and transvaccenic acid – explained 23% of the variability in stress symptoms within the examined population.

Palmitic acid was significantly associated with several key biological markers. It exhibited an inverse relationship with KYNA ($R = –0.37$, $p < 0.05$) and L-KYN ($R = –0.28$, $p < 0.05$), but showed positive correlations with PLT ($R = 0.26$, $p < 0.05$), MPV ($R = 0.26$, $p < 0.05$), PCT ($R = 0.28$, $p < 0.05$), and the MPV to PLT ratio ($R = 0.32$, $p < 0.05$). Additionally, palmitic acid was positively related to lipid concentrations, including total cholesterol ($R = 0.46$, $p < 0.05$), LDL cholesterol ($R = 0.41$, $p < 0.05$), TG ($R = 0.61$, $p < 0.05$), and the TG to HDL ratio ($R = 0.41$, $p < 0.05$), indicating its potential role in stress-related lipid metabolism. It has been proven that palmitic acid induces oxidative stress, senescence, and inflammation in human brainstem astrocytes, which could mediate the stress response in obesity [58].

Stearidonic acid was also linked to stress symptoms, showing positive associations with MPV ($R = 0.31$, $p < 0.05$), PCT ($R = 0.27$, $p < 0.05$), and HDL cholesterol ($R = 0.24$, $p < 0.05$). These associations suggested that higher levels of stearidonic acid might have influenced stress by impacting these particular blood markers.

Conversely, eicosatrienoic acid showed a more complex relationship with various biomarkers. It was inversely associated with KYNA ($R = –0.24$, $p < 0.05$) and the MPV to PLT ratio ($R = –0.24$, $p < 0.05$), while positively correlated with LYM ($R = 0.24$, $p < 0.05$), PCT ($R = 0.30$, $p < 0.05$), total cholesterol ($R = 0.33$, $p < 0.05$), LDL cholesterol ($R = 0.33$, $p < 0.05$), TG ($R = 0.49$, $p < 0.05$), the TG to HDL ratio ($R = 0.33$, $p < 0.05$), and CRP ($R = 0.29$, $p < 0.05$). These findings suggested that eicosatrienoic acid might have influenced stress through its effects on lipid metabolism and inflammatory pathways. The results of other studies suggest that EPA in serum could be conversely correlated with the severity of posttraumatic stress disorder [59].

Overall, these results highlighted the intricate interplay between specific FAs and stress-related biological markers, emphasizing the potential role of FA profiles in determining the severity of stress symptoms.

Relationship between sleep disturbances and specific fatty acids and other biological markers

In the present study on sleep disturbances, a model was developed that remarkably explained 43% of the variability in sleep disturbance symptoms, as measured by the ISI. This substantial percentage indicated the strong influence of specific FAs on sleep quality in the examined population.

Among the FAs analyzed, some were found to be connected with better sleep quality. Eicosatrienoic acid demonstrated a significant negative correlation with sleep disturbances ($\beta = -0.78$, $p = 0.002$). Higher levels of this omega-6 FA were linked to fewer sleep problems, suggesting a protective role in promoting better sleep. Similarly, linolenic acid exhibited a strong negative association ($\beta = -0.97$, $p = 0.001$), indicating that higher levels of this omega-3 PUFA were connected with improved sleep quality. Behenic acid was another FA that was inversely related to sleep disturbances ($\beta = -1.20$, $p = 0.001$), suggesting that it might have helped protect against sleep issues, contributing to a more restful sleep. Trans-vaccenic acid also demonstrated a negative relationship with sleep disturbances ($\beta = -0.57$, $p = 0.025$), further supporting the idea that certain FAs could have contributed to better sleep.

Some FAs were linked to worse sleep quality. Arachidic acid was positively correlated with sleep disturbances ($\beta = 0.80$, $p = 0.021$), indicating that FA levels might have contributed to more severe sleep problems. Tricosylic acid also positively correlated with sleep disturbances ($\beta = 0.91$, $p = 0.006$). This suggested that elevated levels of this FA were linked to increased sleep issues, potentially exacerbating sleep disturbances. Palmitic acid, a SFA, was positively correlated with sleep disturbances ($\beta = 0.89$, $p = 0.019$). This finding indicated that higher levels of palmitic acid might have worsened sleep quality, contributing to more frequent or severe sleep problems.

Overall, these results highlighted the intricate and significant role of specific FAs in sleep quality. FAs like eicosatrienoic acid, linolenic acid, and behenic acid were associated with better sleep, potentially offering protective effects against insomnia. In contrast, FAs such as arachidic acid, tricosylic acid, and palmitic acid were linked to poorer sleep, suggesting that their higher concentrations might have exacerbated sleep disturbances. This model, which explained 43% of the variability in sleep disturbances, underscored the critical impact of FA profiles on sleep health and opened new avenues for understanding and potentially addressing sleep-related issues.

There are few studies dedicated to the relationship between FAs and sleep quality. In one study involving depressive patients, significant negative correlations were found between the degree of sleep disturbances and concentrations of FAs (myristic, palmitic, palmitoleic, oleic, linoleic, eicosadienoic, and DHA) at both admission and discharge [60]. In a study published in 2023, involving a group of healthy adults, linoleic and arachidonic acids were linked to a connection between serum levels and poor sleep quality and insufficient or excessive sleep duration. Linoleic, but not arachidonic acid, was also linked with a huge risk of obstructive sleep apnea [61]. A study based on dietary intake assessment found that the risk of a very short sleep duration was negatively related to the dietary intake of α-linolenic acid [62].

CONLUSIONS

Our study demonstrated that specific FAs play an important role in influencing mental health of young adults, including depression, anxiety, stress, and sleep disturbances. The identification of FAs such as lauric, myristic, palmitic, and eicosatrienoic acid as potential biomarkers, linked to mental health issues and sleep quality, underscores their importance in diagnostics and possible therapy.

From a clinical perspective, our results indicate that monitoring FA levels could become a profitable tool in the assessment and management of mental health disorders. Interventions aimed at optimizing FA profiles, whether through dietary modifications or supplementation, may provide a promising avenue for enhancing mental well-being and sleep quality. Based on our findings, dietary interventions aimed at increasing levels of protective FAs, such as eicosatrienoic and linolenic acid, and reducing levels of FAs associated with worsened mental health (e.g., palmitic acid) could have beneficial effects on mental health and sleep quality in patients. The present study highlights the importance of personalized treatment approaches in managing mental health disorders, considering differences in FA profiles. Patients may benefit from therapies tailored to their specific lipid profiles, potentially leading to better clinical outcomes.

STRENGTHS AND LIMITATION OF STUDY

Given the scope and objectives of the study, it is important to highlight both the strengths and limitations of our findings, which may impact the interpretation and generalizability.

The strengths of our study are: 1. Providing comprehensive analysis of FAs: the primary strengths of this study is the detailed analysis of a wide range of specific FAs. By focusing on individual FAs rather than broad categories, we were able to identify distinct associations between particular FAs and various mental health outcomes, offering more precise insights. 2. Involving a homogeneous study group in terms of age and demographic characteristics, which helped control for confounding variables related to demographic diversity. 3. Taking a holistic approach to mental health: the study comprehensively addressed multiple aspects of mental health, including depression, anxiety, stress, and sleep disturbances. This holistic approach allowed for a more thorough understanding of the way FAs may influence different facets of psychological well-being. 4. Exploring potential clinical applications: the identification of specific FAs as potential biomarkers for mental health issues and sleep quality provides a strong basis for future clinical applications.

The findings offer actionable insights that could be translated into dietary or supplementation strategies to improve mental health outcomes. 5. Providing integration of biological and psychological measures: the study integrated biological data (FA profiles) with psychological assessments, creating a robust framework for exploring the biochemical underpinnings of mental health. 6. Using advanced statistical methods, including decision tree analysis (C&RT), allowed us to identify potential biomarkers and predict mental health symptoms with higher precision. These methods facilitated a deeper apprehending of the relationships between FA concentrations and mental health, enhancing the robustness and applicability of our findings.

Unfortunately, the study is also not without certain limitations. A significant limitation of this study is its small sample size, which may limit the generalizability of the findings. Studies with bigger number of participants are needed to confirm the observed associations and to ensure that the results can be applied to larger populations. The cross-sectional nature of the study limits its ability to infer causality. While associations between FAs and mental health outcomes were identified, the directionality of these relationships remains unclear. Longitudinal studies are necessary to establish causal links. The study did not include comprehensive dietary assessments, which could have provided additional context for the FA levels observed in participants. Without this information, it is difficult to fully comprehend the sources of FAs and their direct impact on mental health. The reliance on self-reported data for assessing mental health symptoms introduces the potential for bias, such as underreporting or overreporting of symptoms. Incorporating objective clinical assessments alongside self-reported measures could have strengthened the findings.

In summary, while the study offers valuable understanding of the relationship between FAs profile and mental health, certain limitations, particularly regarding sample size, study design, and data collection methods should be addressed in future research, to further validate and expand upon these findings.

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Conflict of interest

Absent.

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