Effect of Body Mass Index and Intra-Abdominal Fat Measured by Computed Tomography on the Risk of Bowel Symptoms

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Abstract

Background
This study aims to investigate the association between body mass index (BMI) or intra-abdominal fat measured by computed tomography (CT) and bowel symptoms.

Method
A cohort of 958 Japanese adults who underwent colonoscopy and CT and completed questionnaires after excluding colorectal diseases was analyzed. Six symptoms (constipation, diarrhea, loose stools, hard stools, fecal urgency, and incomplete evacuation) using a 7-point Likert scale were evaluated between baseline and second questionnaire for test-retest reliability. Associations between BMI, visceral adipose tissue (VAT), subcutaneous adipose tissue (SAT), and symptom score were analyzed by a rank-ordered logistic model, adjusting for age, sex, smoking, and alcohol consumption, hypertension, diabetes mellitus, and dyslipidemia.

Results
Some bowel symptom scores were significantly (p<0.05) different between the age groups, sexes, smoking, and alcohol consumption. In multivariate analysis, constipation was associated with low BMI (p<0.01), low VAT area (p = 0.01), and low SAT area (p<0.01). Moreover, hard stools was associated with low BMI (p<0.01) and low SAT area (p<0.01). The remaining symptoms were not significantly associated with BMI or intra-abdominal fat. Test-retest reliability of bowel symptom scores with a mean duration of 7.5 months was good (mean kappa, 0.672).
Conclusions

Both low BMI and low abdominal fat accumulation appear to be useful indicators of increased risk for constipation and hard stools. The long-term test-retest reliability of symptom score suggests that bowel symptoms relevant to BMI or visceral fat remain consistent over several months.

Introduction

Gastrointestinal (GI) symptoms are common in the general population, but studies on the role of GI symptoms in overweight individuals are limited.[1,2] Several studies have reported an increased risk of upper GI symptoms associated with high body mass index (BMI);[3–6] however, little information is available on the association between high BMI and functional bowel disorder.[4,6,7] Recent studies have shown that abdominal visceral fat as measured by computed tomography (CT) is a better predictor of the risk of upper GI disease (e.g., gastroesophageal reflux disease or Barrett's esophagus) than BMI.[8,9] However, the association between lower GI symptoms and CT-evaluated intra-abdominal fat has not been reported previously.

This study examined the relationship of BMI, CT-measured visceral adipose tissue (VAT), and CT-measured subcutaneous adipose tissue (SAT) with the risk of bowel symptoms. Bowel symptoms are caused by various colorectal diseases; however, previous population-based studies have not excluded colorectal diseases.[10–12] We therefore used colonoscopy to exclude the presence of colorectal diseases and applying the criteria of functional bowel disorder.[13]

Methods

Study Design, Setting, and Participants

We conducted a prospective, hospital-based, cross-sectional study of Japanese adults at the National Center for Global Health and Medicine (NCGM), Japan between September 2009 and June 2013. Participants who underwent elective colonoscopy and CT and completed a questionnaire were enrolled. The patient population and data collection procedure are described in detail in our previous report of a study with different research objectives from the present study [14]. We included patients > 18 years of age presenting with bowel symptoms or requiring colorectal cancer screening. Patients were excluded if their medication use was unknown, they were not independent in activities of daily living, or they were being followed after colonoscopy. Of the 11,222 eligible participants, 3798 Japanese patients completed the questionnaire (Fig 1), of which 1715 underwent multidetector computed tomography (MDCT) before colonoscopy. At our institution, MDCT is performed for individuals who request screening for non-colorectal cancer (e.g., stomach, pancreas, liver, biliary tract, lung, prostate, uterus, or ovarian cancer) or for the investigation of rectal bleeding, diarrhea, and abdominal pain in patients presenting to our institution’s emergency outpatient department. The remaining 2083 participants who did not undergo MDCT (1393 men; mean age, 64.0 years) declined either because of anxiety due to radiation exposure or cost or because they had previously undergone CT at another institution. From the 1715 patients who underwent colonoscopy and MDCT, we excluded the following patients: (i) those with colorectal diseases identified by colonoscopy and CT (n = 212); (ii) those who did not fulfill the criteria for functional bowel disorder[13] (n = 512); and (iii) those who could not undergo total colonoscopy (n = 122). This left 958 patients for analysis in this study.
This study was approved by the ethics committee of the National Center for Global Health and Medicine Center (No. 1012) and was implemented in accordance with the provisions of the Declaration of Helsinki. Written informed consent was obtained from all patients prior to endoscopy and CT.

**Evaluation of Bowel Symptoms**

Diagnosis of functional bowel disorder requires the existence of certain characteristic bowel symptoms over the past 3 months, with an onset of more than 6 months before colonoscopy. [13] On day of pre-colonoscopy, bowel symptoms were evaluated using the GI symptom rating...
scale (GSRS), which covered 6 bowel symptoms using a 7-point Likert scale (1, none at all; 2, minor; 3, mild; 4, moderate; 5, moderately severe; 6, severe; and 7, very severe).[15,16] The validity of GSRS has been well documented in conditions of functional bowel disorder.[17–19] The 6 bowel symptoms included constipation, diarrhea, loose stools, hard stools, fecal urgency, and incomplete evacuation.

To assess the test-retest reliability of bowel symptoms scores, we conducted a secondary questionnaire using the same GSRS among participants who visited our department over 1 week after the first interview.

**Diagnosis of colorectal diseases**

An electronic high-resolution video endoscope (model CFH260; Olympus Optical, Tokyo, Japan) with full preparation was used for diagnosis of colorectal diseases. Endoscopy was performed by well-trained staff who were blinded to the questionnaire results. When abnormalities were detected by colonoscopy, biopsy, polypectomy, or endoscopic mucosal resection was performed. All removed specimens were evaluated by expert pathologists, and final diagnoses of colorectal diseases were made.

Colorectal diseases included early and advanced colorectal cancer, other colorectal tumor, inflammatory bowel disease, ischemic colitis, and other colitis, as reported previously.[20] During the same period (within 1 week of colonoscopy), upper endoscopy was performed for 110 patients, none of whom were found to have cancerous or ulcerous lesions or severe gastritis.

**Exposure Variables**

A detailed questionnaire was completed at the endoscopy unit on the same day prior to colonoscopy.[14] Patients were asked about alcohol consumption and smoking status, and their medical history was recorded by well-trained medical researchers. Researchers also checked prescriptions and medical records in addition to the information provided by the patients to avoid inadvertences. Medical history included diseases such as hypertension, diabetes mellitus, and dyslipidemia, which were considered present in patients taking disease-specific drugs. Smoking status was classified as current (daily or occasionally) smoker, former smoker, or never smoker. BMI was calculated as weight divided by height squared (kg/m²).

**Measurement of the Abdominal Adipose Tissue Area by multidetector CT**

The technique used for measuring the adipose tissue area on CT has been standardized and validated,[21] and shows only negligible inter-observer variation.[22] Participants were assessed in the supine position using a 320-row area detector CT scanner (Aquilion ONE, Toshiba Medical Systems, Japan). All CT examinations were performed with helical scanning using the following parameters: 64 × 0.5 mm collimation, 120 kVp; auto exposure control (AEC) beam pitch, 0.83 (table feed per gantry, 53 mm; collimation beam width, 64 mm); gantry rotation time, 0.5 s; matrix, 512 × 512; and field of view, 350–500 mm. All images were reconstructed using a standard reconstruction algorithm with a section thickness of 5 mm. The cross-sectional abdominal surface areas (cm²) of different abdominal fat compartments were calculated at this slice using commercially available CT software (Aquilion ONE, Toshiba Medical Systems) to determine the adipose tissue area electronically by setting the attenuation values for a region of interest within the range of -150 to -30 Hounsfield units. The VAT area was defined as intra-abdominal fat bound by the parietal peritoneum or transversalis fascia, excluding the vertebral column and paraspinal muscles (Fig 2). The SAT area was defined as fat superficial to the abdominal and back muscles (Fig 2). A region of interest drawn around the external margin of
the dermis was used to calculate the total adipose tissue area. The SAT area was calculated by subtracting the VAT area from the total adipose tissue area.

Statistical Analysis

GSRS scores were compared using the Mann–Whitney U test. Rank-ordered logistic model [23] was used to determine the association between bowel symptoms and BMI, VAT area, or SAT area. Multivariate analysis was adjusted for age, sex,[20] alcohol consumption,[24] smoking status,[20,25] and diabetes mellitus,[26] all of which are known factors associated with functional bowel disorder.[13] Dyslipidemia and hypertension were potential confounders between obesity and bowel symptoms; we therefore also included these in the multivariate model. These associations were evaluated after excluding colorectal diseases on colonoscopy.

The test-retest reliability of the bowel symptom scores in the GSRS from the first and second questionnaires was analyzed using kappa statistics. Kappa values $>0.80$ denoted excellent agreement, $>0.60–0.80$ good, $>0.40–0.60$ moderate, $>0.20–0.40$ fair, and $<0.20$ poor.[27] $P<0.05$ was considered significant. All statistical analysis was performed using Stata version 13 software (StataCorp, College Station, TX).

Results

Patient Characteristics

Baseline characteristics are shown in Table 1. Of the 958 patients who underwent colonoscopy plus CT and completed questionnaires, 441 (46%) were aged $\geq 65$ years, and 647 (68%) were male. The mean BMI was 22.8 kg/m$^2$ and 244 patients (26%) had a BMI of $\geq 25$ kg/m$^2$.

Patient Characteristics and Bowel Symptoms

The association of patient characteristics and 6 bowel symptom scores is shown in Table 2. Among the age groups (age $\geq 65$ and $<65$ years), patients aged $<65$ years had higher symptom scores for diarrhea, loose stools, fecal urgency, and incomplete evacuation than those aged $\geq 65$ years. Among the 2 sexes, males had higher symptom scores for diarrhea and loose stools, whereas females had higher symptom scores for constipation and hard stools. Smokers had higher symptom scores for constipation, diarrhea, loose stools, and fecal urgency than non-smokers. Drinkers had lower symptom scores for constipation, diarrhea, loose stools, and fecal

![Fig 2. Measurement of intra-abdominal fat area by use of multidetector CT. A 61-year-old-male with a BMI of 24.8. (a) Initial CT images. (b) Intra-abdominal adipose tissue areas. Regions of red and blue color indicate visceral (107.3 cm$^2$) and subcutaneous (104.1 cm$^2$) adipose tissue, respectively. doi:10.1371/journal.pone.0123993.g002](https://plosone.org/doi/10.1371/journal.pone.0123993.g002)
urgency than non-drinkers. Between patients with and without hypertension, no significant difference was noted in any of the 6 bowel symptoms. Patients with diabetes had higher symptom scores for hard stools than patients without diabetes.

**Table 1. Characteristics of the 958 patients included in the study.**

| Characteristic                              | Value               |
|---------------------------------------------|---------------------|
| Age (years)                                 | 60.7 ± 14.5         |
| Age ≥65 (years)                             | 441 (46.0)          |
| Male sex                                    | 647 (67.5)          |
| Current smoker                              | 232 (24.2)          |
| Former smoker                               | 269 (28.1)          |
| Never smoker                                | 457 (47.7)          |
| Current drinker                             | 516 (53.9)          |
| Hypertension                                | 340 (35.5)          |
| Diabetes mellitus                           | 158 (16.5)          |
| Dyslipidemia                                | 167 (17.4)          |
| Height                                      | 163.2 ± 9.5         |
| Weight                                      | 61.0 ± 12.8         |
| Body mass index, kg/m²                       | 22.8 ± 3.8          |
| < 18.5                                      | 107 (11.2)          |
| 18.5–24.9                                   | 607 (63.4)          |
| 25–29.9                                     | 206 (21.5)          |
| 30–34.9                                     | 32 (3.3)            |
| 35–39.9                                     | 5 (0.5)             |
| ≥ 40                                        | 1 (0.1)             |
| Visceral adipose tissue area, cm²            | 112.5 ± 82.6        |
| Subcutaneous adipose tissue area, cm²        | 124.8 ± 74.4        |
| Visceral adipose tissue to subcutaneous adipose tissue ratio | 1.02 ± 0.75 |
| Total adipose tissue area, cm²               | 234.8 ± 128.0       |
| **Bowel symptom scores (range)**            |                     |
| Constipation (1–7)                           | 2.0 ± 1.5           |
| Diarrhea (1–7)                               | 2.1 ± 1.5           |
| Loose stools (1–7)                           | 1.9 ± 1.3           |
| Hard stools (1–7)                            | 1.9 ± 1.3           |
| Fecal urgency (1–7)                          | 2.1 ± 1.5           |
| Incomplete evacuation (1–7)                  | 2.3 ± 1.3           |

Values presented with plus/minus sign represent mean ± standard deviation.

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Associations between Obesity Index and Bowel Symptoms

The association of BMI and intra-abdominal fat and bowel symptoms is shown in Table 3. Rank-ordered logistic model revealed that constipation was associated with low BMI (p < 0.01), low VAT area (p = 0.01), and low SAT area (p < 0.01), while hard stools was associated with low BMI (p < 0.01) and low SAT area (p < 0.01) in multivariate analysis. However, diarrhea, loose stools, fecal urgency, and incomplete evacuation were not associated with BMI or intra-abdominal fat.
Table 2. Association of patient characteristics and bowel symptom scores (n = 958).

|                  | Age ≤65/ <65 | p   | Gender | Male/female | p   | Current smoking (yes/no) | p   | Alcohol consumption (yes/no) | p   | Hypertension (with/without) | p   | Diabetes mellitus (with/without) | p   | Dyslipidemia (with/without) | p   |
|------------------|--------------|-----|--------|-------------|-----|--------------------------|-----|-----------------------------|-----|-----------------------------|-----|--------------------------------|-----|-----------------------------|-----|
| Constipation     | ≤65: 2.0±1.4/2.0±1.5 | 0.795 |       | <0.01       | 2.2±1.5/2.0±1.4 | 0.04 | 2.0±1.5/2.0±1.5 | 0.04 | 2.0±1.6/2.0±1.5 | 0.35 | 2.2±1.4/2.0±1.5 | 0.48 | 2.0±1.4/2.0±1.5 | 0.81 |
|                  | <65: 1.9±1.4/2.2±1.5 |<0.01 |       | <0.01       | 2.0±1.6/2.0±1.5 | 0.02 | 2.0±1.6/2.0±1.5 | 0.02 | 2.0±1.4/2.0±1.5 | 0.40 | 2.0±1.4/2.0±1.5 | 0.92 | 1.9±1.3/2.1±1.5 | 0.97 |
| Diarrhea         | ≤65: 1.8±1.3/2.3±1.6 | <0.01 |       | <0.01       | 2.1±1.4/2.0±1.5 | 0.03 | 1.9±1.2/1.9±1.3 | 0.03 | 1.8±1.2/2.0±1.4 | 0.16 | 1.9±1.1/1.9±1.3 | 0.67 | 1.9±1.3/2.1±1.5 | 0.91 |
|                  | <65: 1.7±1.1/2.1±1.4 | <0.01 |       | <0.01       | 2.0±1.3/1.8±1.2 | 0.01 | 1.9±1.3/1.9±1.3 | 0.01 | 1.9±1.2/2.0±1.3 | 0.20 | 2.2±1.5/1.9±1.2 | 0.02 | 2.0±1.4/1.9±1.3 | 0.28 |
| Loose stools     | ≤65: 1.9±1.3/1.9±1.3 | 0.579 |       | 0.01       | 1.9±1.3/1.9±1.3 | 0.85 | 1.9±1.2/1.9±1.3 | 0.85 | 1.9±1.2/2.0±1.3 | 0.20 | 2.2±1.5/1.9±1.2 | 0.02 | 2.0±1.4/1.9±1.3 | 0.28 |
|                  | <65: 1.8±1.2/2.1±1.4 |       |       |            | 1.9±1.3/1.9±1.3 |       |            |       | 1.9±1.2/2.0±1.3 |       |            |       | 1.9±1.3/2.0±1.3 |       |
| Hard stools      | ≤65: 1.9±1.3/2.3±1.6 | <0.01 |       |          | 2.1±1.4/2.0±1.4 | <0.01 | 2.1±1.4/2.1±1.4 | <0.01 | 2.1±1.5/2.1±1.5 | 0.41 | 2.0±1.4/2.1±1.5 | 0.71 | 2.0±1.4/2.1±1.5 | 0.74 |
|                  | <65: 1.9±1.3/2.2±1.4 |       |       |          | 2.3±1.5/2.0±1.4 |       |          |       | 2.3±1.3/2.1±1.3 |       |          |       | 2.3±1.3/2.0±1.4 |       |
| Fecal urgency    | ≤65: 2.1±1.3/2.4±1.4 | <0.01 |       |          | 2.3±1.4/2.2±1.3 |       |          |       | 2.3±1.3/2.1±1.3 |       |          |       | 2.2±1.3/2.3±1.3 | 0.63 |
|                  | <65: 2.1±1.3/2.4±1.4 |       |       |          | 2.3±1.4/2.2±1.3 |       |          |       | 2.3±1.3/2.1±1.3 |       |          |       | 2.3±1.3/2.3±1.3 | 0.63 |
| Incomplete       | ≤65: 2.1±1.3/2.4±1.4 | <0.01 |       |          | 2.3±1.4/2.2±1.3 |       |          |       | 2.3±1.3/2.1±1.3 |       |          |       | 2.2±1.3/2.3±1.3 | 0.63 |
| evacuation       | <65: 2.1±1.3/2.4±1.4 |       |       |          | 2.3±1.4/2.2±1.3 |       |          |       | 2.3±1.3/2.1±1.3 |       |          |       | 2.3±1.3/2.3±1.3 | 0.63 |

Values presented with plus/minus sign represent mean ± standard deviation. Differences in symptom scores between 2 groups were analyzed using the Mann–Whitney U test. *p-values of <0.05 represent comparison of patients with and without the corresponding characteristics.

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Repeatability of bowel symptom score

Among the 958 participants, 690 (72.0%) completed a secondary questionnaire of using the GSRS within a mean duration of 7.5±10.7 months. The test-retest reliability of the GSRS was good (mean Kappa values was 0.672; Table 4).

Discussion

To the best of our knowledge, this is the first study evaluating the relationship between functional bowel symptoms and BMI, VAT area, and SAT area as calculated by CT. After excluding colorectal diseases using colonoscopy and applying the criteria of functional bowel disorder, we found that constipation was associated with low BMI, low VAT area, and low SAT area, while hard stools was associated with low BMI and low SAT area. Finally we found that long-term test re-test reliability of GSRS was good.

Table 3. Effect of body mass index, visceral adipose tissue, and subcutaneous adipose tissue on the risk of bowel symptoms (n = 958).

|                     | Univariate coefficient | p-value | Multivariate coefficient* | p-value |
|---------------------|------------------------|---------|---------------------------|---------|
| **Constipation**    |                        |         |                           |         |
| Body mass index     | −0.0588                | <0.01   | −0.0537                   | <0.01   |
| Visceral adipose tissue area | −0.0026             | <0.01   | −0.0024                   | 0.01    |
| Subcutaneous adipose tissue area | −0.0027          | <0.01   | −0.0032                   | <0.01   |
| **Diarrhea**        |                        |         |                           |         |
| Body mass index     | −0.0191                | 0.25    | −0.0181                   | 0.30    |
| Visceral adipose tissue area | −0.0005             | 0.51    | 0.0001                    | 0.90    |
| Subcutaneous adipose tissue area | −0.0019          | 0.03    | −0.0007                   | 0.41    |
| **Loose stools**    |                        |         |                           |         |
| Body mass index     | −0.0167                | 0.31    | −0.0236                   | 0.18    |
| Visceral adipose tissue area | −0.0015             | 0.07    | −0.0013                   | 0.11    |
| Subcutaneous adipose tissue area | −0.0014          | 0.09    | −0.0008                   | 0.39    |
| **Hard stools**     |                        |         |                           |         |
| Body mass index     | −0.0422                | 0.01    | −0.0481                   | <0.01   |
| Visceral adipose tissue area | −0.0009             | 0.26    | −0.0006                   | 0.47    |
| Subcutaneous adipose tissue area | −0.0018          | 0.04    | −0.0026                   | <0.01   |
| **Fecal urgency**   |                        |         |                           |         |
| Body mass index     | −0.0292                | 0.08    | −0.0312                   | 0.08    |
| Visceral adipose tissue area | −0.0011             | 0.15    | −0.0008                   | 0.32    |
| Subcutaneous adipose tissue area | −0.0015          | 0.07    | −0.0010                   | 0.28    |
| **Incomplete evacuation** |                  |         |                           |         |
| Body mass index     | −0.0260                | 0.10    | −0.0224                   | 0.18    |
| Visceral adipose tissue area | −0.0009             | 0.24    | −0.0005                   | 0.57    |
| Subcutaneous adipose tissue area | −0.0014          | 0.08    | −0.0009                   | 0.31    |

*Adjusted for age, sex, current smoking, alcohol consumption, hypertension, diabetes mellitus, and dyslipidemia.

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Reliability of bowel symptom score

Among the 958 participants, 690 (72.0%) completed a secondary questionnaire of using the GSRS within a mean duration of 7.5±10.7 months. The test-retest reliability of the GSRS was good (mean Kappa values was 0.672; Table 4).

Discussion

To the best of our knowledge, this is the first study evaluating the relationship between functional bowel symptoms and BMI, VAT area, and SAT area as calculated by CT. After excluding colorectal diseases using colonoscopy and applying the criteria of functional bowel disorder, we found that constipation was associated with low BMI, low VAT area, and low SAT area, while hard stools was associated with low BMI and low SAT area. Finally we found that long-term test re-test reliability of GSRS was good.
In previous studies, the relationship between bowel symptoms and BMI has been controversial. For example, a cross-sectional study of 16,078 participants from China demonstrated that high BMI was associated with functional diarrhea.[28] A case-control study of 96 IBS patients from Sweden identified high BMI to be associated with the severity of bloating, gas, urgency, loose stools, and stool frequency.[29] In contrast, a well-designed birth cohort study of young adults in Australia showed that BMI was not associated with IBS, including bloating and constipation.[30] In a Korean study of 5,605 participants who took part in a health screening program, BMI and waist circumference were not risk factors of IBS after excluding organic disease.[20] Among 2,712 Japanese who underwent health check-ups, BMI was not associated with increased risk of any type of IBS.[25] In another study of 2,495 Japanese subjects who underwent health check-ups, BMI did not differ among groups of non-IBS, patients with constipation type-IBS, or patients with diarrhea type-IBD. Although different results were observed on account of the differences in study design, sample size, and ethics, diarrhea symptoms appear to be positively associated with obesity, particularly in Western countries. However, in Asian studies including the present study, no relationship between bowel symptoms and high BMI has been identified.

A few studies have investigated the relationship between low BMI and bowel symptoms. Kubo et al.[25] reported that low BMI (OR: 0.95) was significantly associated with IBS in multivariate analysis. Farzaneh et al.[31] identified low BMI (OR: 0.94) as an independent risk factor associated with IBS in Iran. These 2 Asian studies support our findings.

Reproducible relates to the interpretation of scores from psychometric instruments (eg, symptom scales, questionnaires, and observer ratings) used in clinical practice. In this study, we confirmed a good long-term test-retest reliability (mean kappa, 0.66), which is above the kappa value of 0.6 usually considered to be good.[32] Our results imply that patients with specific GI symptoms and the severity of these symptoms remain consistent over several months.

This study has several strengths. First, colonoscopy enables the exclusion of colorectal diseases. Second, we were able to confirm the long-term reliability of the bowel symptom scores. Third, the sample size was relatively large, facilitating adjustment for confounding factors. However, this study also has limitations. First, although, our subjects met the definition of functional bowel disorder, we could not classify functional bowel disorder into IBS, functional bloating, functional constipation, functional diarrhea, and unspecified functional bowel disorder because we did not assess stool condition, such as improvement with defecation, onset associated with a change in stool frequency, or onset associated with a change in stool form.[13] Second, although we collected data on smoking and alcohol consumption habits and metabolic factors while interviewing patients in the pre-colonoscopy setting in the endoscopy room, we did not obtain information on educational level or somatic disorders that may be associated with functional bowel disorder.[13] In particular, somatic disorders, which are characterized

| Table 4. Test-retest reliability of bowel symptom score between 1st and 2nd questionnaire (n = 690). |
|---------------------------------|--------|-----|--------|
| Agreement                      | Kappa  | SE  | P      |
| Constipation                   | 79.0%  | 0.686| <0.001 |
| Diarrhea                       | 80.1%  | 0.691| <0.001 |
| Loose stools                   | 79.1%  | 0.675| <0.001 |
| Hard stools                    | 78.1%  | 0.667| <0.001 |
| Fecal urgency                  | 76.7%  | 0.656| <0.001 |
| Incomplete evacuation          | 74.9%  | 0.657| <0.001 |

Abbreviations: GI, Gastrointestinal; SE, standard error.

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by somatic symptoms (e.g., pain, GI distress, and sexual problems) and pseudoneurological symptoms (e.g., amnesia and breathing difficulties), tend to be accompanied by high levels of worry, anxiety, and increased reactions in response to physical symptoms[33] and to show a positive association with bowel symptoms.[34] Thus, the lack of assessment of somatic disorder in this study is a major limitation. Third, we did not evaluate the composition of feces (bacteria, fat, or pH), conduct lactose intolerance tests, or perform breath tests to rule out small intestinal bacterial overgrowth in this study, which are all useful examinations for diagnosing functional bowel disorder.[35–37] Fourth, both bowel symptoms and BMI or intra-abdominal fat was associated with dietary intake or dietary pattern[38], but we could not the diet information. In the pre-colonoscopy setting in the endoscopic room, we could gather information only on lifestyle habits, medication use, comorbidities, and bowel symptoms scores.

In conclusion, both low BMI and low abdominal fat accumulation increased risk of constipation and hard stools. The long-term test-retest reliability of symptom score suggests that bowel symptoms relevant to BMI or visceral fat remain consistent over several months.

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Author Contributions

Conceived and designed the experiments: NN NU MN. Performed the experiments: K. Sakamoto TA MS. Analyzed the data: T. Shimbo NN. Wrote the paper: NN NI. Collected clinical information and performed endoscopy: RN K. Sekine HO KW T. Sakurai CY MY JA.

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