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The Effects of Dietary Tryptophan on Affective Disorders

Glenda Lindseth, **Brian Helland**, and **Julie Caspers**

University of North Dakota

Abstract

Using a randomized crossover study design, 25 healthy young adults were examined for differences in anxiety, depression, and mood after consuming a high tryptophan and a low tryptophan diet for four days each. There was a two week washout between the diets. A within-subjects analysis of the participants' mood indicated significantly ($p < .01$) more positive affect scores after consuming a high tryptophan diet as compared to a low tryptophan diet. Negative affect differences between the diets were not statistically significant ($p > .05$). Also, consuming more dietary tryptophan resulted in ($p < .05$) less depressive symptoms and decreased anxiety.

Keywords

tryptophan; anxiety; depression; mood

Tryptophan, an essential amino acid, is a precursor of serotonin synthesis. The synthesis of serotonin from tryptophan derives from a two-step process with the rate of serotonin synthesis dependent on tryptophan concentrations in the brain (Fernstrom, 2013). Because serotonin is involved in the regulation of mood and anxiety, low brain serotonin levels may contribute to increased anxiety and depression (Fernstrom, 2013; Hakkarainen et al., 2003; Robinson, Cools, Crockett, & Sahakian, 2010). However, tryptophan is obtained through the diet because it cannot be synthesized by the body (Soh & Walter, 2011); and as a result, "dietary factors that influence the blood levels of tryptophan and other amino acids can modify tryptophan uptake in the brain, and consequently the rate of serotonin formation" (Fernstrom, 1985). However, dietary consumption of tryptophan has been questioned as having an effect on anxiety, depression, or mood, especially in healthy individuals (Fernstrom, 2013; Soh & Walter, 2011; Wurtman & Wurtman, 1995). Therefore, this study examined the effects of high dietary tryptophan and low dietary tryptophan on anxiety, mood, and depression scores in a healthy adult population.

Correspondence concerning this manuscript should be addressed to: Glenda Lindseth 430 Oxford-- Stop 9025; University of North Dakota, Grand Forks, ND 58202. glenda.lindseth@und.edu Telephone (701) 777-4506 Fax (701) 777-4096.

Author Note: Glenda Lindseth, RN, PhD, FAAN, FADA Professor of Nursing, University of North Dakota; Grand Forks, ND glenda.lindseth@und.edu

Julie Caspers, RN, PhD, Faculty of Nursing; Northland Community and Technical College, Bemidji, MN Julie.caspers@ntcmn.edu

Brian Helland, MPA, Behavioral Research Coordinator; University of North Dakota; Grand Forks, ND brian.helland@und.edu

Tryptophan, Mood, and Anxiety

As the availability of serotonin depends on the intake of tryptophan, dietary sources of this amino acid are seen as essential for good mental health and well-being. However, study results are mixed regarding the effects of tryptophan levels on mood and anxiety. For example, plasma tryptophan and mood levels of 50 healthy women were compared following a 3-week, protein-sparing 1000 kcal diet, with a final week of being randomly allocated to receive either dietary tryptophan or a placebo (Attenburrow et al., 2003). Profile of Mood States (POMS) testing on the final day of the diet showed no change in mood (Attenburrow et al., 2003). In another long-term study, more than 29,000 Finnish men ages 50–69 years were assessed over a 5- to 8-year period using a self-report dietary history questionnaire to determine amino acid consumption of the participants' self-reported depression and mood. No associations were found between tryptophan intake and depression and mood (Hakkarainen et al., 2003).

The effects of tryptophan supplementation on the mood of healthy participants were also tested in another study (Markus, Firk, Gerhardt, Kloek & Smolders, 2008). Although the same quantities of tryptophan were given to participants, significant improvements in mood were seen only in participants supplemented with a protein hydrolysate and pure tryptophan in comparison to other tryptophan supplementation (Markus et al., 2008).

Another study focused on the use of a high tryptophan diet (50 mg/kg/d) along with a carbohydrate diet to improve smoking abstinence. Sixteen participants were randomly assigned to receive tryptophan and 15 participants received a placebo in addition to group therapy sessions. Anxiety symptoms were lower in the tryptophan group compared to the control group (Bowen, Spring, & Fox, 1991).

Tryptophan Depletion, Mood and Depression

In studies examining the effects of tryptophan depletion on mood and depression, results have been consistent (Ruhé, Mason & Schene, 2007). For example, in a meta-analysis of studies from 1966 through 2006, tryptophan depletion showed decreased mood states in participants with major depressive disorders, with a family history of depressive disorders, or with major depressive disorders in remission (Ruhé, et al., 2007). However, there was no effect on the mood of healthy participants who were subjected to tryptophan depletion.

Other authors have reached similar conclusions (Neumeister et al., 1998; Spillmann et al., 2001). For example, in a double-blinded crossover study, eleven recovered patients with a history of depression and who had suffered from recurrent seasonal affective disorder were randomly assigned to receive beverages with and without tryptophan. The tryptophan depleted beverages caused a transient recurrence of depressive symptoms (Neumeister et al., 1998). Because no healthy participants were included in the sample, this could be construed as a shortcoming of the study (Neumeister et al., 1998). Spillmann et al. (2001) conducted a double-blind, crossover study involving ten formerly depressed patients and found that tryptophan depletion correlated significantly with increased depression and anxiety scale scores. Both clinician-rated questionnaires and self-rating depression and anxiety scales had been used to measure the results (Spillmann et al., 2001).

In another study, tryptophan whey-rich protein products were compared to placebo in 23 recovered depressed patients and 20 matched controls (Booij, Merens, Markus, & Van der Does, 2006). While there was significant improvement in the mood states of the tryptophan product compared to the placebo, only those individuals who had experienced depression in the past suffered from negative mood changes when tryptophan was depleted.

Enhanced Tryptophan Consumption and Depression

In a 3-week randomized, crossover clinical trial, 30 institutionalized, elderly Malaysian residents consumed a cultural food (Talbinah). The authors identified Talbinah as high in tryptophan and assessed it for effects on depression, stress, and anxiety levels of the participants (Badrasawi, Shahar, Manaf & Haron, 2013). The residents were interviewed and measured in weeks 0, 3, 4, and 7. One group was randomized into a control group and consumed the food provided to them by the long-term care facility they lived in. The other group served as the intervention group and was served Talbinah once per day. Study results indicated that depression and stress were reduced and mood was significantly enhanced ($p < .05$) after consumption of the high tryptophan food (Badrasawi et al., 2013). The authors concluded that high tryptophan foods, such as Talbinah, may have behavioral benefits for the older adults.

Sylvia, Peters, Deckersbach, and Nierenberg (2013) identified 23 studies published from 1960 to 2011 that focused on the future possibility of using nutrient-based treatments to help alleviate manic–depressive disorders (Sylvia, Peters, Deckersbach & Nierenberg, 2013). Of these, one involved enhanced tryptophan consumption (Chouinard, Young & Annable, 1985). The Chouinard, Young and Annable (1985) study was an earlier unpublished study that was conducted as a two-phase trial involving 24 participants with mania who consumed large doses of an L-tryptophan amino acid over a two week period. Using the Clinical Global Inventory, the authors found that severity of symptoms was significantly reduced in the tryptophan group (Chouinard et al., 1985). Sylvia et al (2013) recommended further study of nutrient-based treatments, especially since published studies related to depression disorders and tryptophan were extremely limited (Sylvia et al., 2013).

Background Summary

Little evidence is available on the effects of diet on mood or depressive symptoms. Soh and Walter (2011) have explained that it is difficult to change plasma tryptophan levels through diet alone; therefore, most studies have focused on tryptophan supplementation and depletion (Markus et al., 1998; Markus et al., 2008; Mitchell et al., 2011). Very few publications have described the effect of consuming dietary foods and depression, although a study of elderly Malaysian residents conducted by Badrasawi et al. (2013) is an exception. Another group examined tryptophan depletion and its effect on mood but identified no changes in mood (Attenburrow et al., 2003). In previous study reports, dietary consumption of tryptophan produced notable effects in those individuals who suffered from neuropsychological disorders or had a history of such disorders, rather than in healthy individuals (Markus et al., 2008; Neumeister et al., 1998). Also, those studies involved the use of tryptophan supplementation or manufactured nutrient powders rather than actual

study meals. Although existing results are mixed, further study of nutrient-based treatments has been recommended because of the potential impact and benefits on human health as a whole (Sylvia et al., 2013). Therefore, the purpose of this study was to examine the effects of high dietary tryptophan and low dietary tryptophan on anxiety, mood, and depression scores in a healthy population.

Research Design and Sampling Methods

Study Design

Twenty-five participants were recruited into a within-subjects crossover-designed study. The participants were randomized to receive two 4-day dietary treatments; one was a low tryptophan diet (<5 mg/kg body weight/d) and one was a high tryptophan diet (>10 mg/kg body weight/d). There was a randomization of treatment order so all participants did not receive the same diets at the same time, and to prevent an error of variance. To prevent carry-over effects from the intervention diets, 2-week “washout” periods were included between the intervention diets. Differences among the participants’ anxiety, mood, and depression scores were then analyzed following their consumption of both the high and low tryptophan diets. A double-blinded intervention plan resulted in neither the participant nor the researcher conducting the psychological tests knowing when the participant received the high and the low tryptophan treatment diets.

Population Description and Sampling Plan

Using the following selection criteria, 25 healthy young men and women who consented to participate in the study, were randomly selected from 700 professional studies students at a midwestern university. The participants: 1) were in their third term of university study; 2) gave informed consent to participate in the study; 3) were over 18 years of age; and 4) were proficient in reading, speaking and comprehending the English language.

A power analysis was based upon a population mean for the Zung’s depression and anxiety scales used in this study and in previous work. Using Borenstein, Rothstein, and Cohen’s (2001) “Power & Precision” software (2001), the statistical power was calculated at .70 with a 5% level of significance and a “medium” effect size. Statistical power calculations were based upon using paired *t* -test analyses. Possible effects of the dietary interventions were based on information gathered in a preliminary study of dietary intakes and using a similar study population. In addition, a pilot study was conducted with eight participants who were recruited to determine psychometric properties of the study instruments, test study procedures and instrumentation, and to refine study protocols.

Research participants received a small compensation of $25 per week for their time in the study and as an expression of appreciation for contributing to the body of research knowledge. The U.S. Army Human Research Protection Office and the University’s Institutional Review Board reviewed and approved the study’s protocols. This was a requirement of the project’s funding agency. Participants were assured of their right to refuse to participate without prejudice and that their responses would be kept confidential. Study data was summarized prior to being reported.

Dietary Interventions

This within-subjects study was planned to determine differences in anxiety, mood, and depression scores of participants receiving high and low tryptophan diets. The low tryptophan diet contained 5 mg/kg body weight/d of tryptophan. This amount of tryptophan was based on the U.S. Recommended Daily Allowance (US RDA) of tryptophan (Food and Nutrition Board, 1989). The high tryptophan diet contained twice the US RDA for tryptophan (10 mg/kg body weight/d). Participants were served meals that met their required kilocalorie levels so that the participants' would not lose weight, feel hungry or be over-fed. Their individual energy (kilocalorie) requirements were determined by indirect calorimetry. Also, to mitigate unplanned effects arising from possible micronutrient deficiencies, study meals were planned to meet the US RDA within a 5% variance.

During an initial meeting with the study dietitian, eating schedules for each participant were determined. Weekends were also excluded to prevent logistical disruptions for both the participants and the research project. A two week washout period separated the dietary interventions. Tryptophan levels were calculated according to each participant's individual body weight for the first day of each study week. A variety of foods containing tryptophan were served, including mozzarella cheese, soy products, pumpkin seeds, and egg whites.

The preparation and consumption of study foods was closely monitored by the research team to ensure strict compliance with consuming the study foods. The study meals were planned by the registered dietitian in consultation with the Principal Investigator. Portion sizes of the prescribed foods were weighed before and after eating under the supervision of the study dietitian. Weighing study foods and beverages is considered the most precise method of measuring the food consumption of an individual (Gibson, 1990).

The study diets were served in an on-campus, centrally located, metabolic dining area. The dining space was arranged within a behavioral research facility to provide a controlled environment for serving study meals. Meals were served by research team members and participants were reminded of the importance of compliance with study protocols to consume only study foods and beverages. Participants were told that non-compliance could result in being eliminated from the study.

The beverages served included water and non-caloric and calorie-containing drinks such as milk and assorted fruit juices. Caffeine intake was limited to no more than 100 mg of caffeine per day to avoid confounding effects. Participants could consume as much water as desired with all beverages measured and recorded to the nearest one-tenth of a fluid ounce. Participants were provided with bottled water. All bottles and any remaining contents were to be returned so accurate amounts of each participant's consumed foods and beverages could be weighed and recorded.

Each day, the participants verified in writing that no other foods or beverages had been consumed during the previous 24 hours other than those issued by the study. All foods were eaten in the study's metabolic dining room except for the weighed snacks given to the study participants to consume during the evening to sustain the participants until morning.

Tests and Measurement

Data collected during the study included the following participant measurements:

Demographics are composed of the following variables: place of residence, age, employment status, years of education, marital/social living status, ethnicity, and anthropometric weight and height measurements. Body mass indices (BMI) were also calculated.

Salivary cortisol was measured because it has been shown to reflect changes in mood (Markus, Panhuysen, Tuiten & Koppeschaar, 2000). A cortisol *Salivette*© swab, placed in each participant's mouth under the tongue, was used to collect the saliva specimens.

Zung's Self-Rating Anxiety Scale (Zung, 1965) was used to evaluate and quantify 20 items as they applied to the participant's anxiety within the past 24 hours. Degrees of anxiety were scored using the following values: None of the time = 1; Some or a little of the time (mild) = 2; Good part of the time (moderate) = 3; Most or all of the time (severe) = 4. An index score was obtained by dividing the sum of all scores of the 20 items by a maximum possible score of 0.8. Alpha reliabilities ranged from 0.61 to 0.80 as "substantially" reliable in previous studies (Bucky & Spielberger, 1973). Zung established the validity of the instrument through previous correlation comparisons of 96 age-matched normal participants using the Taylor Manifest Anxiety Scale (Zung, 1973). For this study, the Self-Rating Anxiety Scale had a reliability of alpha = .85.

Zung's Self-Rating Depression Scale (SDS) was used to measure the participant's depression symptoms. The Zung SDS is a 20-item scale developed from interview data of patients who exhibited various depressive symptoms (Zung, Richards, & Short, 1965; Zung, 1965; Zung, 1986). Each item has a scoring range from 1 (least depressed) to 4 (most depressed). The reliability of Zung's SDS was alpha = .91 for this study and alpha = .85 for depression measurements of a sample of 415 undergraduate students (Campbell, Maynard, Roberti & Emmanuel, 2012). Concurrent validity for the Zung SDS was established with the Minnesota Multiphasic Personality Inventory (MMPI). Based on depression measures for 152 patients, a correlation coefficient of .70 was obtained between the Zung SDS and MMPI Depression Scales (Zung, 1967).

Mood was measured using the *PANAS (Positive Affect Negative Affect Schedule*) (Watson, Clark, & Tellegen, 1988). Ten items assessed positive affect or mood (e.g., excited), and 10 items measured negative affect or mood (e.g., irritable). A state measure of mood was assessed by having the participants indicate "to what extent do you feel this way right now" (Watson et al., 1988). Their answers ranged from 5 (extremely) to 1 (very slightly or not at all). The PANAS scale scored acceptably high alpha reliabilities, ranging from .86 to .90 for Positive Affect and from .84 to .87 for Negative Affect in 101 undergraduate students (Watson et al., 1988). In addition to these 20 items from the PANAS, 40 items were added from the expanded PANAS (PANAS-X) to measure irritability. Research set the internal consistency of the positive and negative affect scales at alpha =.90 in a study of 328 participants (Watson & Clark, 1994).

A *Health Status Assessment* checklist, modified from Doenge's (1989) Health Assessment Checklist, consisted of nine factors ascertained during a medical assessment of the participants. A history of diabetes, heart disease, hypertension, respiratory insufficiency, metabolic or gastrointestinal disorder, and urinary or neurological disorder was assessed and recorded for each study participant by the research nurse. Diabetes and pregnancy were exclusion factors for this study because of the special dietary requirements that are necessary for prenatal and diabetic conditions. The participants' medication intakes and health status assessments were also used to identify conditions that might compromise performance outcomes.

Plan for Data Collection and Analysis

Plan for Data Collection

During an initial meeting, potential participants who met the study's inclusion criteria were invited to be in this study. The study's purpose and participation details were explained and questions answered by the investigators. Those who consented met with the research nurse to complete demographic questionnaires and baseline health assessments. Height and weight measurements were taken during the baseline week and on the first day and last day of the treatment weeks. Directions for completing the dietary interventions and laboratory and psychological tests were then explained. Each participant was assigned an eating schedule that accommodated their academic and/or work schedules within the serving times of 6:30 a.m. and 6:30 p.m. During arranged eating times for the tryptophan intervention weeks, each participant was served meals weighed and measured to within one tenth of an ounce of accuracy for each food item. Each participant was monitored to ensure their meals were eaten and that food intakes were weighed and recorded accurately. On the fourth day of receiving each of the high and low dietary tryptophan meals, respectively, each participant met with the psychologist for testing. Each participant received a $25 stipend per study week for time and inconvenience and as an expression of appreciation for the meaningful contribution each individual made to the research.

Data Entry and Analysis

Study data were entered into and analyzed using the Statistical Package for Social Sciences (SPSS). Data were confirmed through a double entry procedure to further reduce error rates. Frequencies were tabulated for responses to demographic questions and measures of anxiety, depression, and mood (irritability). Statistical significance was set at alpha $\leq .05$. Paired-sample *t*-tests and analysis of variance were used to compare participants' anxiety, mood, and depression scores following high and low dietary tryptophan intakes. The ESHA *Food Processor Nutrition Analysis Software*© program was used to analyze the nutritional content of the weighed food and beverage intakes that were served to each participant (ESHA Research, 2010). The nutrients selected for assessment and analysis were based on the US RDA (Food and Nutrition Board, 1989).

Results

Demographics

The study participants' average age was 20.5 years (*SD* = 1.6), and they had 13.9 years of education (*SD* = 0.8). BMI averaged 23.5 (*SD* = 2.9) for all participants (See Table 1).

Effects of Tryptophan Consumption on Anxiety

Zung's Self-Rating Anxiety Scale scores were analyzed following the participants' consumption of high and low dietary tryptophan (see Table 2). Using a paired-sample *t*-test, anxiety scores were significantly lower (paired $t = 2.2$, $p = .04$) when the participants had consumed high tryptophan in comparison to when they had consumed low tryptophan. Self-Rating Anxiety scores showed significant improvement in participants who consumed more dietary tryptophan.

Effects of Tryptophan Consumption on Mood

The PANAS basic positive and negative affect scale (mood) scores and irritability scores for the participants consuming high tryptophan and low tryptophan intakes are displayed in Table 2. Participants had significantly higher positive affect (mood) scores (paired $t = 2.8$, $p = .01$) when consuming high dietary tryptophan than when the same participants consumed low dietary tryptophan. The PANAS basic negative affect scale (mood) scores for the participants consuming high tryptophan and low tryptophan intakes were also not significantly different ($p > .05$). The Undergraduate Affective Irritability Subscale (Sakamoto, Kijima, Tomoda, & Kambara, 1998; Zung, 1965) scores were analyzed following the participants' consumption of high and low dietary tryptophan intakes. Using a paired-sample *t*-test, irritability scores trended higher (paired $t = 2.03$, $p = .05$) when the participants had consumed a low tryptophan diet in comparison to when they had consumed a high tryptophan diet.

Effects of Tryptophan Consumption on Depression

Using Zung's SDS Depression Scale, participants' mean depression scale scores were calculated when the participants consumed high dietary tryptophan and when they consumed low tryptophan (See Table 2). Participants were not clinically depressed upon entry into the study. However, a within-subjects analysis of participants' depression scale scores indicated they reached thresholds for depression (paired $t = 2.2$, $p = .02$) after consuming less dietary tryptophan in comparison to when there was more tryptophan in their diet.

Effects of Tryptophan Consumption on Salivary Cortisol

Salivary cortisol swabs were taken and analyzed following the participants' consumption of the high dietary tryptophan diet and the low dietary tryptophan diet (See Table 2). The cortisol swabs were taken at the end of both of the treatment weeks for all participants. The cortisol lab values were not significantly different ($p = > .05$) when comparing the saliva samples.

Discussion

The results of this double-blinded, within-subjects study indicate that participants consuming higher levels of tryptophan (>10 mg/kg body weight/d) had significantly less depression and irritability and decreased anxiety than when they consumed lower levels of tryptophan (<5 mg/kg body weight/d). This finding may be explained by other results indicating that dietary tryptophan can affect serotonin neurotransmitter levels in the brain, and in turn, influence the occurrence of depressive behavior in participants (Badrasawi et al., 2013). Also, earlier work has shown that serotonin-releasing neurons typically release neurotransmitters at levels determined by nutritional intakes (Wurtman & Wurtman, 1995). In addition, unlike similar studies showing that high tryptophan levels dampen salivary cortisol levels (Markus et al., 2000), we found no significant differences in cortisol lab values when comparing the saliva samples.

Although other tryptophan researchers have hypothesized that tryptophan consumed as a dietary food item would not have significant effects on affective mood states in healthy individuals (Fernstrom, 2013), an analysis of healthy participants in our study showed that higher doses of tryptophan consumed in dietary foods resulted in significantly ($p < .05$) less depression and irritability and decreased anxiety. Similarly, in a study of 30 older Malaysian residents who consumed a high tryptophan native food over several weeks the residents experienced benefits related to mood, depression, stress, and anxiety levels (Badrasawi et al., 2013). However, our results differed from those of Attenburrow et al. (2003), who compared consumption of nutritionally sourced tryptophan (1.8 g daily) to a placebo in a weight loss study, and found no significant changes in the participants' mood (Attenburrow et al., 2003).

Neumeister et al. (1998) achieved similar results with participants who had recovered from seasonal affective disorder and were served beverages with and without tryptophan. Transient recurrences of depressive symptoms resulted in the non-tryptophan group (Neumeister et al., 1998). The negative mood states because of lack of tryptophan in participants with a history of depression was consistent with our research in that lower tryptophan consumption also led to depressed mood states. However, the Neumeister et al. (1998) study included participants with a history of depressive symptoms and our study was with healthy participants (Neumeister et al., 1998). Similarly, in a study by Spillman et al. (2001) of formerly depressed patients, tryptophan depletion was associated with increased depression and anxiety (Spillman et al., 2001).

Our results fit with other evidence that dietary intervention can help mitigate depressive symptoms (Badrasawi et al., 2013; Fernstrom, 2013). Although the neurotransmitter serotonin has a role in mood alterations and depression, central serotonin availability depends on the availability of its precursor tryptophan being made accessible to the central nervous system through the blood brain barrier. However, its precursor, tryptophan, can pass through the blood– brain barrier and is converted to serotonin in the presence of a vitamin B_6 derivative (Dakshinamurti, Paulose & Viswanathan, 1990; Shabbir, et al., 2013). While many of the studies described in the literature did not indicate the role of vitamin B_6 and its potential effect on their study outcomes, we controlled for possible micronutrient effects in

our study by planning all of the diets to meet the US RDA values, including vitamin B_6. Our study also focused on the effects of higher doses of dietary tryptophan on affective disorders unlike many of the published studies that focused on the effects of tryptophan depletion.

Implications for Practice

Based on the findings from our study, recommendations can be made for nursing practice. With the continued rise in mental health disparities, it seems important for nurses to provide information to patients related to health and dietary interventions that can decrease anxiety, irritability, and depression. The benefits of a diet for patients susceptible to affective disorders seem important since tryptophan – dense diets also improved mood and decreased symptoms of depression among depressed individuals in other studies (Badrasawi et al., 2013, Markus et al., 2008; Neumeister et al., 1998). However, the benefits in some of the studies resulted from a tryptophan supplement or manufactured nutrient powder (Markus et al., 2008; Neumeister et al., 1998).

Although study results suggest that tryptophan could be used as a remedy for improvement of affective disorders, considerations may also need to be taken before initiating tryptophan supplement treatments. For example, very high doses of up to 200 kg body weight/d of ingested tryptophan can result in side effects such as nausea, dizziness, and tremors when taken alone or in conjunction with serotonin enhancement drugs (Fernstrom, 2012). In rare instances serotonin syndrome, a condition in which individuals can present with more serious symptoms such as delirium or even coma, can result (Martin, 1996; Sternbach, 1991). Tryptophan supplementation taken in conjunction with medications such as monoamine oxidase inhibitors, for example, should also be used with caution. With the increasing use of selective serotonin reuptake inhibitor medications (e.g. Prozac or Zoloft) and, if used in combination with higher doses of tryptophan, could increase the risk of serotonin syndrome. More research is needed in order to understand the point at which side effects begin to occur when tryptophan is administered and at what dosage levels do significant side effects develop (Fernstrom, 2012).

The results of our study and other studies highlight the positive effects that dietary tryptophan can have on symptoms of behavioral and depressive disorders (Badrasawi et al., 2013; Fernstrom, 2013; Markus et al., 2008; Neumeister et al., 1998). By concentrating on the positive effects of diet on affective processes, nurses can provide support for both healthy individuals and those at risk for affective disorders.

Summary and Conclusions

In summary, our study of healthy participants revealed that higher doses of dietary tryptophan resulted in significantly ($p \leq .05$) less depression and irritability and decreased anxiety. This outcome differs, however, from most of the existing research using tryptophan powders, tablets, capsules or supplementation rather than the effects of diet alone on depression, mood, or anxiety. Also of note, studies that focus on healthy participants are sparse. Our results are consistent with those of other studies in which dietary consumption of

tryptophan produced notable effects in individuals with a history of behavioral and depressive disorders (Markus et al., 2008; Neumeister et al., 1998).

In conclusion, the results of our study indicated that increasing dietary intake of tryptophan may affect depression and mood scores of healthy participants resulting in less depressive symptoms and better mood states when more tryptophan was present in their diet. Also, consuming less dietary tryptophan resulted in more irritability and anxiety in comparison to when the same individuals consumed more tryptophan. However, consuming more tryptophan did not have a significant effect on salivary cortisol levels. Results of our study may have limited generalizability because of the small, homogeneous sample; however, each participant did serve as their own control in this within-subjects designed study. Future work could be strengthened by using a placebo or comparison group. Given that few clinical studies have addressed the effects of dietary tryptophan consumption on affective disorders such as mood, depression and anxiety in healthy individuals, further research is recommended.

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Highlights

- Neither high nor low dietary tryptophan intakes influenced negative affect (mood)
- Positive affect was significantly better with high tryptophan dietary intakes
- Increased dietary tryptophan resulted in fewer depressive symptoms and less anxiety

Table 1

Participant Demographics

Variables	Mean	SD
Demographics		
Age (Years)	20.5	1.6
Education (Years)	13.9	0.8
Body Mass Index	23.5	2.9

Note: N = 25

Table 2

Within-Subject Differences for High and Low Dietary Tryptophan Intake

Variable	M	SD		Paired *t-test*	*p*
Anxiety					
Low Tryptophan	38.0	6.5	>	2.2	.04*
High Tryptophan	35.9	5.7			
Positive Affect					
Low Tryptophan	16.6	4.1	>	2.8	.01**
High Tryptophan	18.8	3.5			
Negative Affect					
Low Tryptophan	7.8	2.5	>	.92	N.S.
High Tryptophan	7.5	1.8			
Irritability					
Low Tryptophan	35.3	11.6	>	2.0	.05*
High Tryptophan	31.7	7.9			
Depression					
Low Tryptophan	39.6	8.3	>	2.2	.02*
High Tryptophan	37.1	6.2			
Cortisol					
Low Tryptophan	.2	.1	>	.50	N.S.
High Tryptophan	.2	.09			

Note: N = 25

* $p \leq .05$;

** $p \leq .01$