Prevalence of Disaccharidase Deficiency in Adults With Unexplained Gastrointestinal Symptoms

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Background/Aims
Disaccharidase assay is used for assessing carbohydrate intolerance in children, but its usefulness in adults is not known. The aim of this study is to assess the prevalence of disaccharidase deficiency in patients with unexplained gastrointestinal symptoms.

Methods
A retrospective review of adults with chronic (> 1 year) abdominal symptoms and negative imaging and endoscopy/colonoscopy and who completed bowel symptom questionnaire and duodenal biopsy for lactase, maltase, sucrase, and palatinase was performed. A subset also underwent 25 g lactose breath test (LBT).

Results
One hundred twenty patients (females = 83) were evaluated, of whom 48 also underwent LBT. Fifty-six (46.7%) patients had enzyme deficiency; 44 (36.7%) had single (either lactase or maltase), 1 had 3 enzyme deficiencies, 11 (9.2 %) had all 4 disaccharidase enzyme (pan-disaccharidase) deficiency, and 64 (53.0%) had normal enzyme levels. Baseline prevalence and severity of 11 gastrointestinal symptoms were similar between normal and single enzyme deficiency groups. The sensitivity and specificity of LBT was 78.3% and 72.0%, respectively and overall agreement with lactase deficiency was 75.0%.

Conclusions
Isolated disaccharidase deficiency occurs in adults, usually lactase and rarely maltase, and pan-disaccharidase deficiency is rare. Baseline symptoms or its severity did not predict enzyme deficiency.
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Key Words
Breath tests; Disaccharidase; Lactose intolerance; Sucrase-isomaltase deficiency

Introduction
After oral ingestion, dietary carbohydrates are digested and absorbed from the gastrointestinal (GI) tract, and provide 40-60% of the average caloric intake in humans.1 The main carbohydrates ingested in the human diet are starch, sucrose, and lactose and these sugars are broken down into monosaccharides by various enzymes,
including disaccharidases (carbohydrate-specific hydrolases) that are produced by the brush-border membrane and enterocytes lining the small intestine.1

Disaccharidase deficiency can cause malabsorption of carbohydrates. The unabsorbed sugars can serve as an osmotic load in the small bowel, drawing fluid into the lumen and leading to intestinal distension and rapid propulsion into the colon. This can produce diarrhea, gas, bloating, flatulence, and abdominal pain which are symptoms typically reported by patients with carbohydrate intolerance. Over the last decade, measurement of disaccharidase levels, notably lactase, sucrase, maltase, and palatinase from small bowel biopsies obtained during an upper endoscopy, has been increasingly used to assess disaccharidase deficiency, particularly in children.2

The incidence of sucrase-isomaltase deficiency has been estimated at 0.2% in North America and up to 10.0% in Greenland Eskimos.3 In contrast, the incidence of lactase deficiency varies between 15.0-80.0%, depending on the ethnicity of the population.4 While carbohydrate intolerance is a well-established but rare cause of chronic abdominal pain in young children, its frequency and associated symptoms in adults, especially non-lactase deficiency has not been well described. Furthermore, the problem of carbohydrate malabsorption and/or intolerance is important because of the rising consumption of sugars in the United States.5,6 Given the apparent lack of compensatory enzyme production, the clinical implications of disaccharidase deficiency in patients with unexplained abdominal pain may be significant.5 It is possible that disaccharidase deficiency may have been under-recognized in the United States, particularly in adults, but there has been no systematic assessment of its prevalence or symptom profiles.

Our aims were 3-fold: (1) to examine the clinical utility of disaccharidase testing in patients presenting with unexplained GI symptoms; (2) to correlate GI symptoms with enzyme deficiency; and (3) to assess the diagnostic correlation of lactase enzyme deficiency with the lactose breath test (LBT).

Materials and Methods

We retrospectively examined the medical records of patients who underwent esophagogastroduodenoscopy with small bowel biopsies for disaccharidase testing that were performed by 2 gastroenterologists, and data were extracted from chart review and collated into an Excel spreadsheet. Our study population included 120 adult patients, at least 18 years of age, who presented to the Digestive Health Center at Augusta University Medical Center over 3 years, with at least 1 year of unexplained upper and lower GI symptoms, including abdominal pain, bloating, nausea and vomiting. All of these patients had normal upper and lower endoscopy with biopsy, normal abdominal computed axial topography scan, normal stool tests and normal hematology and biochemistry profile. All patients completed a 11-symptom questionnaire to record baseline GI symptoms.7 Patients with a history of upper GI surgery, including small bowel resections, known celiac disease or olmesartan use were excluded from the study.

Additionally, a subset of patients (n = 48) who underwent LBT, in addition to disaccharidase assay were also included. All of these patients had a glucose breath test to evaluate small intestinal bacterial overgrowth, and only if glucose breath test was negative, they had lactose breath test. In this subgroup, we performed a correlative assessment of breath testing with lactase deficiency, and assessed the sensitivity, specificity, positive and negative predictive value, and agreement of LBT with lactase deficiency. The study was approved by IRB number 993793-2.

Disaccharidase Assay

Two biopsy specimens were obtained from the second portion of the duodenum for disaccharidase testing. The tissue fragments were placed in a dry, empty specimen container. Tissue samples were sent to Kaleida Health Children’s Hospital Laboratory, Buffalo, NY, USA. The biopsies were analyzed for levels of sucrase, maltase, lactase, and palatinase levels using the Dahlqvist method as follows: an intestinal homogenate is incubated with the appropriate disaccharide,8,9 Disaccharidase activity is then interrupted by the addition of Tris, and the glucose liberated is measured with a glucose oxidase reagent.8,9 Disaccharidase activity is then expressed as micromoles of disaccharide hydrolyzed per minute per gram of protein.8,9 Normative data from this laboratory were based on fasting levels of disaccharidase levels (lactase > 15.0 µM/min/g, sucrase > 25.0 µM/min/g, maltase > 100.0 µM/min/g and palatinase > 5.0 µM/min/g) and these ranges were used to determine whether enzyme deficiency was present in our patients.10 Enzyme values that were below the normal cutoff were considered diagnostic of one or more disaccharidase deficiency. Previous studies of disaccharidase levels have also relied on this assay and normative data.10,12

Lactose Breath Testing

After a 12-hour overnight fast, patients ingested a mixture of 25 g lactose dissolved in 250 mL water. End expiratory alveolar breath samples were collected at baseline and at 30-minute intervals after ingestion of lactose over 5 hours and analyzed for hydrogen
Table 1. Baseline Characteristics of Normal Enzyme vs Single Disaccharidase Enzyme Deficient vs Pan-disaccharidase Enzyme Deficient Patients

| Characteristics       | Total (N = 120 [100.0%]) | Normal (n = 64 [53.3%]) | Pan-disaccharidase (n = 11 [9.2%]) | Single deficiency (n = 45 [37.5%]) | Raw P-value | Bonferroni adjustment |
|-----------------------|---------------------------|--------------------------|-----------------------------------|-----------------------------------|-------------|-----------------------|
| Gender                |                           |                          |                                   |                                   | 0.478       |                       |
| Female                | 83 (69.2)                 | 44 (68.8)                | 6 (54.6)                          | 33 (73.3)                         |             |                       |
| Male                  | 37 (30.8)                 | 20 (31.3)                | 5 (45.3)                          | 12 (26.7)                         |             |                       |
| Pain                  |                           |                          |                                   |                                   | 0.027       | 0.324                 |
| Yes                   | 93 (77.5)                 | 51 (79.7)                | 5 (45.5)                          | 37 (82.2)                         |             |                       |
| No                    | 27 (22.5)                 | 13 (20.3)                | 6 (54.6)                          | 8 (17.8)                          |             |                       |
| Cramping              |                           |                          |                                   |                                   | 0.012       | 0.144                 |
| Yes                   | 71 (59.2)                 | 42 (65.6)                | 2 (18.2)                          | 27 (60.0)                         |             |                       |
| No                    | 49 (40.8)                 | 22 (34.4)                | 9 (81.8)                          | 18 (40.0)                         |             |                       |
| Bloating              |                           |                          |                                   |                                   | 0.838       | > 0.99                |
| Yes                   | 99 (82.5)                 | 54 (84.4)                | 9 (81.8)                          | 36 (80.0)                         |             |                       |
| No                    | 21 (17.5)                 | 10 (15.6)                | 2 (18.2)                          | 9 (20.0)                          |             |                       |
| Fullness              |                           |                          |                                   |                                   | 0.030       | 0.360                 |
| Yes                   | 85 (70.8)                 | 47 (73.4)                | 4 (36.4)                          | 34 (75.6)                         |             |                       |
| No                    | 35 (29.2)                 | 17 (26.6)                | 7 (63.6)                          | 11 (24.4)                         |             |                       |
| Nausea                |                           |                          |                                   |                                   | 0.070       | 0.840                 |
| Yes                   | 69 (57.5)                 | 41 (64.1)                | 3 (27.3)                          | 25 (55.6)                         |             |                       |
| No                    | 51 (42.5)                 | 23 (35.9)                | 8 (72.7)                          | 20 (44.4)                         |             |                       |
| Belching              |                           |                          |                                   |                                   | 0.050       | 0.600                 |
| Yes                   | 61 (50.8)                 | 37 (57.8)                | 2 (18.2)                          | 22 (48.9)                         |             |                       |
| No                    | 59 (49.2)                 | 23 (35.9)                | 8 (72.7)                          | 20 (44.4)                         |             |                       |
| Indigestion           |                           |                          |                                   |                                   | 0.003       | 0.036                 |
| Yes                   | 69 (57.5)                 | 41 (64.1)                | 1 (9.1)                           | 27 (60.0)                         |             |                       |
| No                    | 51 (42.5)                 | 23 (35.9)                | 10 (90.9)                         | 18 (40.0)                         |             |                       |
| Diarrhea              |                           |                          |                                   |                                   | 0.071       | 0.852                 |
| Yes                   | 71 (59.2)                 | 41 (64.1)                | 3 (27.3)                          | 27 (60.0)                         |             |                       |
| No                    | 49 (40.8)                 | 23 (35.9)                | 8 (72.7)                          | 18 (40.0)                         |             |                       |
| Gas                   |                           |                          |                                   |                                   | 0.053       | 0.636                 |
| Yes                   | 90 (75.0)                 | 51 (79.7)                | 5 (45.5)                          | 34 (75.6)                         |             |                       |
| No                    | 30 (25.0)                 | 13 (20.3)                | 6 (54.6)                          | 11 (24.4)                         |             |                       |
| Constipation          |                           |                          |                                   |                                   | 0.931       | > 0.99                |
| Yes                   | 61 (50.8)                 | 33 (51.6)                | 6 (45.5)                          | 22 (48.9)                         |             |                       |
| No                    | 59 (49.2)                 | 31 (48.4)                | 5 (45.5)                          | 23 (51.1)                         |             |                       |
| Vomiting              |                           |                          |                                   |                                   | 0.807       | > 0.99                |
| Yes                   | 43 (35.8)                 | 24 (37.5)                | 3 (27.3)                          | 16 (35.6)                         |             |                       |
| No                    | 77 (64.2)                 | 40 (62.5)                | 8 (72.7)                          | 29 (64.4)                         |             |                       |
| Weight loss           |                           |                          |                                   |                                   | 0.480       | > 0.99                |
| Yes                   | 10 (8.3)                  | 5 (7.8)                  | 3 (27.3)                          | 2 (4.4)                           |             |                       |
| No                    | 110 (91.7)                | 59 (92.2)                | 8 (72.7)                          | 43 (95.6)                         |             |                       |
| PPI                   |                           |                          |                                   |                                   | 0.090       | 0.807                 |
| Yes                   | 53 (44.2)                 | 33 (51.5)                | 2 (18.2)                          | 18 (40.0)                         |             |                       |
| No                    | 67 (55.8)                 | 31 (48.4)                | 9 (81.8)                          | 27 (60.0)                         |             |                       |
| Diabetes              |                           |                          |                                   |                                   | 0.649       | 0.807                 |
| Yes                   | 20 (16.7)                 | 10 (15.6)                | 1 (9.1)                           | 9 (20.0)                          |             |                       |
| No                    | 100 (83.3)                | 54 (84.4)                | 10 (90.9)                         | 36 (80.0)                         |             |                       |
| Prior GI surgery      |                           |                          |                                   |                                   | 0.070       | 0.807                 |
| Yes                   | 31 (25.8)                 | 22 (34.4)                | 2 (18.2)                          | 7 (15.6)                          |             |                       |
| No                    | 89 (74.2)                 | 42 (65.6)                | 9 (81.8)                          | 38 (84.4)                         |             |                       |
| Age (yr)              | 49.5 (34.0-63.0)          | 46.5 (30.5-59.5)         | 42.0 (41.0-65.0)                  | 52.0 (36.0-65.0)                  | 0.223       |                       |
| BMI (kg/m²)           | 26.4 (21.0-31.1)          | 26.4 (20.8-30.8)         | 24.7 (18.7-37.1)                  | 26.6 (21.8-31.2)                  | 0.977       |                       |

aWe included 1 patient with maltase, sucrase, and palatinase deficiency in this group.

PPI, proton pump inhibitor; GI, gastrointestinal; BMI, body mass index.

Data are presented as number (%) or median (interquartile range).
and methane levels (QuinTron Instrument Company Inc, Milwau-
kee, WI, USA). Baseline symptom profiles as well as symptoms
experienced during the test were recorded on validated question
naires. An increase of 20 ppm of hydrogen or 15 ppm of methane
or a combined increase of at least 20 ppm of hydrogen and methane
above baseline values were considered positive breath test for lactose
intolerance. 

Measurements and Statistical Methods

The prevalence of one or more abnormal disaccharidase levels
were assessed. We also compared the prevalence of proton pump
inhibitor use, diabetes, previous GI surgery and patient symptom
profiles with the presence or absence of disaccharidase deficiency.
Baseline abdominal symptom prevalence and their severity were
also assessed and compared between the normal enzyme, single de-
ficiency, and pan disaccharidase deficiency groups using ANOVA
test with Bonferroni correction. Kruskal-Wallis test was used to
test the differences in age and body mass index as they were not
normally distributed. Sensitivity, specificity, positive and negative
predictive values for the LBT, and agreement between LBT and
lactase mucosal assay results were calculated and compared. All sta-
tistical analyses were performed in SAS version 9.4 (SAS institute,
Cary, NC, USA).

Results

A total of 120 patients were included in this analysis. Their
mean age was 48.1 years (20-67), and 83 (69.2%) patients were
females. There were no demographic differences between normal
and disaccharidase deficient cohorts, and this included the presence
do diabetes, proton pump inhibitor use and previous surgery (Table
1). We found that 56/120 (46.7%) patients had one or more disac-
charidase enzyme deficiency (Fig. 1). Of these, 44 were deficient in
only one enzyme: isolated lactase deficiency was seen in 43 (35.8%)
patients and maltase in 1 (0.8%) patient. Eleven subjects (9.2%)
were deficient in all 4 disaccharidases that were assayed and were
categorized as pan-disaccharidase deficiency (Fig. 1). One patient
exhibited combined maltase, sucrase, and palatinase deficiency
(0.8%).

Prevalance of Gastrointestinal Symptoms With
Disaccharidase Deficiency

The prevalence of baseline symptoms in all 120 patients were
as follows: bloating (82.5%), pain (77.5%), gas (75.0%), fullness
(70.8%), cramping (59.1%), diarrhea (59.1%), nausea (57.5%),
indigestion (57.5%), belching (50.8%), vomiting (35.8%), and
weight loss (8.3%). Patients with normal enzymes (64/120, 53.3%)
shared a similar baseline symptom profile to the total patient popu-
lation (Table 1); bloating (84.4%), pain (79.7%), gas (79.7%), full-
ness (73.4%), cramping (65.6%), diarrhea (64.0%), nausea (64.1%),
indigestion (64.1%), belching (57.8%), vomiting (37.5%), and
weight loss (7.8%). Fewer patients with normal enzymes reported
vomiting (37.5%) and weight loss (7.8%) (Table 1). Likewise,
single disaccharidase deficient patients (45/120) also had similar
symptom(s) prevalence; abdominal pain (82.2%), bloating (80.0%),
fullness (75.6%), gas (75.6%), indigestion (60.0%), cramping
(60.0%), and nausea (55.6%) (Table 1). Single disaccharidase defi-
cient patients reported less vomiting (35.6%) and weight loss (4.4%).
The prevalences of various baseline symptoms were not statistically
different between subjects with normal enzymes and those with
single enzyme deficiency (Table 1). Also, we examined the severity
of each symptom and found that the mean symptom severity scores
were not significantly different between the normal enzyme, single,
and pan-disaccharidase deficient groups (Table 2).

Pan-disaccharidase Deficiency Group

The most common symptoms reported by the pan-disaccha-
ridase deficiency cohort were bloating (81.8%) and constipation
(54.5%) at baseline (Table 1). However, they reported relatively less
cramping (18.2%), pain (54.5%), fullness (36.4%), nausea (7.3%),
belching (18.2%), diarrhea (27.3%), and gas (45.5%) when com-
pared to both normal and single disaccharidase deficient patients,
but these data were not significant. They also reported more weight
loss (27.3%) when compared to single disaccharidase deficient pa-
patient (4.4%) or normal group (7.8%) but this was not significant.

**Diagnostic Performance of Lactose Breath Test**

Of the 48 patients who had both tests, 23 (47.9%) had decreased lactase enzyme levels suggesting lactase deficiency, and in this group, 18/23 (78.3%) had abnormal LBT (Fig. 2). In the normal lactase enzyme group, 7/25 (28.0%) had abnormal LBT (Fig. 2). The overall diagnostic agreement between lactase deficiency and lactose breath test was 75.0%, sensitivity was 78.3%, and specificity was 72.0%. The positive predictive value was 72.0% and negative predictive value was 78.3%. These data suggest good diagnostic agreement, specificity, and sensitivity for the LBT.

**Discussion**

Although disaccharidase deficiency has been reported in children,\(^2,3,6\) its prevalence in adults has not been systematically assessed. We found that lactase was the most common enzyme deficiency with a prevalence of 35.8% that was comparable to the pediatric study. Interestingly, the next highest prevalence of disaccharidase deficiency (9.2%) involved all 4 enzymes and these subjects were categorized as pan-disaccharidase deficient. Previous pediatric studies also described a similar prevalence of pan-disaccharidase deficiency,\(^2,3,6\) although 1 pediatric study reported a prevalence of 44.7% for lactase, 7.6% for sucrase, 3.5% for sucrase-isomaltase, and 3.2% for pan-disaccharidase deficiency.\(^14\) Interestingly, they found a significant positive correlation between disaccharidase testing frequency and the number of disaccharidase deficiencies found,\(^14\) suggesting that increased awareness and testing for these deficiencies may be useful in patients with unexplained gastrointestinal symptoms who may otherwise be labeled as having irritable bowel syndrome; the same may be true in adults. Also, even in children, aside from lactase deficiency, other single disaccharidase deficiencies are rare.\(^15\)

In our cohort, pan-disaccharidase deficient patients reported a

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**Table 2. Baseline Symptom Severity of Patients With Normal Enzymes vs Single Disaccharidase Deficiency vs Pan-disaccharidase Deficiency Patients**

| Symptoms | Total (N = 120 [100.0%]) | Normal (n = 64 [53.3%]) | Pan-disaccharidase (n = 11 [9.2%]) | Single deficiency (n = 45 [37.5%]) | Raw P-value | Bonferroni adjustment |
|----------|--------------------------|--------------------------|-----------------|---------------------|-------------|-----------------------|
| Pain     | 6.1 (3.1)                | 6.5 (2.7)                | 4.7 (4.0)       | 5.8 (3.4)           | 0.207       | > 0.99                |
| Cramping | 4.7 (3.4)                | 5.2 (3.3)                | 4.3 (3.8)       | 4.0 (3.4)           | 0.251       | > 0.99                |
| Bloating | 6.3 (3.2)                | 6.5 (2.9)                | 6.3 (3.7)       | 6.1 (3.5)           | 0.851       | > 0.99                |
| Fullness | 6.1 (3.3)                | 6.3 (3.2)                | 5.9 (3.3)       | 5.9 (3.6)           | 0.865       | > 0.99                |
| Nausea   | 4.6 (3.2)                | 5.3 (3.2)                | 2.4 (2.5)       | 4.1 (3.2)           | 0.023       | 0.253                 |
| Belching | 4.1 (3.2)                | 4.5 (3.3)                | 3.9 (2.8)       | 3.6 (3.2)           | 0.432       | > 0.99                |
| Indigestion | 4.8 (3.5)               | 5.2 (3.3)                | 2.1 (3.2)       | 4.8 (3.7)           | 0.069       | 0.759                 |
| Diarrhea | 3.9 (3.4)                | 4.3 (3.4)                | 3.1 (3.7)       | 3.5 (3.5)           | 0.469       | > 0.99                |
| Gas      | 5.6 (3.0)                | 5.9 (2.7)                | 5.0 (3.3)       | 5.2 (3.3)           | 0.522       | > 0.99                |
| Constipation | 4.8 (3.6)           | 5.3 (3.5)                | 4.3 (4.4)       | 4.1 (3.7)           | 0.329       | > 0.99                |
| Vomiting | 2.0 (2.9)                | 2.8 (3.2)                | 0.3 (1.0)       | 1.2 (2.2)           | 0.010       | 0.110                 |

We included 1 patient with maltase, sucrase, and palatinase deficiency in this group. Data are presented as mean (SD).

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**Figure 2. Flow chart of patients who underwent both the lactose breath test (LBT) and the lactase enzyme deficiency assay testing.**
higher prevalence of weight loss than single disaccharidase deficient patients, but a larger cohort is required to evaluate its significance. Interestingly, they had less cramping, fullness, belching, and indigestion compared to patients with normal enzymes although not significant. In contrast, chronic abdominal pain was an important feature in pediatric studies of pan-disaccharidase deficiency, where this was seen in 45.5% of our pan-disaccharidase population and similar to those with normal enzyme levels. The prevalence of abdominal symptoms could not differentiate between those with or without enzyme deficiency.

Carbohydrate malabsorption has been implicated in the pathogenesis of chronic abdominal pain and also in the pathogenesis of irritable bowel syndrome, unexplained gas, and bloating in adults.6,11,16-19 The enterocytes lining the intestinal mucosa form the brush border which secrete the disaccharidases enzymes.20 In one pediatric study, 49.0% patients were found to have one or more disaccharidase deficiencies,6 of these, 37.0% were lactase deficient, 21.0% had sucrase deficiency and 21.0% had glucoamylase or maltase, 8.0% had palatinase and 4.9% had pan-disaccharidase deficiency.5 Although this prevalence of pan-disaccharidase deficiency is lower than 9.2% seen in our study, a population study of 27 875 mucosal biopsy analysis also reported a prevalence of 8.0%.21 Thus, whether adults acquire this at a later stage in life or this is persistent from childhood or is secondary to small intestinal bacterial overgrowth is unclear. In contrast to the pediatric studies, the prevalence of sucrase deficiency was significantly low in our adult population, although lactase deficiency was similar. It is therefore unclear whether children recover their ability to synthesize brush border disaccharidases as they grow into adulthood or whether our sample represents a new, de novo population that has developed this deficiency as adults is unclear. While sucrase breath testing is another non-invasive test option, it may be difficult to distinguish between sucrose and fructose intolerance, and the breath test may be falsely positive with coexisting small intestinal bacterial overgrowth. Additionally, when sucrase is deficient, both our study and study by El-Chammas et al6 show that it occurs alongside pan-disaccharidase deficiency, and rarely in isolation. Thus, our findings in adults show similar and comparable prevalence of disaccharidase deficiencies as seen in children.

Lactase is the most common disaccharidase deficiency worldwide.4 Although congenital lactase deficiency is recognized early in life,14,19,22 the mechanism that leads to adult onset lactase deficiency is unclear.19 It may be an acquired phenomenon unmasked by an enteric infection or gene polymorphism.19,22,24 The high prevalence of lactase deficiency could be due to the ethnic distribution of our population, approximately 25.0% were African Americans. In a recent systematic review, the prevalence of lactose intolerance was 36.0%, which is similar to our study.23 We observed that LBT had an excellent diagnostic yield with good specificity, sensitivity, and predictive values compared to lactase enzyme assay and that the diagnostic performance of LBT was similar to those reported previously.25 However, mucosal lactase deficiency may be patchy and could be missed by biopsy sampling, and some patients with normal lactase enzyme levels may have a false positive lactose breath test due to bacterial overgrowth. In clinical practice, one ought to also consider cost implication. Because LBT is significantly less expensive (approximately $88.00-189.00) when compared to pan-disaccharidase mucosal assay testing ($208.00 plus cost of endoscopy and biopsy), non-invasive, and the genetic testing is expensive and not widely available, we recommend LBT as the preferred and most cost-effective test for evaluation of lactose intolerance. It is important to point out that we used the 25 g lactose dose for LBT, as recommended by the North American Consensus,13 and that higher rates of sensitivity/specificity (> 90%) have been reported when using a higher dose (50 g).26

The enzyme levels used to adjudicate disaccharidase deficiencies were based on normative data in fasting patients, and therefore applicable to our patients who were fasting for endoscopy. In previous case reports of adult disaccharidase deficiencies, it was found that a lactose free diet did not lead to depressed brush border lactase activity, with the corollary being true as well, as was similar in the case of sucrase. However, maltase does seem to increase with increased daily carbohydrate intake.15 These observations suggest that enzyme deficiencies may be partly restored by repeated carbohydrate challenge.

Our study has few limitations. This was a retrospective analysis of prospectively collected data. We used questionnaires to collect baseline symptoms that allows for recall bias; however, this questionnaire has been validated.7 Additionally, we are a major referral center for functional GI disorders, and may have encountered patients with more severe disease, and our findings may represent an overestimation of disaccharidase deficiency in adults. However, our prevalence data for disaccharidase deficiency is similar to those in a pediatric community study.6 The biopsies for disaccharidase assays were collected by 2 gastroenterologists and analyzed in one laboratory, decreasing the collection and reporting errors. Also, the Dalqvist method of disaccharidase assay is a widely used commercial option for measurement of endoscopic samples. We did not evaluate a control group of asymptomatic subjects to examine the prevalence of disaccharidase deficiency in the community, but in clinical practice only symptomatic patients are likely to undergo this assessment. Finally, our study was not designed to address treat-
ment outcomes with dietary interventions, following a diagnosis of disaccharidase deficiency.

In conclusion, our study demonstrates that disaccharidase deficiencies are frequently encountered in adults with unexplained symptoms; 9.2% may have pan-disaccharidase deficiency, and 35.8% have lactase deficiency. Isolated sucrase deficiency is rare and usually part of the pan-disaccharidase deficiency spectrum. Therefore, we recommend the assessment of disaccharidase enzyme levels in patients with unexplained GI symptoms.

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