

Association of Physical and Psychological Factors with Physical Activity Levels in Adults with Celiac Disease

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Abstract

The only treatment of CeD, genetically mediated autoimmune condition, is lifetime adherence to a gluten-free diet (GFD). This study describes the physical activity (PA) levels of adults with CeD and examine factors that may be associated with those in the highest and lowest categories of PA, as determined by IPAQ scores, as well as the relationship between PA levels and quality of life (QOL).

Methods: A cross sectional study of 39 individuals with CeD. Data collection included sociodemographics, medical history, anthropometrics physical activity (IPAQ), GFD adherence (CDAT), QOL (CDQOL), anxiety (STAI), and depression (CES-D). Descriptive statistics were generated for all variables. PA levels were compared to the 2018 Physical Activity Guidelines for Americans, calculated by IPAQ scoring, and classified into subgroups.

Results: 79.4% of the study population met the 2018 Physical Activity Guidelines for Americans. The study population was active, as over half (51.3%) met the criteria for high IPAQ classification; and the BMI was in the normal range for all three IPAQ activity classifications. There was a significant association between low activity, anxiety, and depression. Those in the low activity group had increased anxiety ($p=0.008$) and higher depression scores ($p=0.043$) than those in either the moderate or high activity level groups.

Discussion: The study found increased PA was associated with decreased anxiety, depression, and increased dietary adherence in adults with CeD. These findings highlight the benefits that routine PA may have on an individual's emotional health and QOL. PA recommendations should be part of standard clinical practice.

Keywords: Celiac disease; Physical activity; Gluten free diet; Anxiety; Depression

Introduction

Celiac disease (CeD) is a genetically mediated autoimmune condition that affects approximately one percent of the population worldwide [1]. Intestinal malabsorption associated with CeD is caused by the ingestion of gluten, which is found in foods containing wheat, barley, or rye. CeD affects multiple systems in the body and can manifest with a variety of symptoms and health problems, including anemia, osteoporosis, cancer, and other autoimmune diseases [2,3]. CeD prevalence has increased up to 5-fold in the United States since 1950, and diagnosis rates continue to rise; a consequence of both increased prevalence and improved awareness and testing [4,5]. The only treatment of CeD is lifetime adherence to a gluten-free diet (GFD).

The effect of the GFD on body mass index (BMI) of patients with newly diagnosed CeD varies across studies [6-10]. Several studies have indicated a growing association between increased body weight and the GFD [11-13]. Three studies documented the incidence of overweight and obesity in CeD individuals at diagnosis [6,10,12]. In a recent retrospective study, Drosdak [6] and colleagues found that 45% of newly diagnosed patients were obese. Over a five-year period after starting the GFD, the rate of obesity continued to increase in all classes of obesity, especially in the class II (BMI 35-39.9) category. These findings highlight the risk for obesity as a comorbidity in individuals with CeD [6].

In the study by Kabbani, 31.9% of study participants were in the



overweight and/or obese category at diagnosis [12]. Of concern was the increase of mean BMI of the group from 24.0 to 24.6 ($p < 0.001$) and the shift to the overweight and obese category for 17.0% of patients who were of normal BMI at diagnosis. Parada and colleagues [10] found that 28.1% of their study population was in the overweight to obese range. However, there were no differences in symptoms or histology between the individuals in the low, normal, overweight, or obese categories. Other weight related concerns have been reported [13] in addition to the increased weight gain associated with the GFD and the high rate of overweight at diagnosis in individuals with CeD. Tortora and colleagues described an increased risk of metabolic syndrome one year after starting a GFD and a 4-fold increase in the risk for systemic hypertension in CeD patients [14]. Indeed, increased absorption due to recovered intestinal function may be a cause of weight gain in individuals on a GFD [13,14]. However, the typical composition of the GFD and use of low nutrient dense foods must also be considered. There have been many studies demonstrating the nutritional concerns associated with the GFD [15-18]. A typical GFD is limited in fiber, iron, B vitamins, calcium, and is also high in sugar, fat, and salt [19-21]. In addition to the nutrient gaps of the GFD, an individuals' lifestyle, and degree of activity may play a role in the observed weight changes.

The Department of Health and Human Services of the United States Government has noted that routine physical activity plays a vital role in an individuals' health, and they developed a set of guidelines for routine activity. The 2018 Physical Activity Guidelines for Americans [22] recommends that adults generally should move more than they sit. Specifically, adults should participate in at least 150 to 300 minutes of moderate intensity or 75 to 150 minutes of vigorous intensity aerobic activity each week. In addition, adults should have two or more days of moderate or high intensity muscle strengthening activities [22].

There have been several reviews of the benefits of routine activity on health outcomes for the general population [23,24]. In an overview of Cochrane systematic review on physical activity and health outcomes the authors noted that routine physical activity was associated with improved QOL as well as reduced mortality rates [23]. In a review of several randomized control trials noted that PA improves QOL in adult general population [24]. In light of the reported decreased QOL found in individuals with CeD [25-27] and increased anxiety and depression, little is known about PA and the relationship to QOL in individuals with CeD.

Historically, individuals with CeD have reported increased rates of depression, anxiety, and lower quality of life (QOL) scores [25-29], and often experience ongoing symptoms despite a GFD. These factors may influence the frequency and intensity of routine physical activity in this population. The purpose of this study was to describe the physical activity levels of a group of adults with CeD and examine factors that may be associated with those in the highest and lowest categories of physical activity, as determined by IPAQ scores [30], as well as the relationship between physical activity levels, anthropometric data, psychosocial factors, and quality of life (QOL).

Materials and Methods

The current investigation was ancillary to a cross sectional study of 50 adults with CeD, with the aim of understanding the extent to which eating disorders and disordered food attitudes and beliefs related to the GFD were common in a sample of young adults with CeD. Data from the main study will be reported separately. In that cross-sectional study, we measured physical activity levels in the study sample and the sociodemographic, physical, and psychological factors that may be associated.

Recruitment

Consecutive adult participants attending the Celiac Disease Center

for a clinic appointment with their gastroenterologist were invited to participate in the study. The population for this study included the 39 participants who completed the IPAQ survey of the original 50 adult participants.

Inclusion Criteria

Inclusion criteria: age 18 – 45, duodenal biopsy-confirmed diagnosis of CeD, following a GFD for at least one year, and a patient at the Celiac Disease Center. Exclusion criteria: self-report current or prior diagnosis of an eating disorder.

Study Measures

Data collection included sociodemographics, medical history, anthropometrics, Food avoidance questionnaire, dietary adherence (Celiac Disease Adherence Tool, CDAT), International Physical Activity Questionnaire (IPAQ), CeD symptoms measured using the paper-version of the Celiac Disease Symptom Diary (CDS), quality of life (Celiac Disease Quality of Life, CDQOLL), anxiety (State Trait Anxiety Inventory, STAI), depression (Center for Epidemiologic Studies Depressive Scale, CESD/CES-DC).

Physical activity questionnaire (IPAQ): The International Physical Activity Questionnaire (IPAQ) short form is a 7-item valid and reliable tool (for adults and adolescents) that assesses the types and intensity of physical activity and sitting time that people engage in as part of their daily lives [30]. The IPAQ estimates total physical activity in MET/min per week and time spent sitting. Physical activity was assessed according to IPAQ scoring protocols. The categories of low, moderate, and high activity are defined as follows:

Category 1 - (Low level of physical activity): Those individuals who do not meet criteria for Categories 2 or 3 are considered to have a 'low' physical activity level.

Category 2 - (Moderate Level of Physical Activity): Criteria were:

- a. 3 or more days of vigorous-intensity activity of at least 20 minutes per day OR
- b. 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day OR
- c. 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET-minutes/week. Individuals meeting at least one of the above criteria would be defined as accumulating a minimum level of activity and therefore, be classified as "moderate".

Category 3 (High Levels of Physical Activity): Criteria were

- a. vigorous-intensity activity on at least 3 days achieving a minimum total physical activity of at least 1500 MET-minutes/week OR b) 7 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum total physical activity of at least 3000 MET-minutes/week.

Sociodemographics: Self-described gender (male/female/nonbinary), age, race, ethnicity (Hispanic, non-Hispanic), household income (<\$50K, \$50 - \$100K, >100K), education (<High school, grade 12 or GED, some college, 4+ Years of college, post-graduate training), and whether or not the participant was seeing a registered dietitian (how often, for how long), and years since diagnosis were also obtained.

Anthropometric measurements: Height was measured via a stadiometer (model #HR200) in a private room. Weight and body composition were measured using the Tanita Dual frequency body composition analyzer (Model # DC430U). Tanita is an ISO 9001 certified company producing precision scales with FDA clearance for research



use. Per scale protocol, patients were weighed barefoot, with two pounds subtracted from the value to account for the weight of clothing. Age, gender, and height were inputted into the Tanita scale to compute BMI, percent body fat, and muscle mass.

Gluten-free diet adherence: (CDAT)- Dietary adherence was measured using the Celiac Dietary Adherence Test (CDAT) [31]. The CDAT is a 7-item validated, self-administered, survey instrument that includes two items about persistent symptoms (i.e.; headaches and low energy) and 5 items about attitudes and behaviors related to gluten exposure (including one specifically asking about frequency of eating gluten on purpose). Total scores range from 7 to 35, total scores > 13 indicate poor adherence to the GFD [31].

Depression: The Center for Epidemiologic Studies Depression Scales for adults (CESD) is a 20-item, self-administered survey instruments that ask about depression-related symptoms over the past week on a 4-point Likert scale (<1/day, 1 – 2days, 3-4 days, 5-7 days). CESD scores range between 0 and 60, with scores > 15 suggesting depression [32, 33].

Anxiety: The State-Trait Anxiety Inventory (STAI) is a validated, reliable, 40 item self-administered survey instrument that asks about anxiety-related symptoms. The STAI measures both state anxiety (anxiety at the moment) and trait anxiety (usual anxiety level). The STAI for adults is based on a 4-point Likert scale. Scores range between 20 and 80, with higher scores indicating more anxiety [34, 35].

Gastrointestinal symptomatology: The Celiac Disease Symptom Diary (CDS) is a 6-item, self-administered survey that asks about celiac symptoms over the past 24 hours [36]. The CDS covers frequency and severity of diarrhea, spontaneous bowel movements, abdominal pain, bloating, feelings of nausea, and tiredness. Scores range between 0 and 5, with lower scores suggesting fewer symptoms. The CDS will be administered in-person at the clinic visit and again at each telephone interview.

Quality of life (CD-Specific & General): The CD-specific QOL (CDQOL) measure for adults is a 20-item validated survey instrument [37]. Participants answer questions with Likert scales ranging from 1

(Not at all) to 5 (A great deal). Answers are transformed and combined to obtain an overall score and four clinically relevant subscales: Dysphoria (4 items), Limitations (9 items), Health Concerns (5 items), and Inadequate Treatment (2 items). Participants answer questions with Likert scales from (0 = Never to 4 = Almost always). Answers are transformed and combined to obtain an overall score and four clinically relevant subscales: Social (7 items), Uncertainty (3 items), Isolation (4 items), and Limitations (3 items). Each final score had a possible range of 20 to 100, with higher scaled scores suggesting better QOL. General QOL will be measured using a one item validated question, “Would you say your health in general is excellent, very good, fair, or poor?” This item was adopted by NHANES in 2013 and will allow us to compare our study sample with a nationally representative sample of individuals with and without CeD [38].

Statistical Analysis

Physical activity levels were compared to the 2018 Physical Activity Guidelines for Americans [22] and were calculated by IPAQ scoring [30] and then classified into each activity level. Total number of minutes of self-reported activity by intensity determined an individual’s activity group. The differences between demographic group, anthropometric measures, physical activity, QOL, and symptoms are analyzed by chi square.

Ethical Approval

The Institutional Review Boards at Columbia University Medical Center (AAAS5501) and Teachers College approved this study. Written consent was obtained at the time of enrollment.

Results

Characteristics of the Study Sample

A total of 39 individuals, from the original 50, completed the IPAQ survey and form the study population for this analysis. The study sample was predominately female (69.2%), white (92.3%), and well-educated (92.3% i.e. college-educated). 62% had a household income of over \$100,000. The mean age of the study sample was 30.1 (Table 1).

Table 1: Physical activity characteristics of study sample (N = 39).

	IPAQ classification			TOTAL N =39
	Low N = 4	Moderate N = 15	High N = 20	
	Median (IQR)	Median (IQR)	Median (IQR)	
MET-minutes per week ¹	80 (0, 400)	480 (480, 960)	1860 (1080, 2880)	960 (480, 1920)
Vigorous intensity activity	60 (0, 210)	360 (120, 720)	440 (60, 1280)	360 (80, 720)
Moderate intensity activity	297 (50, 1881)	660 (198, 1386)	693 (334, 1386)	693 (198, 1386)
Walking	677 (270, 2031)	1878 (1506, 2232)	3688 (2398, 4982)	2331 (1662, 3804)
TOTAL				
Minutes per week (truncated)	10 (0, 50)	60 (60, 120)	232 (135, 360)	120 (60, 240)
Vigorous intensity activity	15 (0, 52)	90 (30, 180)	110 (15, 320)	90 (20, 180)
Moderate intensity activity	90 (15, 570)	200 (60, 420)	210 (101, 420)	210 (60, 420)
Walking				
Minutes per weekday sitting ¹	450 (375, 502)	420 (300, 600)	420 (180, 600) ²	420 (240, 600)

¹Walking MET-minutes/week = 3.3 * walking minutes * walking days, Moderate MET-minutes/week = 4.0 * moderate-intensity activity minutes * moderate days, Vigorous MET-minutes/week = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days, Total MET-minutes/week = sum of Walking + Moderate + Vigorous MET-minutes/week.

²N = 19



Physical Activity

Overall, the study population was a relatively active group of young adults. The majority of individuals (79.4%) met the Physical Activity Guidelines for Americans of at least 150 minutes of moderate or 75 minutes of intense activity per week. Based on IPAQ scoring, 51.3% (n=20) were classified in the high activity group, 38.5% (n=15) were classified as moderate, only 10.3% (n=4) were classified in the low activity group. Interestingly while there were differences in the amount and intensity of activity between the groups, there was no significant difference between the groups in the amount of time spent sitting. Those in the low activity category spent 450 minutes sitting per week-day, while those in the moderate and high activity groups both spent 420 minutes per weekday. The total minutes spent in vigorous activity was predictably low (10 minutes) in the low group compared to 232 minutes per week in the high activity group. There were similar differences between groups for the category of moderate intensity activity with the low group participating in only 15 minutes per week compared to 110 minutes in the high group. In the category of walking, however, there was a smaller range; 90 minutes per week for the low activity group and 200 minutes for the moderate activity group and 210 for the high activity group.

Physical Activity Levels and Sociodemographic Factors

There were no significant differences across low, moderate, and high IPAQ classifications for age, gender, ethnicity, income, or education level.

Physical Activity Levels and Anthropometrics

Of the anthropometric measures obtained from the Tanita scale, there was no difference in the BMI of the different activity groups. The BMI was categorized according to the National Center for Health Statistics criteria [39]. The categories are: Underweight below 18.5kg/m², normal as 18.5 – 24.9kg/m², overweight as 25 – 29.9kg/m², and obese

as over 30kg/m² [40]. The BMI for all groups was in the normal range. While there was minimal difference in BMI between groups; the low and moderate activity groups had a mean BMI of 23.5kg/m², while the mean BMI for the high activity group was 23.2kg/m² there were differences in body composition between groups. Only the percentage of body fat was statistically significant between the activity groups (p=0.007). With the low activity group having the highest level of body fat of 36.0% compared to those in the moderate group (23.2%) and the high activity group (22.1%). According to Gallagher's guidelines [41], those in the low activity group were considered in the poor range for body fat, while those in the moderate and high activity groups were considered to be in the good to excellent body fat range. Interestingly, there was minimal difference in body fat between the moderate and high activity groups. Muscle mass was highest amongst those in the moderate activity group with a mean of 108.5 pounds compared to those in the high activity group (105.5 pounds) and those in the low activity group (102.8 pounds) (Table 2).

Physical Activity Levels and Dietary Measures

A score over 13 on the CDAT indicates poor dietary adherence, the low activity group had the highest dietary adherence score of 13.8 but did not reach statistical significance (p=0.168). In contrast the dietary adherence scores for those in the moderate and high activity groups were 11.7 and 11.4 indicating good dietary adherence.

Physical Activity Levels, Anxiety, and Depression

Both anxiety and depression were associated with low activity levels. State anxiety (anxiety at the moment) (p=0.025) and trait (usual anxiety level) (p= 0.08) were both significantly associated with activity levels. Looking specifically at the usual level of anxiety (trait) an individual reported, the scores ranged from 51.2 in the low activity group compared to 40.9 in the moderate group, and 35.8 in the high activity group. Higher scores, such as those in the low activity group, indicate increased levels of anxiety.

Table 2: Body composition of the study sample by IPAQ classification.

	IPAQ classification			Linear trend df = 1
	Low N = 4	Moderate N = 15	High N = 20	
	Mean (SD)	Mean (SD)	Mean (SD)	F p
BMI	23.5 (2.6)	23.5 (4.4)	23.2 (3.3)	0.0 .889
% Body fat ¹	36.0 (2.6)	23.2 (5.3)	22.1 (7.5)	8.1 .007
Muscle mass ²	102.8 -	108.5 (28.9)	105.5 (21.3)	0.0 .916

There were similar findings in regards to the depression scale scores. There was a statistically significant difference in the association of activity and depression. The low activity group score of 18.8 met the cut-off (clinical cut point of > 15) suggesting depression while those in the moderate (14.1) or high activity group (14.2) did not.

Physical Activity Levels and QOL

Overall QOL scores were consistent with high QOL, with a mean score of 62.75. While there were trends between QOL scores and activity level, none were statistically significant. In the low physical activity group, the overall QOL score was lower, with a mean of only 55.6 (p=0.485) compared to those with either a moderate level of physical activity (63.2) or a high physical activity classification (63.5) (Table 3).

There were similar trends when we looked at the sub dimensions of QOL in each activity level. Those in the low activity category had the lowest overall QOL score (55.6), as well as the lowest scores for the subcategories of dysphoria (57.8), limitations (49.3), and treatment (53.1). Those in the high activity category, in contrast, had the highest overall QOL score (63.5), as well as the highest scores for limitations (62.5) and treatment (70.6). Interestingly, the moderate activity group

had the highest score for dysphoria (80.8) reflecting the lowest feelings of general unhappiness, dissatisfaction, and frustration.

Physical Activity Levels and RD Visits

Interestingly, 52% of the population were not currently seeing a dietitian and 28% had never seen a dietitian about their GFD and CeD diagnosis. Of those in the moderate activity group, 53.3% were currently seeing a dietitian compared to 46.7% who had never seen a dietitian or saw one in the past. Interestingly, in the high activity group 60.0% had never seen a dietitian or had seen one in the past.

Discussion

The key take aways from this study prompt many questions around nutritional counseling, dietary recommendations, and concerns. The study group had high levels of PA which may not be generalizable to the overall population of individuals with CeD. However, when looking at the differences in types of physical activity between the groups, the results are somewhat predictable. The low activity group spent very little time in high intensity activity and more time walking; whereas the high activity group spent significantly more time in high intensity activities compared to walking. Of note, there was not



a significant difference between groups on the amount of time spent sitting each week.

An important finding from this study was the link between lower PA and higher degree of body fat is an important finding that has a potential impact of future nutritional counseling. Whereas BMI re-

ports a ratio of height to weight, body composition analysis reports the amount of muscle mass, fat mass, and degree of obesity [40,41]. Studies have indicated the degree of obesity, not weight or BMI, as a better predictor of health outcomes and risks. [41- 44]. It has also been reported that body composition assessment correlates more closely with positive predictive health outcomes [44,45].

Table 3: Psychosocial characteristics of the study sample by IPAQ classification.

	IPAQ classification			Linear trend df = 1
	Low N = 4	Moderate N = 15	High N =20	
	Mean (SD)	Mean (SD)	Mean (SD)	F p
CDAT	13.8 (2.8)	11.7 (2.9)	11.4 (3.2)	2.0 .168
QOL				
Overall	55.6 (16.9)	63.2 (18.8)	63.5 (22.2)	0.5 .485
Dysphoria	57.8 (45.5)	80.8 (19.8)	74.7 (25.6)	1.4 .242
Limitations	49.3 (10.7)	58.7 (23.6)	62.5 (21.2)	1.3 .270
Health	66.2 (19.3)	57.0 (19.8)	53.6 (28.3)	0.9 .355
Inadequate treatment	53.1 (41.3)	63.3 (31.5)	70.6 (35.2)	0.9 .359
Anxiety				
State	50.5 (19.0)	38.0 (9.4)	34.3 (13.4)	5.5 .025
Trait	51.2 (11.1)	40.9 (9.3)	35.8 (10.4)	7.9 .008
CES-D	18.8 (7.6)	14.1 (3.0)	14.2 (3.8)	4.4 .043

The association of greater levels of anxiety and depression in the individuals with lower IPAQ scores was not only significant but warrants further investigation. The trends of lower dietary adherence, higher anxiety, and depression in the lowest activity group raises several questions. Are lower activity levels a result of the anxiety and depression or the reverse? And is being less compliant to the diet a result of the anxiety and depression or again the reverse? And could increasing an individual's physical activity mitigate the anxiety or depression and positively influence dietary adaptation? These questions indicate the need for further studies as well as increased awareness of monitoring those individuals with low activity levels for potential psychosocial complications.

We also found a nonsignificant trend between QOL scores and physical activity level. The moderate activity group had a similar overall QOL score to the individuals in the high activity group (63.2 compared to 63.5); however, they had the highest score for dysphoria reflecting the lowest score for general unhappiness, dissatisfaction, and frustration. The moderate activity group also had the lowest percentage (13.3%) of overweight individuals and the highest rate of normal weight (73.3%) individuals.

In a study investigating the effect of high intensity interval training program it was found that not only did participants report better QOL, less fatigue, and decreased gastrointestinal symptoms, but also developed self-compassion and improved exercise behavior [46]. These findings also highlight the importance of not looking at just weight and BMI, but rather investigating body composition, activity levels, and overall lifestyle. Several studies have highlighted the nutritional gaps of the GFD [15-20] and the concern of increasing weight on the GFD [13,12]. In a recent study of grain consumption patterns of individuals with CeD on a GFD [20], 88% of adults and 83% of adolescents consumed grains in the ultra-processed form. The majority of grains consumed were brown rice and GF oats. Both adults and adolescents infrequently consumed alternative grains (quinoa, millet, buckwheat) and when included in the diet, they were in the processed or ultra-processed forms [20].

Additional studies have reported similar intake patterns of highly

processed, convenience foods, and ready-to-eat items [21-27]. In a study of Italian children [19], the overall caloric intake was similar to the general population, but subcategories of foods were significantly different. The individuals with CeD consumed more desserts, sweetened juices, simple carbohydrates and as a result their intake was higher in sugar and fat [19]. Other studies have also reported grain-based foods were often consumed in refined and highly processed forms [21,26]. Unfortunately, there is limited research on the physical activity habits of individuals with CeD. One study measured bone mineral density, general fatigue, and physical activity of women at diagnosis and at intervals of 2- and 5-years post diagnosis of CeD [45]. Using IPAQ scores to measure physical activity, 53.2% of participants reported low physical activity at 2 years compared to 46.3% at five years after CeD diagnosis. There was a similar increase in activity at the high physical activity level of only 10.6% at 2 years compared to 14.6% at the 5-year measure [45].

While there is limited research on physical activity in individuals with CeD, there are a few studies in a comparable group of individuals with Inflammatory Bowel Disease (IBD). In one study, individuals with IBD were less active than a non-IBD control group and overall failed to meet the Physical Activity Guidelines for Americans recommendations [47]. In the study, 33.3% of individuals with IBD met the criteria for low activity by IPAQ standards. Only 17.1% of the study participants met the classification as high activity and 49.6% as moderate activity [47]. Participants reported increased fatigue, joint and muscle pain, GI symptoms, and depression as reasons for decreased activity [46]. Of note individuals with CeD often present with similar symptoms as the participants in the IBD study, including fatigue, GI symptoms, and additionally neurologic symptoms [48].

As there are increasing numbers of individuals being diagnosed with CeD in the overweight or even obese category, these results indicate the need for change in clinical practice guidelines. The moderate PA group, who had similar QOL scores to the high PA group, had the highest percentage of individuals (53.3%) who were currently seeing a dietitian. This may reflect the positive impact of continued nutritional counseling, which emphasizes the benefits of consistent moderate



activity on overall health, body composition, and weight. The results of this study indicate the need for inclusion of physical activity recommendations for individuals with CeD as part of routine clinical care. Not only would inclusion of physical activity guidelines enhance the overall health of our patients, but the increased activity has the potential to improve their QOL as well [46].

Strengths

This study is one of the first to look at physical activity levels in the CeD populations. Beyond reporting PA characteristics of the CeD population, a unique aspect of this study is the in-depth look at the associations between PA and QOL, anxiety, depression, and dietary adherence.

Limitations

There are several limitations to this study including the small and homogenous nature of the study population. Therefore, due to lack of diversity of the study population, some of the findings may not be generalizable to the larger CeD population.

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Conflict of Interest

None of the authors have a conflict of interest to disclose.

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