

## ABSTRACT

### Relationship Between Dietary Fiber and Measures of Mental Health

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This study examined the relationship between dietary fiber and mental health among college students. Food frequency data and mental health responses taken as part of the Neuro-regulation in Attachment to God, Human Relationships, and Health study initiated by Baylor University were used to determine potential effect of fiber on mental health. It was found that the odds of being depressed were reduced with higher intakes of insoluble fiber. This relationship persisted after adjusting for participants' age, sex, and BMI. Our findings indicate that college students may experience a lessening in number and severity of depressive symptoms with increased insoluble dietary fiber intake.

Relationship Between Dietary Fiber and Measures of Mental Health

by

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A Thesis

Approved by the Department of Human Sciences and Design

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## CHAPTER ONE

### Background

In 2005, fiber was labeled as a “nutrient of concern” by the *Dietary Guidelines for Americans* to underline the importance it has as a component of human health.<sup>1</sup> Dietary fibers include plant-derived non-starch polysaccharides, resistant oligosaccharides, lignin, and resistant starch.<sup>2</sup> Dietary fiber can subsequently be categorized as either soluble or insoluble fiber, depending on the fibers’ solubility in a buffer at a defined pH and/or its solubility *in vivo* in an aqueous environment.<sup>3</sup> The vast majority of Americans have fallen exceedingly low in their daily fiber intake, despite many believing they understand the health benefits and reporting attempting to increase their total fiber intake.<sup>1</sup> Similarly, with a recommended goal of between 22 and 30 grams of fiber per day (or 14 grams/100 kcals), the average U.S. adult exhibits an intake that is less than half this goal, with only 5% of the population actually meeting recommendations.<sup>4,5</sup> This trend persists despite low fiber intake being linked to coronary heart disease, hypertension, diabetes, gastrointestinal disease, and mental illness.<sup>6</sup>

The incidence of depression and other mental health disorders increased significantly in the United States between 2005 and 2015, as well as the reported prevalence of depression, generalized anxiety, and social anxiety among college students.<sup>7</sup> Around 15-20% of people will experience a mental health disorder such as a depressive or anxiety episode in their lifetime; anxiety and depression are ranked among the top 10 causes of the global burden of disease.<sup>7</sup> Recent approaches for the

management of depression and anxiety have focused on the link between diet and mood, as up to 40% of those with depression do not adequately respond to pharmacological or psychological treatment.<sup>7</sup> Critically, diet is a modifying determinate of the diversity, relative abundance, and functionality of the microbiota within the intestine, with fiber being likely the most influential dietary component.

There is increasing evidence that fiber is a mediator in an axis of brain, gut, and microbiota communication.<sup>8</sup> The system of gut-brain communication not only ensures proper maintenance and coordination of gastrointestinal functions to support behavioral and physiological processes, but also allows for feedback from the gut to effect mood, behaviors, and some higher cognitive functions.<sup>9</sup> A recent explosion of growth in literature detailing the bidirectional interactions between the gut microbiome and brain supports a model that integrates the central nervous system, gastrointestinal, and immune systems.<sup>8</sup> This system was coined the gut-brain axis, after work, namely using germ-free mice, suggested that the gut microbiota may influence stress-related behaviors specifically; particularly those pertinent to anxiety and depression.<sup>10,11,12,13</sup> In addition, transplanted gut microbiota from human donors with Autism spectrum disorder (ASD) to germ-free mice revealed that colonization with ASD microbiota was sufficient to induce hallmark behaviors.<sup>14</sup> Similarly, both ASD symptoms and gastrointestinal symptoms in humans have shown improvement following fecal microbiota transfer, for as long as 2 years post intervention.<sup>15,16</sup> From these models, it is increasingly clear that an imbalance in the structure and function of the gut microbiota impacts multiple stress-related neurotransmitter systems across multiple brain regions.<sup>17</sup>

The definitive role that the microbiota plays in the gut-brain signaling pathway is elusive. The limited current state of knowledge regarding the identity and function of the gut's massive and diverse microbial composition is hindering advances in mental health treatment and diagnosis.<sup>9</sup> A proposed mechanism connecting the gut microbiome with mental disorder is through the loss of gut barrier function and translocation of microbial factors that either directly or indirectly affect brain function and subsequently mental health. Specifically, bacterial metabolites, principally lipopolysaccharides, that are able to gain entry to systemic circulation via intestinal epithelial tight junction permeability defects.<sup>18</sup> Human bodies produce antibodies against these and other metabolites, and antibody levels against these factors are higher in patients with major depression disorders than in controls.<sup>18</sup> The gut microbiota also makes neurotransmitters including dopamine, noradrenaline, GABA, acetylcholine, histamine, and serotonin.<sup>19</sup> Furthermore, dysbiosis (alterations in composition and function) and inflammation of the gut microbiome have been linked to several mental illnesses including anxiety and depression.<sup>20</sup>

Importantly, fiber is shown to be a way to fortify intestinal barrier function.<sup>21</sup> Microbiota-accessible carbohydrates (MACs) are found in dietary fiber and are complex carbohydrates that are indigestible by host enzymes but are able to be fermented by gut microbiota.<sup>21</sup> The association between consumption of dietary fiber and maintenance of a functioning intestinal barrier can be partially attributed to the production of short chain fatty acids in the gut lumen, which support intestinal epithelial cell proliferation and protect barrier integrity.<sup>21</sup> Short chain fatty acids also constitute the primary energy source for colonocytes and induce mucus secretion, another important component of

proper barrier function.<sup>21</sup> Reduced short chain fatty acid production has been found in general anxiety patients and could result in intestinal barrier dysfunction, compromising immune response or neurotransmitter levels, and in-turn contributing to brain dysfunction.<sup>7</sup> This brain dysfunction can manifest in a multitude of disorders including anxiety and depression.

To date, a limited number of studies have explored the possible relationship between dietary fiber intake and brain dysfunction on mental health disorders. Results from a prospective cohort study indicated that higher consumption of dietary fiber was associated with a reduced risk of depressive symptoms among postmenopausal women in the U.S.<sup>22</sup> Furthermore, a cross-sectional study performed among older Chinese individuals and a case control study with a population of Korean adolescent girls both suggested an inverse relationship between dietary fiber and risk of depressive symptoms.<sup>23,24</sup> Among the Japanese adult workforce, the risk of depressive symptoms was only significantly associated with consumption of fiber from vegetables and fruits, but not intake measures of total, soluble, and insoluble fiber.<sup>25</sup> Cross sectional analysis of a Korean national database found an inverse relationship between clinical depression diagnosis and seaweed and mushroom fiber in adults.<sup>26</sup> An exploration of a large U.S. national database, with subjects ranging in age from 20 to over 60, found that intakes of total, vegetable, and fruit fiber were inversely associated with depressive symptoms.<sup>27</sup> Likewise, in U.S. adults over the age of 55, consumption of fruits and vegetables was associated with a lower likelihood of depressive symptoms.<sup>28</sup>

Studies with national databases from Korea and the U.S. have found dietary fiber intake to be inversely associated with depression incidence in premenopausal women.<sup>29,30</sup>

Depression presence was also associated with insufficient fiber intake in elderly Polish individuals.<sup>31</sup> When it comes to studies in college aged populations, literature is lacking. Support for the inverse association between dietary fiber and depression is limited to a study of Korean female college students that showed that average fiber intake was lower in depression patients than in control individuals.<sup>32</sup>

With respect to anxiety, the literature reports varying degrees of association between dietary fiber intake and anxiety risk. One study found that habitual diets high in fiber have been seen to reduce the risk of anxiety and stress.<sup>33</sup> At the same time, a meta-analysis of randomized controlled trials found that sampled women observed significantly greater benefits from dietary interventions for symptoms of both depression and anxiety.<sup>34</sup> However, the study also reported a majority of included trials found no effect of dietary interventions for anxiety.<sup>34</sup> A study using germ-free mice found that short chain fatty acids, colonocyte fuel generated from fermenting dietary fiber, decrease anxiety in control but not stressed animals.<sup>35</sup> Evidently, work has not adjudicated the relationship between dietary fiber and anxiety to the same degree it has for depression.

In order to obtain more insight between dietary fiber intake and mental health, we conducted a sub-analysis using data from the study Neuro-regulation in Attachment to God, Human Relationships, and Health. This study was initiated in 2018 by the Baylor University Nutrition Sciences department (Principal Investigator: Dr. Maria Boccia) in an attempt to advance understandings of the neurobiological mechanisms involved in how relationships, particularly relationships (specific attachment styles) with God, affect health. This “Attachment to God” (ATG) study is what was used to produce the findings of this study. Data collected, pertinent to the present study, included responses to the

National Cancer institute FFQ (DHQ II), which is considered the most valid dietary history assessment. Data collected also included responses to the survey questionnaire Hospital Anxiety and Depression Scale and the Medical Outcomes Study Questionnaire (Short-Form 36 Health Survey).<sup>36,37</sup>

Overall, insoluble fiber was determined to be a significant predictor of depression among participants in the ATG study. This association remained significant after adjusting for age, sex, and BMI of the subjects. These findings suggest that an increase in daily insoluble dietary fiber may result in a reduction of depression symptoms and severity among college aged individuals.

#### *Purpose*

The purpose of this study was to determine if there is a relationship between mental health, particularly anxiety and depression, and dietary fiber in college aged students at Baylor University.

#### *Objective*

Determine a relationship between mental health and dietary fiber using data collected by the Baylor University Nutrition Sciences “Attachment to God” study.

## CHAPTER TWO

### Materials and Methods

#### *Study Inclusion*

Data was obtained from the Neuro-regulation in Attachment to God, Human Relationships, and Health study (ATG). Participants were recruited from Baylor University and were included if they were over the age of 18, not pregnant or breastfeeding, and fluent in English. Participants were required to go through the consent process, complete all study questionnaires including the food-frequency questionnaire (FFQ), Hospital Anxiety and Depression Scale, and Short-Form 36 Health Survey, collect a total urine sample, and complete a DXA body composition analysis. The project period was an 18-month window beginning June of 2018. This study was approved by the Baylor University IRB reference #1217290.

This sub-analysis of the parent ATG study was conducted to determine if there is a relationship between consumption of dietary fiber and mental health. The DHQ II food-frequency questionnaire consist of 134 questions relating to food consumption habits over 24 hours.<sup>38</sup> This tool is then able to assess macronutrient and micronutrient consumption using a previously evaluated database. Participants' FFQ-measured dietary fiber intake levels were normalized by adjusting for their daily Caloric intake using the RDI of 14g fiber per 1000 kcals.<sup>39</sup> This standardized fiber intake level was then categorized into either Low Total Fiber Intake and Adequate Total Fiber Intake depending on whether the participant did not meet or exceeded the RDI. Both fiber intake

categories were then adjusted for age, sex, race, level in school, religious affiliation, method of paying for school, times drank in the last month, height, weight, BMI, percent body mass, lean body mass, visceral fat mass, Short-Form 36 general health, anxiety, and depression. When it was clear there were no differences between the categories after controlling for these possible confounding variables, fiber types of total, soluble, insoluble were compared to mental health scores. The final adjusted model included three variables: age, sex, and BMI.

Fiber was categorized as either total fiber, representing all dietary fiber ingested in a day, soluble fiber, representing digestible dietary fiber consumed in a day, and insoluble fiber, representing unfermentable dietary fiber consumed in a day. Mental health was assessed in-part by using the “Short-Form 36” self-survey. The Short-Form 36 questionnaire includes multi-item scales to measure 8 dimensions of general mental health. These dimensions relate to physical functioning, role limitations due to physical health problems, bodily pain, social functioning, general mental health, role limitations due to emotional problems, vitality, and general health perceptions. Mental health was also assessed using the Hospital Anxiety and Depression Scale, which focuses on non-physical symptoms that can be used to diagnose people with significant ill-health. With this tool, anxiety and depression are assessed as separate entities, as anxiety often precedes depression in response to stressors.<sup>36</sup> Although, anxiety and depression questions are interspersed throughout the questionnaire, they are scored separately. Seven questions for each disorder (depression and anxiety) were administered then a points system was used rank the severity of score in terms of possible diagnosis. Responses were assigned points, then cumulative points were compared to a scale in which 0-7

points were non cases of anxiety or depression, 8-10 points is indicative of mild cases, 11-14 points moderate cases, and 15-21 points severe cases.

### *Statistics*

Ordinal data were used from the Short-Form 36 and the Hospital anxiety and Depression Scale. There were 139 participants who were included in the Neuro-regulation in Attachment to God, Human Relationships, and Health study in 2018. One hundred and thirty-four of these participants were included in this study after four were excluded because of lack of FFQ responses. One participant was excluded because of biologically improbable fiber intake levels. Logistic regression was used to analyze total, soluble, and insoluble fiber types with the dichotomized model for Hospital anxiety and Depression scores. Linear regression was used to analyze the square of Short-Form 36 responses with total, soluble, and insoluble fiber types, as this continuous analysis model was deemed more appropriate. JMP Pro 14 and STATA 14.2 software was used to complete regression analyses. A chi squared test was used when analyzing fiber levels into low and adequate categories to determine if significant differences arose. Pearson correlation analysis was performed between each mental health score and total, soluble, and insoluble fiber using Prism GraphPad 9. For all analyses, significance level was set at  $p \leq 0.05$ .

## CHAPTER THREE

### Results

#### *Participants*

Of the 139 participants who completed the Neuro-regulation in Attachment to God, Human Relationships, and Health study, 134 (n=134) were included in the analysis. Fiber intake data was categorized into “low” or “adequate” levels according to the 14 g per 1000 kcals RDA. Characteristics between both fiber levels are presented in Table 1.

Table 1. Characteristics of fiber intake categories

	Low total fiber intake	Adequate total fiber intake	P
No. of participants (%)	97 (72)	37 (28)	
Age	20.94 (6.36)	22.43 (8.08)	0.2626
Sex (%)			0.2134
Male	16 (16.49)	3 (8.11)	
Female	81 (83.51)	34 (91.89)	
Race (%)			0.8180
Caucasian	59 (80.82)	22 (59.46)	
African American	10 (10.31)	5 (13.51)	
Hispanic/Latino	7 (7.22)	4 (10.81)	
Asian	14 (14.13)	3 (8.11)	
Native American	0	0	
Mixed	7 (7.22)	3 (8.11)	
Level in School (%)			0.4147
Freshman	17 (17.89)	3 (8.33)	
Sophomore	28 (29.47)	9 (25)	
Junior	23 (24.21)	12 (33.33)	
Senior	21 (22.11)	11 (30.56)	
Graduate School	6 (6.32)	1 (2.78)	
Religious Affiliation			0.2815
Christian	38 (39.18)	12 (32.43)	
Protestant	38 (39.18)	17 (45.95)	
Catholic	16 (16.49)	3 (8.11)	
Jewish	0	0	
Muslim	0	0	
Other	2 (2.06)	1 (2.70)	
Unaffiliated	3 (3.09)	4 (10.81)	
Paying for school (%)			0.1502
Working	1 (1.05)	1 (2.78)	
Family	19 (20.00)	9 (25.00)	
Loans	2 (2.11)	1 (2.78)	
Scholarships/grants	0	2 (5.56)	
Multiple sources	73 (76.84)	23 (63.89)	
Times drank in last month (%)			0.3911
None	39 (40.21)	16 (43.24)	
1-2	34 (35.05)	9 (24.32)	
3-9	21 (21.65)	9 (24.32)	
10-19	2 (2.06)	3 (8.11)	
20+	1 (1.03)	0	
Height (in)	65.43 (2.91)	65.67 (3.11)	0.6816
Weight (lbs.)	149.31 (30.93)	147.95 (41.12)	0.8370
BMI	24.40 (4.09)	24.01 (5.28)	0.6445
Percent Body Mass	28.79 (8.71)	27.34 (8.69)	0.3908
Lean Body Mass	105.19 (20.22)	(105.21 (18.34)	0.9953
Visceral Fat Mass	8.20 (4.75)	7.59 (8.85)	0.5162
RAND General Health	70.48 (19.80)	75.27 (14.95)	0.1847
Anxiety (%)			0.8898
Normal	44 (45.36)	17 (45.95)	
Borderline	18 (18.56)	8 (21.62)	
Clinically Anxious	35 (36.08)	12 (32.43)	
Depression (%)			0.3315
Normal	84 (86.60)	35 (94.59)	
Borderline	9 (9.28)	2 (5.41)	
Clinically Depressed	4 (4.12)	0	

Data are mean (standard deviation) or number of participants (percentages).

Participants provided background and demographic information, as well as completed a DEXA body composition scan as part of the Neuro-regulation in Attachment to God, Human Relationships, and Health study. This data was analyzed in combination with dietary fiber data derived from the Food Frequency Questionnaire fiber intake data, then linear regression was used to determine if there were significant differences between each group, as evidenced by the included P values. The P values, all above 0.05, indicate there were no statistically significant differences between the Low total fiber intake and the Adequate total fiber intake groups for each potentially confounding variable.

#### *Fiber and Mental Health*

Pearson's correlational analysis was utilized to determine strength of and direction of relationship between the measures of mental health, Short-Form 36 and the Hospital Anxiety and Depression Scale, and each fiber type (total, soluble, and insoluble). Pearson's correlation coefficient,  $r$ , and graphical representation are presented in Figure 1.

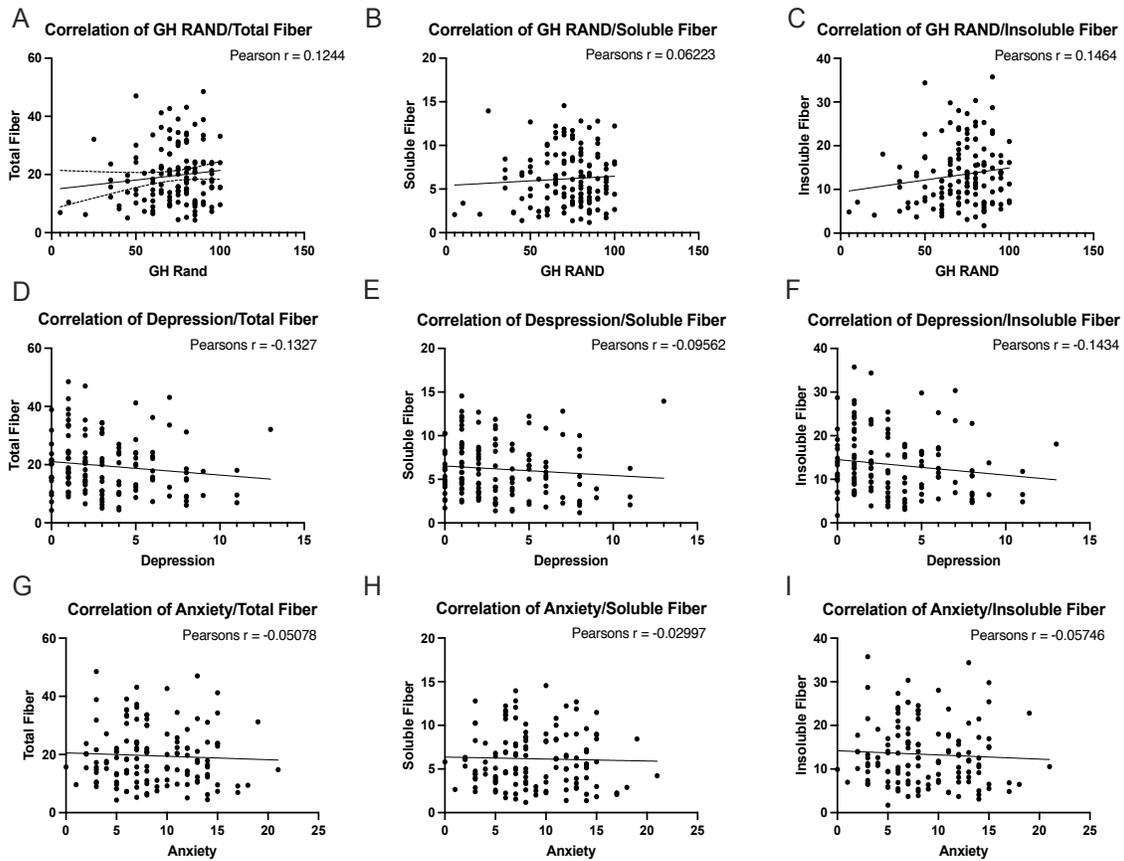


Figure 1. Correlation of fiber intakes for each mental health variable. Pearson's correlations between total, soluble, or insoluble and Short-Form 36 scores (A-C), Depression scores (D-F), and Anxiety scores (G-I).

Dietary fiber intake types, total dietary fiber, soluble fiber, and insoluble fiber, from the Food Frequency questionnaire (DHQ II) were analyzed together with the square of the Short-Form 36 score for each of the participants. Two models were constructed: the first (Model 1) using fiber and Short-Form 36 scores alone, the second (Model 2) adjusting Model 1 for age, sex, and BMI. Dietary fiber intake types compared to Short-Form 36 scores for both Model 1 and Model 2 are presented in Table 2.

Table 2. Relationship between Short-Form 36 scores and dietary fiber intake by fiber type

	N	Coef.	Model 1				Model 2*				
			Std. Err.	LCI	UCI	P	Coef.	Std. Err.	LCI	UCI	P
Short-Form 36											
Total fiber	134	22.573	20.876	-18.722	63.868	0.282	21.097	19.879	-18.233	60.427	0.291
Soluble fiber	134	28.094	64.732	-99.953	156.141	0.665	19.973	61.630	-101.964	141.909	0.746
Insoluble fiber	134	38.576	29.144	-19.074	96.226	0.188	37.252	27.756	-17.664	92.168	0.182

\*Adjusted for AGE, SEX, BMI

In Figure 2, Pearson's correlation analysis demonstrated no significant correlations between dietary fiber type and mental health scores. Table 2 illustrates that total fiber, soluble fiber, nor insoluble fiber were seen to have an effect on Short-Form 36 scores. Similarly, after adjusting for age, sex, and BMI in Model 2, no relationship was seen.

Dietary fiber intake types, total dietary fiber, soluble fiber, and insoluble fiber, from the Food Frequency questionnaire (DHQ II) were analyzed together using logistic regression with the Hospital Anxiety and Depression Scale for each of the participants. Two models were constructed: the first (Model 1) using fiber and Hospital Anxiety and Depression scores alone, the second (Model 2) adjusting for age, sex, and BMI. Dietary fiber intake types compared to Hospital Anxiety and Depression scores for both Model 1 and Model 2 are presented in Table 3.

Table 3. Relationship between Hospital Anxiety and Depression score and dietary fiber intake by fiber type

	N	OR	Model 1			Model 2*			
			LCI	UCI	P	OR	LCI	UCI	P
<b>Depression</b>									
Total fiber	134	0.933	0.869	1.002	0.056	0.932	0.867	1.002	0.057
Soluble fiber	134	0.870	0.718	1.055	0.158	0.867	0.711	1.059	0.162
<b>Insoluble fiber</b>	<b>134</b>	<b>0.896</b>	<b>0.807</b>	<b>0.995</b>	<b>0.041</b>	<b>0.897</b>	<b>0.807</b>	<b>0.996</b>	<b>0.042</b>
<b>Anxiety</b>									
Total fiber	134	0.984	0.951	1.019	0.375	0.984	0.949	1.021	0.394
Soluble fiber	134	0.962	0.864	1.070	0.474	0.965	0.861	1.080	0.533
Insoluble fiber	134	0.978	0.931	1.026	0.363	0.977	0.928	1.028	0.369

\*Adjusted for AGE, SEX, BMI

In Model 1 and Model 2, the odds of being depressed are reduced with higher insoluble fiber intake. Additionally, significance was approached for the odds of being depressed are reduced with increasing total fiber intake. When adjusting for age, sex, and BMI, the relationship persisted. This is evidenced by P values of less than or equal to 0.05. There was no statistically significant relationship between the odds of anxiety and dietary fiber intake.

## CHAPTER FOUR

### Discussion

This study examined whether there was a relationship between dietary fiber intake and mental health in college students. Our results suggest that the odds of having depression and/or anxiety are reduced with increasing intakes of dietary fibers of all types, although intake of insoluble fiber and a reduction in depression symptoms/severity was the sole statistically significant relationship. The odds of depression being reduced by total fiber was nearing significance, but this is likely driven by the insoluble fiber intake relationship. Our results also indicate that dietary fiber does not have a statistically significant relationship with Short-Form 36 General Health scores, which measures 8 dimensions of general mental health relating to physical functioning, role limitations due to physical health problems, bodily pain, social functioning, general mental health, role limitations due to emotional problems, vitality, and general health perceptions. Furthermore, after adjusting for age, sex, and BMI, all relationships remained the same.

Previous research supports these findings as depression has been inversely related to dietary fiber intake in a variety of populations.<sup>22,23,24,26,29,30,31</sup> For the college aged population specifically, these results are in agreement with findings from Korean female college students that showed that average fiber intake was lower in depression patients than in control individuals.<sup>32</sup> The Korean female college student study does not stratify fiber types into soluble or insoluble types and therefore, comparisons between results are limited. Intake of insoluble fiber intake and depression was the only statically significant relationship so conclusions cannot accurately be extended to total dietary fiber intake, as the bulk of literature does.

No significant relationship between dietary fiber, total, soluble, or insoluble type, and anxiety was found. This is consistent with the literature which has done little to establish an association between dietary fiber and anxiety, as only one study found habitual diets high in fiber linked to a reduced risk of anxiety and stress.<sup>33</sup> This is an interesting finding as anxiety often precedes depression in response to stressors.<sup>36</sup> Therefore, it may be expected that an association would be more evident between dietary fiber types and anxiety, rather than depression. This was not the case in the present study.

There were several study limitations which may have influenced the outcomes. First, all data utilized as part of this study, aside from BMI, was self-reported data in the form of questionnaires and FFQs, as part of the Neuro-regulation in Attachment to God, Human Relationships, and Health study. If data were able to be collected with a less subjective method, results may be interpreted as more conclusive. Second, the sample consisted only of students attending Baylor University. Therefore, it may be improper to extend conclusions to blanket all college aged individuals. Third, the Hospital Anxiety and Depression Scale was developed and found to be a reliable instrument in the hospital outpatient clinic setting.<sup>40</sup> Consequently, it may not be entirely reliable at predicting anxiety and depression in college students outside of a medical setting.

## CHAPTER FIVE

### *Conclusion*

By analyzing the Neuro-regulation in Attachment to God, Human Relationships, and Health study data, meaningful conclusions were drawn regarding university aged students and the relationship between dietary fibers and mental health. Results indicate that intake of insoluble fiber resulted in lower odds of experiencing symptoms of depression. This allows the inference that if university aged students wish to lessen depression symptoms/severity, and potentially prevent a depression diagnosis, they could consume more insoluble fiber. The same conclusion cannot be made for anxiety and for general mental health (Short-Form 36 scores), as fiber type was not significantly related, even after adjusting for age, sex, and BMI. Further research should examine the potential for a causal relationship between the fiber and mental health and should examine insoluble fibers as a treatment technique for depression in randomized controlled trial.

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