

Development and Application of a Plant-Based Diet Scoring System for Japanese Patients with Inflammatory Bowel Disease

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ABSTRACT

Context: Plant-based diets (PBDs) are a healthy alternative to westernized diets. A semivegetarian diet, a PBD, has been shown to prevent a relapse in Crohn disease. However, there is no way to measure adherence to PBDs.

Objective: To develop a simple way of evaluating adherence to a PBD for Japanese patients with inflammatory bowel disease (IBD).

Design: PBD scores were assigned according to the frequency of consumption provided on a food-frequency questionnaire, obtained on hospitalization for 159 patients with ulcerative colitis and 70 patients with Crohn disease. Eight items considered to be preventive factors for IBD were scored positively, and 8 items considered to be IBD risk factors were scored negatively. The PBD score was calculated from the sum of plus and minus scores. Higher PBD scores indicated greater adherence to a PBD. The PBD scores were evaluated on hospitalization and 2 years after discharge for 22 patients with Crohn disease whose dietary pattern and prognosis were established.

Main Outcome Measure: Plant-Based Diet score.

Results: The PBD scores differed significantly, in descending order, by dietary type: pro-Japanese diet, mixed type, and pro-westernized diet (Wilcoxon/Kruskal-Wallis test). The PBD scores in the ulcerative colitis and Crohn disease groups were 10.9 ± 9.5 and 8.2 ± 8.2 , respectively. For patients with Crohn disease, those with long-term remission and normal C-reactive protein concentration were significantly more likely to have PBD scores of 25 or greater than below 25 (χ^2).

Conclusion: The PBD score is a valid assessment of PBD dietary adherence.

INTRODUCTION

Inflammatory bowel disease (IBD) is a collective term for ulcerative colitis and Crohn disease, which are chronic inflammatory disorders of the gastrointestinal tract marked by episodes of relapse and remission. Originally, IBD comprised diseases predominantly found in Europe and North America. Their incidence and prevalence have been increasing with time and expanding to different regions around the world, indicating that IBD is a global

disease.¹ Development of IBD in genetically susceptible subjects is triggered by environmental factors,² as with other common chronic diseases.

It is clear now that gut microflora play a role in various chronic diseases, including obesity, diabetes, coronary artery disease, stroke, rheumatoid arthritis, and cancer.³⁻⁷ It is also clear that gut microflora are formed by diet.⁷⁻¹⁰ The concept that diet-associated gut dysbiosis (imbalance of gut microflora) is a critical environmental

factor for development of chronic diseases has been established. Consequently, diet is a prime critical factor in chronic diseases. Dietary reviews recommend plant-based diets (PBDs) to treat and prevent a variety of common diseases.¹¹⁻¹⁴

Crohn disease is worse than ulcerative colitis in respect to relapse rate, surgical rate, and prognosis. The relapse rate per year is 60% to 70% in patients with mild to moderate severity,¹⁵ and lifelong relapse-free status is obtained by only 10% to 15% of patients.¹⁶⁻¹⁸ Clinical remission is gained with total parenteral nutrition or elemental diet. Commencement of omnivorous meals, however, causes gradual elevation of C-reactive protein (CRP) concentration followed by a relapse. Therefore, omnivorous meals are thought to cause gut inflammation.¹⁹ Consequently, an elemental diet, either exclusive or partial, during the active or quiescent phases or both has been developed.²⁰

We regard IBD as a lifestyle disease mainly mediated by westernized diets, which tend to cause dysbiosis in gut microflora.^{2,19} To provide a healthier alternative to a westernized diet, a semivegetarian diet (SVD) was developed, which is lacto-ovo-vegetarian with fish once a week and meat once every two weeks.¹⁹ This SVD, one of the PBDs, has been shown to prevent a relapse in Crohn disease.¹⁹

Dietary recommendations and guidelines for the prevention of specific diseases

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and ways of measuring adherence to these guidelines include the following: the Healthy Eating Index,²¹ the Alternate Healthy Eating Index-2010,²² the Alternate Mediterranean Diet score,²³ the Recommended Food Score,²⁴ and the Dietary Approaches to Stop Hypertension (DASH) Diet score.²⁵ These indexes or scores are generally the sum of the scores of the indicated food groups. For example, a value of 0 or 1 in the Mediterranean Diet score²³ or a value of 0 to 10 in the Healthy Eating Index^{21,22} is assigned to each of the indicated components. Higher scores indicate greater adherence to the corresponding diet. In these dietary guidelines, there are clear common food groups recommended or moderated; namely vegetables, fruits, and legumes are recommended, and meats and sweets are moderated. These dietary recommendations and guidelines are to some extent similar to a PBD.

In IBD, detrimental and beneficial foods have been documented. Because common meals are thought to cause gut inflammation, comprehensive and stricter dietary control is needed. Therefore, detrimental

foods are to be scored not as 0 but scored negatively. Assessment of dietary adherence should be simple enough for patients and clinicians to calculate easily. In the future, the term *PBD*,¹¹⁻¹³ which includes diets of various moderating degrees of animal foods, is expected to be used more frequently by the public than is SVD.

The aim of this study was to develop a suitable PBD score for Japanese patients with IBD and to evaluate the validity of the PBD score. We assumed that the PBD score of a Japanese diet was higher than that of a westernized diet and that the PBD score can predict prognosis of Crohn disease more accurately than can dietary type (SVD or omnivorous diet).

METHODS

Development of Plant-Based Diet Score

We developed a simple scoring method to evaluate adherence to a PBD.²⁶ Components of the PBD,²⁷ which we consider beneficial to IBD, are scored positively: vegetables,²⁸ fruits,²⁸ pulses (beans, soybeans, peas, etc), and potatoes/starches (Table 1). Components of a westernized

diet,²⁹ which we consider as risk factors to IBD, are scored negatively: meat^{28,30-36} including minced or processed meat; cheese, butter, and margarine^{31,32,35,37}; sweets^{28,31,32,37,38}; and soft drinks.³⁹ Components of the traditional Japanese diet, known as *Washoku*,⁴⁰ are scored positively: rice, miso soup, and green tea.^{31,32} Green tea increases beneficial bacteria in the gut.¹⁹ Risk factors for IBD in Japanese individuals are scored negatively: fish^{34,38} and bread.³⁷ Plain yogurt, a probiotic, is scored positively. Alcohol is scored negatively.³³

Scores 5, 3, and 1 are given according to the frequency of consumption: every day, 3 to 5 times/wk, and 1 or 2 times/wk, respectively (Table 1). An exception to the scores is for the consumption of fish. Although fish is a component of *Washoku* and the Mediterranean diet, which are known to be healthy diets, it is also a risk factor in studies in and outside Japan.^{34,38} Therefore, its consumption daily, 3 to 5 times/wk, and 1 or 2 times/wk was scored -2, -1, and 0, respectively.

The PBD score is developed from the sum of plus and minus scores (Table 1).

Table 1. Plant-based diet score for Japanese patients with inflammatory bowel disease

Food group	Scoring by frequency of consumption				Measured plant-based diet score for our patient with Crohn disease		
	Daily	3-5 servings/wk	1-2 servings/wk	Rarely	Baseline (before hospitalization)	SVD during hospitalization (7 wks)	2 years after discharge
Positive score							
Vegetables	5	3	1	0	1	5	5
Fruits	5	3	1	0	0	5	5
Pulses (beans, soybeans, peas, etc)	5	3	1	0	0	5	5
Potatoes/starches	5	3	1	0	0	5	1
Rice	5	3	1	0	5	5	5
Miso soup	5	3	1	0	0	5	5
Green tea	5	3	1	0	0	0 ^a	5
Yogurt (plain)	5	3	1	0	0	5	5
Negative score							
Meat (beef, pork, chicken)	-5	-3	-1	0	-3	0	0
Minced or processed meat	-5	-3	-1	0	0	0	0
Cheese, butter, margarine	-5	-3	-1	0	0	0	0
Sweets, ice cream, milkshake	-5	-3	-1	0	0	0	0
Soft drinks (cola, carbonated beverages, juice)	-5	-3	-1	0	0	0	0
Alcohol	-5	-3	-1	0	0	0	-5
Bread	-5	-3	-1	0	0	0	0
Fish	-2	-1	0	0	0	0	0
Plant-based diet score					3	35	31

^a Green tea is recommended to drink at home but is not provided at the hospital. SVD = semivegetarian diet.

The maximum positive score is 35 for inpatients and 40 for outpatients because green tea is not provided as a drink in the hospital. In hospitals in Japan, inexpensive coarse tea usually is served with meals. The maximum negative score is -37. A higher PBD score indicates a greater adherence to a PBD. An example of how the PBD score is measured is shown for a patient with Crohn disease in Table 1.

Subjects

Patients with IBD who were admitted to Nakadori General Hospital, Akita, Japan, between April 2003 and March 2013 and Akita City Hospital, Akita, Japan, during April 2013 to June 2015 were included in the study. This study (study identification no. UMIN000019061) was approved by the Ethical Committee of each hospital. Informed consent was obtained from all subjects. Three patients with Crohn disease whose food-frequency questionnaire (FFQ)⁴¹ was unavailable were not included in the study. The number of patients with ulcerative colitis and Crohn disease was 159 and 70, respectively (Table 2). The male-to-female ratio was 1.1 (84/75) in ulcerative colitis and 2.7 (51/19) in Crohn disease. Patients age 18 years or younger

consisted of 15 patients (9%) with ulcerative colitis and 16 patients (23%) with Crohn disease. The median age of ulcerative colitis and Crohn disease was 36 and 23 years, respectively. Initial onset cases comprised 73 patients (46%) with ulcerative colitis and 48 patients (69%) with Crohn disease.

All patients with IBD were at least initially recommended to be admitted for their treatment. Patients, even those with mild severity, were recommended to experience and familiarize themselves with an SVD through an educational hospitalization for about 2 weeks.²⁶ Cases of educational hospitalization comprised 48 patients (30%) with ulcerative colitis and 19 patients (27%) with Crohn disease. The subjects' characteristics are presented in Table 2.

Plant-Based Diet during Hospitalization

Our PBD was a lacto-ovo-vegetarian diet with fish allowed once a week and meat allowed once every two weeks, both at about half the Japanese average amount, namely an SVD. Miso (fermented bean paste) soup, vegetables, fruits, legumes, potatoes, pickled vegetables, and plain yogurt were served daily. Details of the SVD were described in a previous article.¹⁹

During hospitalization, foods other than the meal service were discouraged. Consequently, the maximum PBD score during hospitalization was 35 (Table 1). The period of hospitalization differed among patients. Some patients were hospitalized approximately 7 weeks for standard induction therapy with infliximab (3 infusions in 6 weeks),¹⁹ others stayed about 2 weeks for an educational hospitalization,²⁶ and the other patients stayed from 3 weeks to 5 weeks according to the severity of their disease. At the end of hospitalization, a qualified dietician gave dietary guidance to the patient and the patient's meal preparer. The responsible physician (MC) advised them to continue this diet after discharge. They were also advised to preferentially drink green tea.¹⁹

Food-Frequency Questionnaire and Dietary Type

Before providing information about the SVD, patients' dietary habits before onset or relapse of the disease were obtained on the day of admission or immediately thereafter, by means of an FFQ.⁴¹ The questionnaire included 45 questions that covered almost all foods or food groups in Japan.¹⁹ It contained information necessary for calculating the PBD score.

In the questionnaire, there was a question about dietary type that listed 6 types: westernized, pro-westernized, standard mixed diet of *Washoku* and westernized diet, pro-Japanese, Japanese (*Washoku*), and SVD. A definition of dietary types was not mentioned.¹⁹ In ulcerative colitis, the number of patients by dietary type was 3, 19, 92, 25, 17, and 3, respectively (Figure 1A). In Crohn disease, there was no case of SVD. The number of patients by dietary type was 1, 13, 40, 11, and 5, respectively (Figure 1B). The standard mixed diet of *Washoku* and westernized diet was the most popular, making up more than half in both ulcerative colitis (92/159, 58%) and Crohn disease (40/70, 57%) populations (Figure 1).

Evaluation of Plant-Based Diet Score from Food-Frequency Questionnaire

The PBD score was calculated from the patients' dietary type obtained on the FFQ. The FFQ before admission was available for 159 patients with ulcerative colitis and 70 patients with Crohn disease.

Table 2. Study subjects' characteristics

Characteristic	Ulcerative colitis (n = 159)		Crohn disease (n = 70)		p value
Male/female, no.	84/75		51/19		0.0039 ^a
Age, years					
Range	11-85		13-78		
Mean	39.7		29.6		< 0.0001 ^b
Median	36		23		
≤18 years, no. (%)	15 (9)		16 (23)		0.0083 ^a
Type of IBD, no. (%)	Initial attack	73 (46)	Initial case	48 (69)	
	Relapsing-remitting	81 (51)	Relapsed case	22 (31)	
	Chronic continuous	5 (3)	Enteritis	9 (13)	
	Proctitis	61 (38)	Enterocolitis	37 (53)	
	Left-sided colitis	17 (11)	Colitis	24 (34)	
	Entire colitis	78 (49)	Remission	19 (27)	
	Right-sided colitis	3 (2)	Active	51 (73)	
	Mild	86 (54)			
	Moderate	51 (32)			
Severe	22 (14)				
Educational hospitalization, no. (%)	48 (30)		19 (27)		0.6393 ^a

^a Chi-squared test.

^b Wilcoxon/Kruskal-Wallis test.

IBD = inflammatory bowel disease.

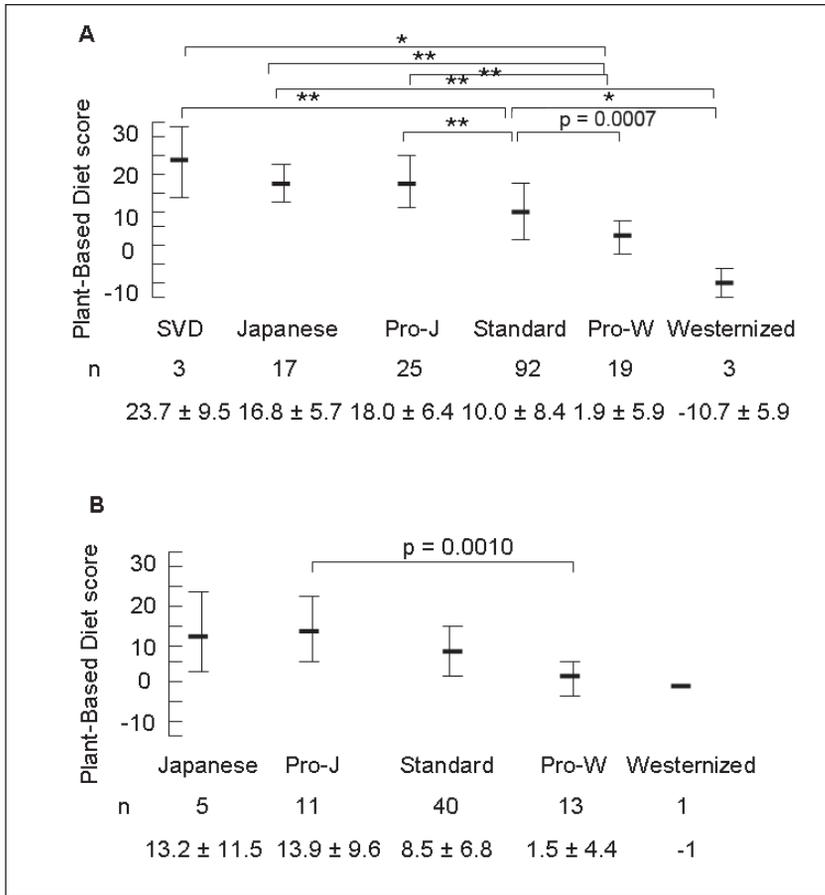


Figure 1. Dietary type and Plant-Based Diet score in patients with ulcerative colitis (n = 159) (A) and Crohn disease (n = 70) (B).

* p = 0.0001, post hoc Tukey honest significant difference test.

** p < 0.0001, post hoc Tukey honest significant difference test.

Bars = mean and standard deviation; Japanese = Japanese diet (*Washoku*); Pro-J = pro-Japanese diet; Pro-W = pro-westernized diet; Standard = standard mixed with Japanese and westernized diet; SVD = semivegetarian diet; Westernized = westernized diet.

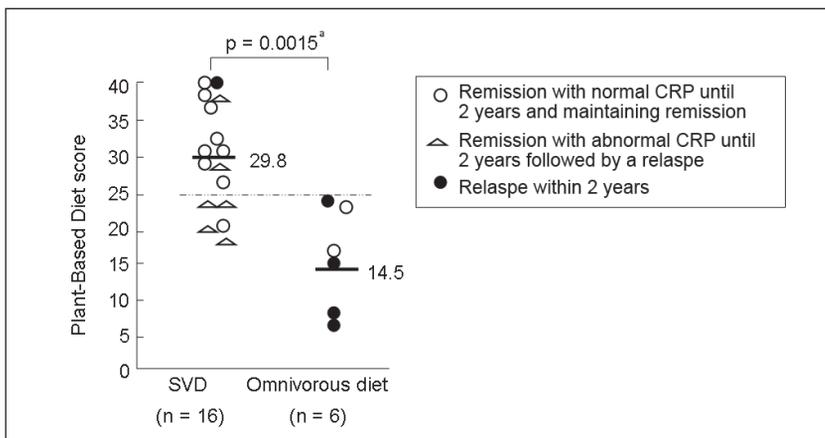


Figure 2. Evaluation of Plant-Based Diet score at 2 years after discharge in 22 patients with Crohn disease, whose prognosis was published.¹⁹

^a Analysis of variance.

Bars = mean; CRP = C-reactive protein; SVD = semivegetarian diet.

In a previous study, 22 patients with Crohn disease in remission were followed-up as outpatients.¹⁹ They were provided 5-aminosalicylic acid with no biologics, immunosuppressants, or steroid hormones. The FFQ was obtained at 3 months, 1 year, and 2 years after discharge or at the time of relapse. In that study, the SVD was shown to be preventive in the time to relapse compared with that in the omnivorous diet (p = 0.0003, log rank test).¹⁹ A PBD score was evaluated in the current study for these 22 patients with Crohn disease with a known outcome at 2 years.

An abnormal CRP concentration precedes clinical relapse for various periods from a few months to a few years in Crohn disease.⁴² This also happened in our cases. Six patients in remission with abnormal CRP concentrations at 2 years after discharge experienced a relapse, but 11 patients with normal CRP concentrations did not (Figure 2). Therefore, a normal CRP concentration with remission is a prerequisite for a long-lasting remission. We evaluated whether dietary patterns or PBD score is related to remission with a normal CRP concentration.

Statistical Analysis

The frequency of categorical variables was assessed with a χ^2 test. Dietary type and PBD score in ulcerative colitis and Crohn disease was analyzed through the Wilcoxon/Kruskal-Wallis test and analysis of variance (ANOVA), respectively, depending on whether scores showed standard normal distribution. When a significant F-ratio was obtained, differences between the means were isolated with the post hoc Tukey honest significant difference procedure. The χ^2 analysis was used to test the hypothesis that there was no difference in dietary type (SVD and omnivorous diet) or PBD score (high and low) for the prognosis from 2 years after discharge in Crohn disease. All p values are two-tailed. A p value of 0.05 or less was considered to indicate a statistically significant difference. Statistical analysis was performed using JMP 8 (SAS Institute Inc, Cary, NC) software.

RESULTS

Results are expressed as the mean \pm standard deviation.

Plant-Based Diet Score in Ulcerative Colitis and Crohn Disease

The positive PBD score (sum of positive scores), negative PBD score (sum of negative scores), and total PBD score were 23.2 ± 8.0 , 12.1 ± 6.0 , and 10.9 ± 9.5 , respectively, in the ulcerative colitis group ($n = 159$), and 20.0 ± 7.5 , 10.8 ± 8.1 , and 8.2 ± 8.2 , respectively, in the Crohn disease group ($n = 70$; Table 3). The total PBD score and positive PBD score were significantly elevated in patients with ulcerative colitis vs those with Crohn disease (Wilcoxon/Kruskal-Wallis test; Table 3).

Relation between Dietary Types and Plant-Based Diet Score

The baseline (preadmission) PBD score by dietary type in the ulcerative colitis group was as follows in a descending order: 23.7 ± 9.5 in SVD ($n = 3$), 18.0 ± 6.4 in pro-Japanese ($n = 25$), 16.8 ± 5.7 in Japanese ($n = 17$), 10.0 ± 8.4 in standard mixed ($n = 92$), 1.9 ± 5.9 in pro-westernized ($n = 19$), and -10.7 ± 5.9 in westernized ($n = 3$, $p < 0.0001$, Wilcoxon/Kruskal-Wallis test, Figure 1A). The PBD score of patients with a pro-westernized diet was significantly lower than for the standard mixed diet, which was significantly lower than for the pro-Japanese diet (see Figure 1A).

The baseline PBD score by dietary type in the Crohn disease group was as follows in a descending order: 13.9 ± 9.6 in pro-Japanese ($n = 11$), 13.2 ± 11.5 in Japanese ($n = 5$), 8.5 ± 6.8 in standard mixed ($n = 40$), 1.5 ± 4.4 in pro-westernized ($n = 13$), and -1 in westernized ($n = 1$, $p = 0.0008$, ANOVA, Figure 1B). The PBD score of patients with the pro-westernized diet was significantly lower than for the pro-Japanese diet (see Figure 1B).

Plant-Based Diet Score and Prognosis in Crohn Disease

The PBD score of patients with an SVD ($n = 16$) and an omnivorous diet ($n = 6$) was 29.8 ± 7.2 and 14.5 ± 7.5 , respectively ($p = 0.0015$, ANOVA, Figure 2). Maintenance of remission until 2 years after discharge was higher in patients with an SVD (15/16) than with an omnivorous diet (2/6, $p = 0.0036$, χ^2). There was no difference in the frequency of maintenance of remission with normal CRP concentration until 2 years after discharge between

Table 3. Plant-based diet score in ulcerative colitis and Crohn disease^a

Group	n	PBD score+	PBD score-	PBD score
Ulcerative colitis	159	23.2 ± 8.0	12.1 ± 6.0	10.9 ± 9.5
Crohn disease	70	20.0 ± 7.5	10.8 ± 8.1	8.2 ± 8.2
p value for ulcerative colitis vs Crohn disease ^b		0.0040	0.2692	0.0117

^aScores are presented as mean \pm standard deviation.

^bWilcoxon/Kruskal-Wallis test.

PBD = plant-based diet; PBD score+ = sum of positive scores on Plant-Based Diet; PBD score- = sum of negative scores; PBD score = sum of positive and negative scores.

patients with an SVD (9/16) and with an omnivorous diet (2/6, $p = 0.3348$, χ^2). The frequency of maintenance of remission with normal CRP concentration until 2 postdischarge years was higher in patients with PBD scores of 25 or greater (8/11) than in those below 25 (3/11, $p = 0.0299$, χ^2).

DISCUSSION

In Japan, the number of patients with ulcerative colitis is about three times those of Crohn disease.⁴³ Male predominance over female is an Asian (including Japanese) characteristic for Crohn disease.^{44,45} Our subjects in this study are consistent with the epidemiology found in Japan.^{43,44} Among dietary types, although their definition was not formal, a mixed type of *Washoku* and Western diet was most popular for both the ulcerative colitis and Crohn disease groups. This means dietary westernization is fully embraced in Japan. The PBD scores by dietary type in both diseases were similar. Although dietary types were distributed across a broad range of PBD score, the PBD score by dietary type on the whole showed significant differences. Namely, the mean PBD scores of patients with a Japanese dietary type and a pro-Japanese type were higher than for patients with pro-westernized and westernized diets, and the standard mixed type was the intermediate of these two groups. This indicates that PBD score reflects dietary type. Our assumption that the PBD score of a Japanese diet was higher than that of a westernized diet was confirmed. Judging from the PBD score, *Washoku* is closer to a PBD than standard mixed, and a westernized diet is far from a PBD.

Altogether, the developed PBD scoring system seems to be successful in reflecting adherence to PBD. The critical factor in our PBD score is the distribution of

negative scores to detrimental foods for IBD. Otherwise, scoring would be unable to discriminate dietary patterns or discrimination of the dietary pattern would be less clear than in the present scoring system.

The efficacy of SVD (PBD) in preventing relapse, namely, maintaining remission, in Crohn disease was shown in a previous study.¹⁹ There are two kinds of remission: remission with a normal CRP concentration and remission with an abnormal CRP concentration. The latter lasts for a few months to a few years before a relapse, whereas the former almost guarantees lasting remission.⁴² In this study, it was found that a PBD score of more than 25 is required to maintain remission with normal CRP concentration. This is 3 times higher than the baseline PBD score of 8.2.

The sample size in this study is very small ($n = 22$). Investigation for the sensitivity and specificity of PBD score predicting Crohn disease prognosis on a large scale is awaited. Needless to say, there are factors other than diet linked to relapse, namely, mucosal healing,⁴⁶ stress,⁴⁷ smoking,⁴⁸ acute gastroenteritis,⁴⁹ and antibiotics.⁵⁰ We experienced a case in which a relapse occurred shortly after discharge even though the patient's PBD score was the maximum of 40. Unpredictability of the prognosis of Crohn disease is well known.¹⁸ Because the concept that IBD is a lifestyle disease mediated mainly by a westernized diet is not widely appreciated, an analysis of diet in the follow-up period in relation to a relapse of IBD has been ignored. Analysis of diet will provide information regarding prediction of relapse and prognosis in patients with IBD.

The variety of diets based on cultural background forms a diversity of gut microflora.⁵¹ In addition, susceptible genes for IBD differ by ethnicity.^{52,53} Therefore, some food items of PBDs will differ from

country to country. Since the PBD score was found to be useful in evaluating adherence to a PBD, the PBD score can in practice be applied broadly: Education of PBD, monitoring of PBD, and the relationship between PBD and health.

CONCLUSION

The PBD score was significantly different according to dietary type in a descending order: Pro-Japanese diet, mixed type, and Pro-westernized type. The PBD score of an SVD was significantly higher than that of an omnivorous diet. In patients with Crohn disease, a PBD score of 25 or greater was needed to maintain long-term remission. The PBD score is a valid assessment of dietary adherence to a PBD. The PBD and PBD score can be modified for a variety of diseases and for different national dietary preferences. ❖

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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Necessity Made Medicine

For the art of Medicine would not have been invented at first, nor would it have been made a subject of investigation (for there would have been no need of it), if when men are indisposed, the same food and other articles of regimen which they eat and drink when in good health were proper for them, and if no others were preferable to these.

But now necessity itself made medicine to be sought out and discovered by men.

— Hippocrates of Kos, 460 BC – 370 BC, Greek physician of the Age of Pericles