***Short Research Article***

Folate Deficiency and Depressive Riskin Celiac Disease in Adult Women: A Retrospective Cohort Analysis

**ABSTRACT**

**Aims:** The goal of this study was to determine the significance of folate deficiency in individuals diagnosed with celiac disease and their subsequent risk of developing depressive episodes.

**Study design:** Retrospective Cohort Study

**Place and Duration of Study:** TriNetX, global health online platform.

**Methodology:** Data for this retrospective study was acquired through TriNetX, a global, health online platform that uses real world patient electronic health records (EHR) with over 100 million patients from 95 healthcare organizations (HCOs). Queries were conducted totaling 206 female patients with celiac disease with folate deficiency and without deficiency for associated risk of depressive episodes. Data analysis was conducted via TriNet’s built-in analysis software. Descriptive statistics were used to compare patient demoics with continuous variables measured with standard deviation and categorical variables measured with frequencies**.**

**Results:** Of 206 patients with celiac disease in our total cohort comparing 28 participants with folate deficiency to 18 participants without deficiency Our odds ratio of 0.464 with 95% confidence intervals (CI) between (0.236,0.909). These results showed female celiac patients without folate deficiency were 46.4% less likely to have depression compared to those with folate deficiency. Our hazard ratio of 0.22 was not statistically significant, as the calculated p-value was 0.7705.

**Keywords**: Celiac Disease, Disease-Specific Immune Cells, Neurotransmitter, Nutritional Therapies,

**INTRODUCTION:**

Celiac disease (CD) is a common chronic autoimmune disorder triggered by the ingestion of gluten in genetically predisposed individuals. More specifically, the gluten proteins present in wheat, barley, rye, and cross-contaminated oats. (Catassi C, 2022). While traditionally regarded as a gastrointestinal condition, CD is increasingly recognized as a systemic disorder with a wide range of clinical manifestations beyond the small intestine. (Holtmeier W & Caspary WF, 2006). Notably, emerging evidence suggests a significant association between CD and mood disorders, including depression and anxiety.

The immunopathogenesis of CD is particularly well understood among other human leukocyte antigen (HLA) associated disorders. (Brown NK et al. 2019). It has been established that individuals carrying the DQ2 or DQ8 human leukocyte antigen haplotypes will develop the disease when ingesting gluten. (De Re V, Magris R, & Cannizzaro R, 2017). That is, T cell reactivity against gluten peptides undergoes a modification, deamidation, whereby certain glutamine residues are converted into glutamic acid. (du Pré MF & Sollid LM, 2015). Antibody production against deamidated gluten and autoantibodies against the enzyme transglutaminase 2 (TG2) results. T cell epitopes are created in the gut, and thus both T cells and B cell antigens allow for the characterization of disease-specific immune cells to be identified in samples of CD patients. (Iversen R & Sollid LM, 2023). This process leads to intestinal inflammation and villous atrophy, which in turn impairs nutrient absorption. The classical presentation of the disease ranges from an asymptomatic patient to one with severe malnutrition. (Schuppan D & Zimmer KP, 2013).

Until recently, it was thought that the disease was limited to individuals of European descent. However, there has been a substantial increase in the prevalence and incidence of CD over the last two decades, which has a global extent not limited to those of European origin. (Ludvigsson JF & Murray JA, 2019). With the surge in cases and individuals diagnosed with CD, it is important to be aware of the significant risks that may come as a result related to depression, anxiety, and panic disorder. (King JA et al. 2020). With the certainty of the disorder being linked to a decreased quality of life (QoL) and certain mood disorders, this is not to be overlooked. Although the disease primarily affects the small intestine, previous studies have confirmed higher rates of neuropsychiatric diseases among CD patients compared to non-CD controls. (Sharma N, Singh K, & Senapati S, 2021).

Common complications of CD related to malabsorption may indicate this link. Folate (vitamin B-9) is a group of water-soluble compounds that play various roles in central nervous system functions such as the synthesis of neurotransmitters such as serotonin, dopamine, and norepinephrine, all of which are involved in mood regulation. (Liwinski T & Lang UE, 2023). Folate is of particular interest as low serum levels are a common hematological manifestation of the disease. (Halfdanarson TR, Litzow MR, & Murray JA, 2007). The link between inadequate diet and the risk of depression is well-established, (Berk M & Jacka FN, 2019). However, malabsorption due to CD can also lead to the same low levels of serum and red blood cell folate often seen in depressed individuals. Thus, it is crucial to take into consideration the role of folate deficiency in such patients. Additionally, folate is associated with an increased risk of depression, severity of symptoms, prolonged duration of depressive episodes, likelihood of relapse, and poor response to antidepressant treatment. (Liwinski T, & Lang UE, 2023).

**METHODS:**

Data for this retrospective study was acquired through TriNetX, a global, health online platform that uses real world patient electronic health records (EHR) with over 100 million patients from 95 healthcare organizations (HCOs). HCOs de-identify all patient information before it is sent to TriNetX to be in compliance with the Health Insurance Portability Act (HIPAA) Privacy Rule and General Data Protection Regulation (GDPR). TrinetX utilizes standardized coding systems such as the International Classification of Diseases (ICD-10), Anatomical Therapeutic Chemical (ATC), Current Procedural Terminology (CPT) to identify specific diagnoses, procedures, medications and demoics. In addition, Institutional Review Board (IRB) approval was not required to gain access to TriNetX network.

**COHORTS:**

Two cohorts were utilized using the TriNetX platform. All patients were female and between the ages of 18-80 years old due to celiac disease is more prevalent in women and is common in older adults. Any individuals with a history of depressive episodes prior to celiac diagnoses were excluded. To reduce potential confounding variables, Trinet’s 1:1 propensity matching was used to balance comorbid conditions of intestinal malabsorption including ulcerative colitis, Crohn’s disease (ICD K50-K52), and pernicious anemia (ICD D51.0) as well as demoics. We did not analyze pediatric associations between folate deficiency and depression.

Cohort 1 consisted of Celiac patients (ICD K90.0) without a diagnosis of folate deficiency (ICD D52.9) and could not have a depressive episode (ICD 10 F31.0). Cohort 2 consisted of individuals with celiac disease (ICD K90.0) and folate deficiency (ICD D52.9) and could not have a depressive episode (ICD F31.0) before the diagnosis of celiac disease. Primary outcomes were the prevalence of a depressive episode (F32.2) within a five-year follow-up period.

Data analysis was conducted via TriNet’s built-in analysis software. Descriptive statistics were used to compare patient demoics with continuous variables measured with standard deviation and categorical variables measured with frequencies. Cohort 1 (Celiac patients without folate deficiency) and Cohort 2 (Celiac patients with folate deficiency) were compared using chi-squared tests and paired t-tests.

Primary outcomes of interest were the prevalence of a depressive episode (ICD F32.2) within a five-year follow-up period. To measure the correlation between folate deficiency and depressive episodes, odd ratios with 95% confidence intervals were calculated by TriNet’s logistic regression models. Time-to-event analysis was performed using Cox proportional hazard models to estimate hazard ratios (HR) for the development of a depressive episode in patients with folate deficiency. Statistically significance was defined as a p value <0.05.

**RESULTS:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Demoics | Mean ± SD | Patients | % of Cohort | P-Value | Std diff. |
| 1  2 | Current Age | 58.4 ± 17.6  58.8 ± 17.7 | 206  206 | 100%  100% | 0.8147 | 0.0231 |
|
|
| 1  2 | Age of Index | 53.8 ± 17  54.1 ± 17 | 206  206 | 100.00%  100.00% | - | - |
|
| 1  2 | Female |  | 206  206 | 100.00%  100.00% | - | - |
|
| 1  2 | White |  | 158  159 | 76.699%  77.184% | 0.0.9069 | 0.0115 |
|
| 1  2 | Not Hispanic or Latino |  | 127  130 | 61.65%  63.107% | 0.7603 | 0.0301 |
|
| 1  2 | Unknown Ethnicity |  | 60  57 | 29.126%  27.67% | 0.7431 | 0.0323 |
|
| 1  2 | Hispanic or Latino |  | 19  19 | 9.223%  9.233% | 1.000 | <0.0001 |
|
| 1  2 | Other Race |  | 17  13 | 8.252%  6.311% | 0.4482 | 0.0748 |
|
|
| 1  2 | Unknown Race |  | 18  18 | 8.738%  8.738% | 1.000 | <0.0001 |
|
| 1  2 | Asian |  | 10  10 | 4.854%  4.854% | 1.000 | <0.0001 |
|
| 1  2 | Black or African American |  | 11  13 | 5.34%  6.311% | 0.6740 | 0.0415 |
|
| 1  2 | Native Hawaiian or Other Pacific Islander |  | 10  10 | 4.854%  4.854% | 1.000 | <0.0001 |
|
| 1  2 | American Indian or Alaska Native |  | 0  0 | 0.00%  0.00% | -  - | -  - |
|

TABLE 1: Demoic comparison between Celiac patients and folate deficiency

Cohort 1: Celiac disease without folate deficiency

Cohort 2: Celiac disease with folate deficiency

Demoic analysis showed no statistical significance between cohorts.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Outcome | Cohort | Patients in cohort | Patients with outcome | Odds ratio (95% CI) |
| Depression | 1 | 206 | 14 | 0.464(0.236,0.909) |
|  | 2 | 206 | 28 |  |

Table 2: Cross-sectional analysis of folate deficiency on depressive episodes in Celiac patients

Cohort 1 (Celiac patients with no folate deficiency) was compared to Cohort 2 (Celiac patients with folate deficiency) to estimate the incidence of depressive episodes at a single point in time. The odds ratio (OR) with 95% confidence intervals (CI) was calculated showing patients without folate deficiency were 46.4% less likely to have depression compared to those with folate deficiency (Table 2).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Hazard Ratio | 95 % Confidence Interval | χ2 | df | p |
| 0.465 | (0.245,0.885) | 2.221 | 1 | 0.1362 |

Table 3: Cox-proportional hazard ratio on development of depressive episode in Celiac patients with folate deficiency.

This table shows the Cox proportional hazards model used to compare the time to event outcome of depression in between Celiac patients with and without folate deficiency. The hazard ratio of 0.465 suggests a reduced risk of developing depression in celiac patients with folate deficiency but these findings were not statistically significant p>0.05 (Table3).

**DISCUSSION:**

The goal of this study was to determine the significance of folate deficiency in individuals diagnosed with celiac disease and their subsequent risk of developing depressive episodes. Overall, the data shows statistically significant higher odds of developing depressive episodes in patients with celiac disease who are deficient in folate. Folate’s role in the synthesis of neurotransmitters responsible for mood regulation, the maintenance of hemostasis, and reducing levels of homocysteine may be clinically relevant in preventing the occurrence of depressive episodes in those with celiac disease (Morris M, 2003).

Folate has been proven to be a necessary component in the biosynthesis of monoamine neurotransmitters (dopamine, norepinephrine, serotonin) (Kunigi H, 2023). 5-Methyltetrahydrofolate (5-MTHF), the biologically active metabolite of folate, serves as a methyl group donor to homocysteine, creating methionine and S-adenosylmethionine (SAMe) (Bender A, 2017). Folate and SAMe have been shown to increase the biosynthesis of tetrahydrobiopterin (BH4), a vital cofactor in the synthesis of monoamine neurotransmitters (Kunigi H, 2023). The lack of these neurotransmitters (dopamine, serotonin, norepinephrine) has been hypothesized to be the pathophysiological basis for the development of depression and other mood disorders. Dean J. & Keshavan M, 2017). Thus, the supplementation of folate may decrease the risk of depressive episodes in individuals who have folate deficiency due to celiac disease.

In addition to its function in monoamine synthesis, 5-MTHF serves as a methyl group donor to reduce homocysteine levels in the body via conversion of homocysteine to methionine. Increased homocysteine levels have been documented to be positively associated with an increased incidence of depression (Bhatia P. & Singh, N. 2015). Of interest is the enzyme methylenetetrahydrofolate reductase (MTHFR), which functions in folate and homocysteine metabolism (Leclerc D 2013). One meta-analysis of 3478 women found that those with decreased MTHFR activity due to being homozygous for the MTHFR C677T polymorphism possessed higher homocysteine levels and were 1.37 times more likely to have been diagnosed with depression when compared to those without (Lewis SL, 2006). Homocysteine is a cytotoxic compound that can cause increased oxidative stress in the central nervous system (CNS) (Guest J, *et al.* 2015). The increased oxidative stress on the CNS leads to the generation of reactive oxygen species (ROS), which cause inflammation, apoptosis, and neurodegeneration (Correia A 2023). These factors combined provide a compelling explanation for the increased incidence of depression among patients with increased homocysteine levels. Consequently, folate supplementation provides the cofactors to prevent elevated homocysteine levels in patients with celiac disease.

The established role of folate in monoamine neurotransmitter biosynthesis and the reduction of homocysteine levels may explain the results of our study. Our odds ratio reflects the decreased incidence of depressive episodes in celiac patients who are folate replete. Our hazard ratio of 0.22 was not statistically significant, as the calculated p-value was 0.7705. This could be attributed to a variety of factors, including the presence of other vitamin deficiencies, other possible causes of depressive episodes unrelated to folate deficiency, and limited follow-up duration. Overall, this study has provided evidence of the association between folate deficiency and increased risk of the development of depressive episodes in celiac patients, which isconcurrent with prior research. However, the use of folate deficiency as a predictive element in the development of depressive episodes in celiac patients warrants further study.

The use of TriNetX inherently comes with certain limitations. First, the platform mainly utilizes electronic health records data. These records may be incomplete and may be missing relevant clinical information. Additionally, the ICD-10 code for folate deficiency used to create this study’s dataset does not include specific folate level measurements, thus limiting detailed comparisons of deficiency severity. Due to the observational study design, there is an inability to infer causality from the results. Furthermore, though the results of our study were statistically significant, the relatively small sample size may limit external validity.

**CONCLUSION**:

Our findings support an association with folate deficiency and depression in patients with Celiac disease. Given folate’s immunological role in monoamine neurotransmitter synthesis, folate deficiency may contribute to neuroinflammation due to interruption of serotonin, dopamine, and norepinephrine synthesis. Future studies should incorporate laboratory measured folate levels to quantify deficiency levels in Celiac patients. Longitudinal studies can clarify the temporal relationship between folate deficiency and onset of depressive symptoms. Randomized control studies should be conducted to determine if folate supplementation mitigates depressive symptoms in Celiac patients. These future directions could provide valuable insight into folate’s role in psychiatric comorbidities in Celiac disease and support more informed tailored nutritional therapies.

DISCLAIMER: (Artificial intelligence)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. OpenAI ChatGPT 4.5 Series Model was used for editing of this manuscript.

2. Inputs prompts provided to generative AI technology include the following:

* *“Improve the clarity of this study title.”*
* *"Polish this discussion para to improve clarity and flow without changing meaning."*
* *"Make this conclusion para more concise for a scientific journal.”*
* *“Rephrase this method's para for publication clarity.”*
* *"List possible ICD-10 codes for exclusion of prior depressive episodes and comorbidities”*

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