

Clinical Trials Study

Latent structure of irritable bowel syndrome symptom severity

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Abstract

AIM: To investigate the latent structure of an irritable bowel syndrome (IBS) symptom severity scale in a population of healthy adults.

METHODS: The Birmingham IBS symptom questionnaire which consists of three symptom specific scales (diarrhea, constipation, pain) was evaluated by means

of structural equation modeling. We compared the original 3-factor solution to a general factor model and a bifactor solution in a large internet sample of college students ($n = 875$). Statistical comparisons of competing models were conducted by means of χ^2 difference tests. Regarding the evaluation of model fit, we examined the comparative fit index (CFI) and the Root Mean Square Error of Approximation (RMSEA).

RESULTS: Results clearly favored a bifactor model of IBS symptom severity (CFI = 0.99, RMSEA = 0.05) which consisted of a strong general IBS somatization factor and three symptom specific factors (diarrhea, constipation, pain) based on the subscales of the Birmingham IBS symptom questionnaire. The fit indices of the competing one factor model (CFI = 0.85, RMSEA = 0.17) and three factor model (CFI = 0.97, RMSEA = 0.08) were clearly inferior. χ^2 difference tests showed that the differences between the models were indeed significant in favor of the bifactor model ($P < 0.001$). Correlations of the four latent factors with measures of pain sensitivity, somatoform dissociation, fatigue severity, and demographic variables support the validity of our bifactor model of IBS specific symptom severity.

CONCLUSION: The findings suggest that IBS symptom severity might best be understood as a continuous and multidimensional construct which can be reliably and validly assessed with the B-IBS.

Key words: Irritable bowel syndrome; Irritable bowel syndrome; Bifactor; Gastrointestinal; Rome-III criteria; Birmingham irritable bowel syndrome scale

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Core tip: The findings suggest that irritable bowel syndrome (IBS) symptom severity might best be understood as a continuous and multidimensional

construct which can be reliably and validly assessed with the B-IBS questionnaire. The B-IBS scale is suitable to assess therapeutic outcomes of IBS treatments because it can measure IBS symptom severity in both, patients suffering from an IBS and participants who do not fulfill the diagnostic criteria for an IBS diagnosis but do show some of the associated symptoms.

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INTRODUCTION

According to the Rome-III criteria^[1], the irritable bowel syndrome (IBS) is characterized by recurrent abdominal pain or discomfort for at least 3 d a month during the last three months. It is one of five functional bowel disorders where functional means that the symptoms reported by the patient suggest the presence of a medical condition without physical evidence of such a condition. Thus, a common feature of diverse functional somatic syndromes are medically unexplained symptoms^[2-4]. A recent meta-analysis yielded an average worldwide prevalence of IBS of about 11% with the highest prevalence estimates in South American populations (21%) and the lowest estimates in Southeast Asian studies (7%^[5]). Given these high prevalence rates, it is not surprising that this illness also poses a high financial burden on both, the national health systems and the economies^[6-8].

In order to ensure an objective diagnosis of the IBS, the Rome III IBS module questionnaire^[9] has been proposed which assesses the frequency of various gastrointestinal symptoms. Unfortunately, this questionnaire includes various different response formats (*i.e.*, 2-, 3-, 5-, and 6-point scales) and for some of the questions every participant has to choose between two different response formats. Therefore, it is not appropriate to sum the items of this questionnaire in order to get a valid estimate of the severity of the symptoms. This limitation is suboptimal as various authors have reported that the severity of IBS symptoms is important as it predicts both, quality of life^[10-12] and medical costs^[13]. For this reason, questionnaires which allow the computation of a symptom severity sum score, such as the Birmingham IBS scale^[14], the functional bowel disorder severity index (FBDSI^[15-16]), or the IBS severity scoring system^[17], are of great value.

A prime example of a questionnaire which assesses the severity of individual IBS symptoms is the Birmingham IBS scale. It consists of frequency ratings for 11 typical IBS symptoms (*e.g.*, diarrhea, hard bowel motions, feeling of urgency) on a 6-point scale (*all of the time till none of the time*) and thus it can represent the whole heterogeneous construct of IBS related severity. From a psychometric

point of view, the Birmingham IBS scale has the advantage of only one response format and the three factor analytically derived subscales (*i.e.*, constipation, diarrhea, and pain) can be regarded as unidimensional. It is important to point out that only in case of scale unidimensionality it is psychometrically justified to create sum scores that permit the valid and reliable comparison of different participants^[18-19].

Given recent taxometric findings on the latent structure of somatic symptoms reporting^[20-21], we assume that the presence of gastrointestinal symptoms is placed on a continuum which ranges from rather mild symptoms (*e.g.*, diarrhea for “a little of the time”) that do not justify an IBS diagnosis up to a definitive IBS with many severe somatic symptoms. This view is supported by the findings of different authors who reported a high prevalence of gastrointestinal symptoms in samples of healthy participants. Hiller *et al.*^[22] examined the prevalence of somatization in a large representative sample of the German population and found that about 35% of the participants reported at least one gastrointestinal symptom according to the DSM-IV somatization disorder list^[23]. This finding is in line with the results of Camilleri *et al.*^[24] who analyzed a representative sample of United States residents and reported that the prevalence for at least one upper gastrointestinal symptom (*e.g.*, postprandial fullness) during the last three months was about 45%. Similar results emerged for a study within the general population of Denmark where 43% of the participants suffered from upper and 38% from lower gastrointestinal symptoms during the past four weeks^[25].

In summary, it is evident that gastrointestinal symptoms of varying degrees occur frequently in the general population. Therefore, we aim at studying the measurement characteristics of the Birmingham IBS scale in a large sample of adults without formal IBS diagnosis in order to ensure that it is a valid instrument to assess the severity of typical IBS-symptoms (*e.g.*, diarrhea) in participants without a definitive IBS diagnosis. From a psychometric viewpoint, we assume that every instrument that is supposed to assess the success of an IBS treatment program should also offer good psychometric characteristics for participants who score below the threshold for an IBS diagnosis. Otherwise, the questionnaire would not provide valid estimates of IBS related symptom severity as soon as the threshold for an IBS diagnosis is undercut.

Until now, the Birmingham IBS scale has only been evaluated by means of exploratory factor analysis in a sample of patients already diagnosed with IBS^[14]. Moreover, to our knowledge, this is the first study which applies confirmatory factor analysis to examine the latent structure of IBS related medically unexplained symptoms. The aim of this study is to apply the Birmingham IBS scale to a sample of participants who have not been diagnosed with IBS yet. We analyzed the latent structure of the IBS by means of structural equation modeling. With structural equation modeling it becomes possible to test clear a-priori hypotheses regarding the latent

structure of IBS severity as measured by the Birmingham IBS scale. The authors of the original scale applied a factor analysis with orthogonal rotation (*i.e.*, varimax) and removed items without a clear loading pattern^[14]. In light of the moderate correlations between the three scales reported by Roalfe *et al.*^[14], we propose a model with correlated symptom factors (*i.e.*, an oblique and not orthogonal structure).

MATERIALS AND METHODS

Participants

The participants were invited to take part in a survey on somatic symptom reporting *via* e-mail. In order to reach a high number of students, we contacted the student councils of all larger German Universities with the request to forward the study invitation to the students. Of the 996 participants who completed the survey, we excluded 121 who stated that they were suffering from any severe medical condition that causes bodily distress. The mean age of the remaining 875 participants (77.5% female) was $M = 25.33$ years ($SD = 7.21$) and 90% stated that they were students. The most frequent study subject was psychology (39%) followed by business science (7.2%) and chemistry (6.6%).

Birmingham irritable bowel syndrome scale

The 11-item Birmingham IBS scale was constructed by Roalfe *et al.*^[14] and is based on the Rome-II criteria for functional gastrointestinal disorders. The participants are asked to answer the degree of presence of various gastrointestinal symptoms on a 6-point scale which ranges from all of the time to none of the time. We translated the questionnaire into German with help of the German version of the Rome-II criteria for the irritable bowel syndrome^[26]. Moreover, the final translation was inspected closely by a native speaker and modified where necessary. The original version of the scale can be downloaded from the BMC Gastroenterology Website (www.biomedcentral.com/content/supplementary/1471-230X-8-30-S1.pdf). The translation of the scale is available from the authors of this article upon request.

Measures for construct validation

In order to examine the construct validity of the Birmingham IBS questionnaire, we included three additional measures in our study. The fatigue severity scale^[27] assesses the subjective experience of “physical and mental tiredness, and apathy”^[28], (p. 1601). It consists of 9-items which are answered on a 7-point Likert scale (1-7) and is regarded as one of the most commonly used measures of fatigue severity^[28]. As a very general measure of psychopathology, we assume that it shows high correlations to a general factor of gastrointestinal symptoms and smaller correlations to symptom specific factors. Moreover, the participants completed the pain sensitivity questionnaire (PSQ) which asks the respondents to imagine how painful

several situations would be on a ten point scale^[29]. The PSQ consists of 17 items which describe situations that are more or less painful (*e.g.*, burning ones tongue on a very hot drink). Participants are supposed to rate the painfulness of the situations on a 11-point Likert scale (not at all painful to most severe pain imaginable)^[29]. Because this questionnaire has a clear focus on pain and not somatization in general, the highest correlation should occur for the pain factor of the Birmingham IBS questionnaire. As a third measure, we included the somatoform dissociation questionnaire (SDQ)^[30] which was designed to assess somatoform dissociative symptoms that are characterized by “physical manifestations of a dissociation of the personality”^[31], (p. 338). The SDQ consists of 20 items that ask for physical symptoms and body experiences and have to be rated using a 5-point scale (not at all to extremely). This scale includes three questions (having trouble/pain while urinating, I feel pain in my genitals) which might lead to some relationship of the whole scale with the pain factor of the Birmingham IBS scale. Still, most of its 20 questions are unlikely to produce larger correlations with any measure of gastrointestinal symptoms such as Item 15 with “It is as if my body, or a part of it, has disappeared”^[32]. Therefore, we only assume a small correlation with the general factor of the Birmingham IBS scale.

Moreover, in line with the findings by Lovell *et al.*^[5], we expected a significantly higher IBS symptom severity for women than for men. Recent studies showed a moderate negative relationship between IBS prevalence and age when enough older participants (*i.e.*, above 50 years) were included in the analysis which was not the case in our study^[5,33-34]. Therefore, we expect only a small negative relationship between age and the severity of gastrointestinal symptoms related to IBS.

Statistical analysis

We applied the MPLUS software Version 7 to analyze our data. A general factor model, a correlated factor model and a bifactor model were calculated and compared by means of Chi-Square difference tests^[35]. The latter is possible in this special case because the number of specific latent factors (pain, constipation, diarrhea) does not exceed three^[36].

While the one-factor model is supposed to serve as a simple base model, the bifactor model is actually a combination of a model which proposes a gastrointestinal factor and independent group factors which represent unique variance components of the three IBS scales (diarrhea, constipation, pain). Bifactor models have recently become quite popular in the domain of clinical psychology and have been applied to various questionnaires such as the Beck Depression Inventory^[37], the Patient Health Questionnaire 15^[38] or the State-Trait Anxiety Inventory^[39].

We applied the weighted least squared with mean and variance adjustment estimation technique (WLSMV^[40]). One of the main advantages of the WLSMV estimation

Table 1 Latent correlations between validation criteria and the four factors of the Birmingham irritable bowel syndrome questionnaire according to a bifactor model

Validation criteria	Birmingham IBS questionnaire			
	General factor	Constipation	Diarrhea	Pain
Age (1 = female; 2 = male)	0.06	-0.13 ^a	-0.21 ^b	-0.27 ^b
Gender	-0.20 ^b	0.01	0.07	-0.39 ^b
Fatigue severity scale	0.34 ^b	0.07	0.01	0.13 ^a
Pain sensitivity questionnaire	0.01	0.13 ^b	0.09	0.23 ^b
Somatoform dissociation questionnaire	0.36 ^b	0.02	-0.01	-0.02

$n = 875$. ^a $P < 0.05$, ^b $P < 0.01$ vs control. WLSMV-estimation. Validation criteria are included into the model as manifest variables. Model fit is CFI = 0.99, RMSEA = 0.05. IBS: Irritable bowel syndrome.

is that it is not affected by the non-normality of the indicator variables such as the typical maximum likelihood estimation method^[41-42]. Regarding the evaluation of model fit, we examined the comparative fit index (CFI) and the Root Mean Square Error of Approximation (RMSEA) because they tap different aspects of model fit (for details see^[43]). There is a long ongoing debate regarding rules of thumb for the interpretation of those indices in the context of SEM^[44-46]. We decided to regard a CFI > 0.95 and a RMSEA < 0.10 as indicating sufficient model fit.

RESULTS

Latent structure of the birmingham IBS scale

A one factor model yielded the worst fit indices with CFI = 0.85, RMSEA = 0.17 which means that the data cannot be satisfactory described by means of only one latent variable. A three factor model provided a much better fit to the data with CFI = 0.97, RMSEA = 0.08. Because the one factor model is statistically nested within the three factor model (*i.e.*, by means of certain constraints on the parameters the three factor model can be transformed to a one factor model), we calculated a chi-square difference test, $\chi^2(3) = 441.55$, $P < 0.001$, which clearly favored the three factor model. Finally, a bifactor model provided the best fit to the data with CFI = 0.99, RMSEA = 0.05 which was also supported by statistical comparison with the three factor model, $\chi^2(8) = 150.77$, $P < 0.001$. The general factor, bifactor, and correlated factor models are depicted in Figure 1.

By comparison of the factor loading pattern of the one-factor model and the bifactor model it can be seen that the general factor is quite strong. Although the three subscale-based latent factors are added to the model, the factor loadings on the general factor remain all significant (*i.e.*, $P < 0.05$). On the other hand some of the scale-specific factor loadings lose significance in the bifactor model compared with the three-factor model where all of the items showed significant loadings (*i.e.*, $P < 0.05$). This is quite obvious for item Ibs 8, ($\alpha = 0.08$, $P = 0.18$) which

belongs to the pain factor and the items Ibs 9 ($\alpha = 0.11$, $P = 0.24$) and Ibs 11 ($\alpha = 0.06$, $P = 0.34$) that both belong to the diarrhea factor. Therefore, we also calculated a bifactor one model without a specific pain factor (*i.e.*, the items Ibs1, Ibs7, and Ibs8 only have loadings on the general factor) and another model without a specific diarrhea factor (*i.e.*, Ibs 2-3, Ibs 9-11 only with loadings on the general factor). Both, the model without a specific pain factor ($\chi^2 = 0.97$, RMSEA = 0.08) and without a nausea factor ($\chi^2 = 0.97$, RMSEA = 0.09) showed a worse fit than the original bifactor model with three specific group factors. This finding was also supported by the results from a chi-square difference tests with $\chi^2(3) = 90.60$, $P < 0.001$ (model without a pain factor) and $\chi^2(5) = 132.13$, $P < 0.001$ (model without a diarrhea factor).

Because the specific and general latent factors of the final bifactor model are orthogonal, it is possible to decompose the variance of each indicator variable into specific and general components. This has been done in Figure 2, where it can be seen that the general factor of IBS symptom severity is strong across all of the questionnaire items. Contrary, the importance of the specific latent factors is not given for all of the items. Especially for Item 9 (have you leaked or soiled yourself), Item 11 (abdominal pain prevented you from sleeping), and Item 8 (passed mucus or slime in your stools), it is obvious that the specific factors do not play an important role.

Construct validity of the birmingham IBS scale

We observed a mean score on the Birmingham IBS symptom questionnaire of $M = 8.74$ (SD = 7.02), and values of $M = 3.17$ (SD = 2.72) for the pain, $M = 2.61$ (SD = 2.96) for the constipation, and $M = 2.96$ (SD = 3.22) for the diarrhea subscales. As expected, women showed higher mean scores on all scales with $t(873) = 6.60$, $P < 0.01$, $d = 0.53$ for the pain subscale, $t(873) = 2.43$, $P = .02$, $d = 0.20$ for the constipation subscale, $t(871) = 2.33$, $P = 0.02$, $d = 0.20$ for the diarrhea subscale, and $t(873) = 4.63$, $P < 0.01$, $d = 0.38$ for the sum score of the scale. This finding is also reflected by the negative latent correlation of gender with the pain and general factor of the Birmingham IBS symptom questionnaire depicted in Table 1.

We also found the expected small to moderate negative relationship between age and IBS symptom severity with the highest absolute relationship for the IBS pain factor with $r = -0.27$, $P < 0.01$. The fatigue severity scale as a very general measure of tiredness and apathy showed the highest relationship with the general factor of IBS symptom severity ($r = 0.34$, $P < 0.01$) which is in line with our a priori hypotheses. We assumed that our measure of pain sensitivity would show the highest latent correlation with the IBS pain factor which was indeed the case ($r = 0.23$, $P < 0.01$). Finally the highest relationship involving the somatoform dissociation questionnaire occurred for the general factor IBS symptom severity (r

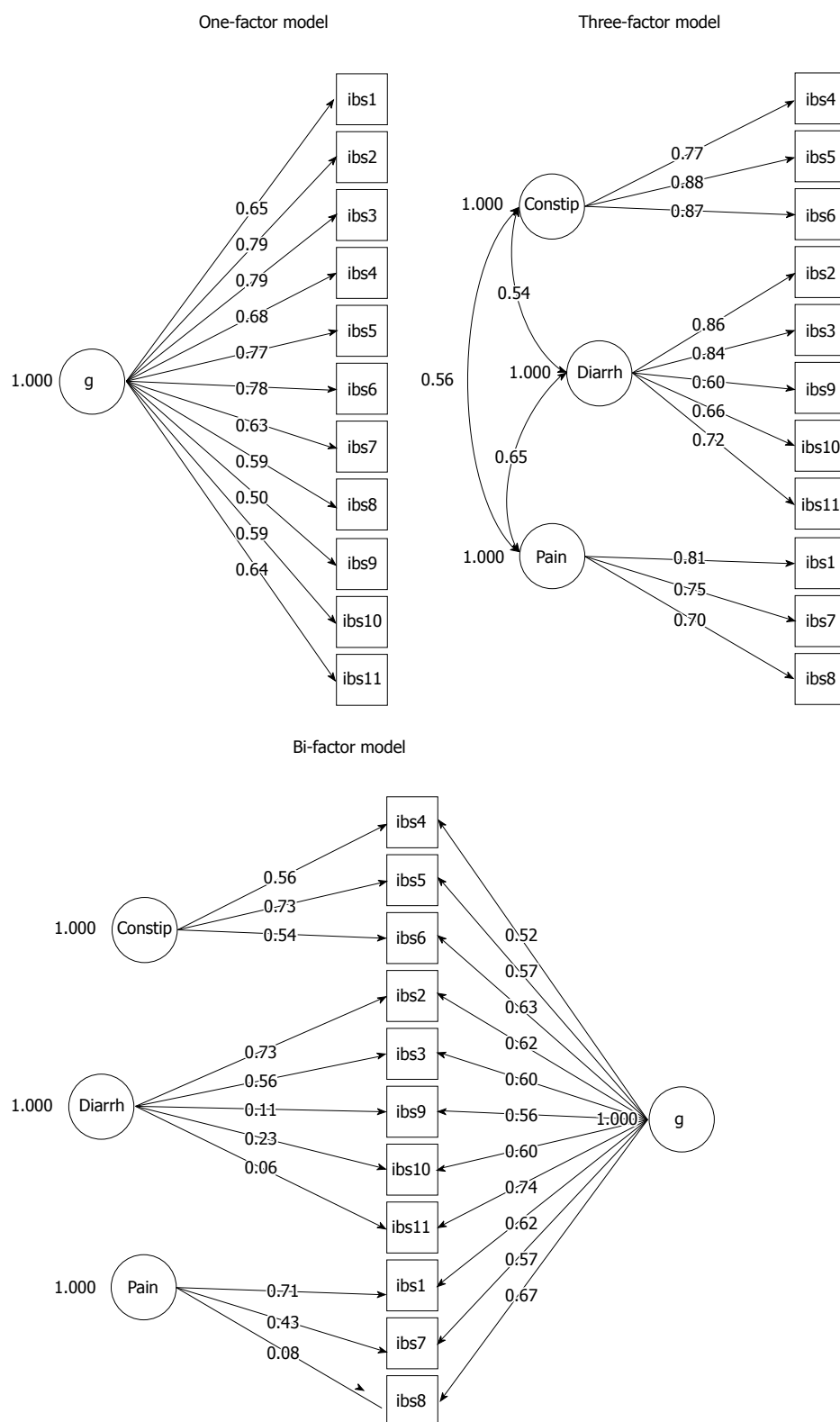


Figure 1 Depiction of the three structural equation models which were tested for the Birmingham irritable bowel syndrome scale. $n = 875$. All latent variables were fixed to $M = 0$, $SD = 1$. Residuals of the manifest variables are omitted for the sake of simplicity. Constip: Constipation; diarrh: Diarrhea; g: General factor of gastrointestinal symptoms.

$= 0.36, P < 0.01$).

DISCUSSION

The primary aim of this study was to clarify the latent

structure of IBS related symptoms in a sample of healthy participants who are unlikely to fulfill the diagnostic criteria for an IBS diagnosis. Based on the results from the study of Roalfe *et al*^[14] who assessed the latent structure of IBS related symptoms in a sample

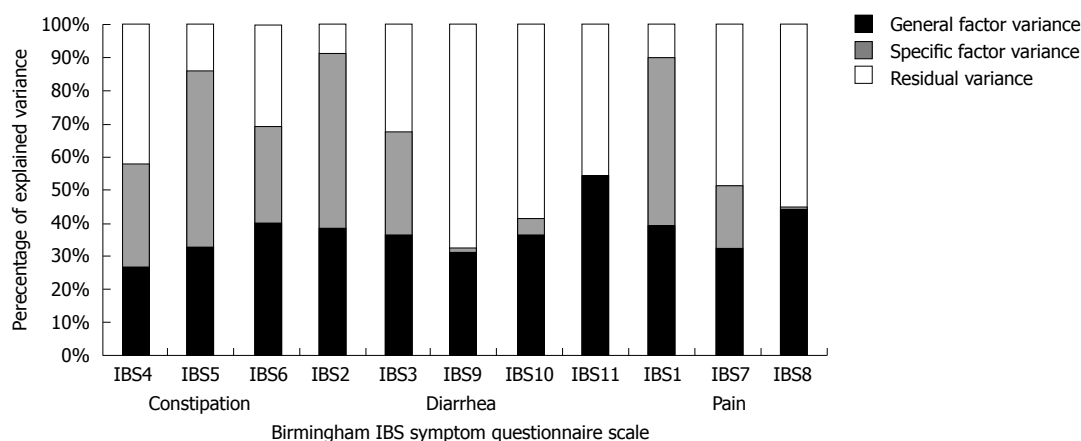


Figure 2 Percentage of variance of the birmingham irritable bowel syndrome symptom questionnaire items which is explained by the general and specific factors of the final bifactor model.

of participants suffering from IBS, we assumed that a structural model with three correlated subscale-based latent factors (*i.e.*, pain, constipation, and diarrhea) would provide the best fit to our data. Contrary to our expectations, a bifactor model with one general factor of IBS related symptoms and three subscale based symptom specific factors (*i.e.*, pain, constipation, and diarrhea) showed a superior fit compared to all other models. Additional questionnaires showed a correlation pattern which was roughly in line with our a-priori expectations regarding convergent and discriminant validity. On the one hand, the superiority of a bifactor model can be seen as a discrepancy between our analysis and the results of Roalfe *et al.*^[14]. On the other hand, the models do not necessarily contradict one another and the main question is probably if a general factor of IBS symptom severity would be weaker (*i.e.*, hard to detect by means of exploratory factor analysis) in a sample of patients with severe IBS symptoms. Therefore, we propose another study to compare a bifactor model and the original three factor model in a sample of IBS patients.

Although we included additional measures and demographic variables in our study to validate the bifactor structure of the Birmingham IBS scale, we propose to conduct studies with more specific instruments to increase the evidence for discriminant and convergent validity. A very interesting approach stems from Campbell and Fiske^[47] and is called multi trait multi method matrix approach. It would involve the inclusion of non-questionnaire based measures (*e.g.*, experimental data, medical data) to validate the factor structure of the scale.

There is still an ongoing debate regarding what is meant by symptom severity in the domain of IBS which is also reflected by the heterogeneity of different instruments such as the FBDSI and the IBS severity scoring system^[48-49]. The severity scoring system also assesses quality of life (*e.g.*, “how many weeks were you at work suffering from IBS”^[17]) as part of symptom severity and the FBDSI includes only a single question (“...please place a vertical mark that indicates the amount of

abdominal pain you feel today”^[16]) to assess the severity of the actual IBS symptoms which is combined with the number of doctor visits and the presence of an IBS diagnosis to yield a weighted sum score. A recent report of the Rome foundation summarized that “individual symptoms, such as abdominal pain, were considered important factors of severity but are insufficient to fully embody the severity concept”^[48]. Thus, our study only deals with a small part of IBS severity which is the actual symptom severity which may be seen as a weakness.

Another possible limitation of this and other internet based studies is that the sample may not be representative of the (German) population^[50-51]. However, there is some evidence that samples obtained by internet surveys are similar to those obtained by more traditional methods and that some preconceptions, such as, the higher prevalence of depression in internet samples, have been refuted^[52]. Nevertheless, we propose to replicate our findings in a sample of participants, across a wider age group, who are more representative of the general population.

The aspect of multidimensionality of IBS severity also becomes particularly important in case of studies that examine the efficacy of a specific treatment program [*e.g.*, cognitive behavior therapy (CBT)] of IBS. Many studies have shown that CBT is the method of choice to treat IBS because it leads to a rapid and stable decrease of IBS symptom severity^[53-57]. It is common practice in those studies to focus on global symptom severity scores because the questionnaires are treated as unidimensional measures of symptom severity^[58]. Unfortunately, this could lead to a loss of information when the construct is indeed multidimensional. For example, it could occur that a patient improves regarding his symptoms associated with diarrhea but shows an increase of symptoms related to constipation. If one only examines a summary score that equally captures both symptom clusters (*e.g.*, diarrhea and constipation), one will not be able to detect changes of the particular symptom pattern. We propose that future therapy studies on IBS should examine the efficacy of CBT on IBS severity separately for each of the Birmingham IBS scales.

The need for a multidimensional assessment of IBS symptom severity also fits well to the recent suggestion of various researchers^[59-60] who propose to explicitly determine whether an existing IBS condition is rather dominated by diarrhea or constipation symptoms. The severity of IBS symptoms on these two specific symptom clusters could be assessed very well by the constipation and diarrhea scales of the Birmingham IBS questionnaire.

We think that a quite interesting question which has been raised by Wessely^[4] and others^[61] is what the different functional syndromes have in common. We argue that it would be interesting to apply the bifactor model to the questionnaires which assess the severity of symptoms associated with different functional syndromes (e.g., fibromyalgia, chronic fatigue syndrome). We would expect that the severity regarding those syndromes can also be described by bifactor models (i.e., one general somatization factor, and syndrome specific factors). Then, one could correlate the general somatization factors related to distinct functional somatic syndromes, which is likely to produce very high intercorrelations. Thus, it seems plausible to us that different somatic syndromes share large amounts of common variance and at the same time each syndrome also accounts for specific variance components. As a consequence, a comparison of the proportion of common variance and specific variance could inspire the debate regarding the appropriate number of those syndromes.

This paper focuses on the measurement of IBS symptom severity. However, one might argue that the B-IBS questionnaire is rather a measure of symptom frequency instead of severity. Indeed, the items of the B-IBS questionnaire require frequency ratings (*all of the time to none of the time*). On the other hand, all of its items require the rating of both, bodily symptoms (e.g., “diarrhea”) and distress related ratings (e.g., Item 10: How often have you “suffered from a feeling of urgency”^[14]). Here, without doubt, the term “suffering” is directly related to the severity of the symptoms. We propose that future studies could put more emphasis on the distinction between the sole presence of a symptom and the degree of suffering or distress caused by the symptom. This distinction could also be an interesting feature for future questionnaires in this domain.

COMMENTS

Background

Irritable bowel syndrome (IBS) is characterized by recurrent abdominal pain or discomfort. The majority of instruments to assess IBS symptom severity do not treat the syndrome as a multidimensional construct. One exception is the Birmingham IBS symptom questionnaire which consists of three symptom specific scales (diarrhea, constipation, pain) and is examined in this article.

Research frontiers

Given the high prevalence of gastrointestinal symptoms in the general population, the authors argue that the validity of such instruments should also be examined in heterogeneous non-patient populations who show those symptoms but do not fulfill the formal criteria for an IBS diagnosis.

Innovations and breakthroughs

This is one of the first applications of advanced structural equation modeling

with bifactor models to the domain of irritable bowel syndrome severity. Moreover, the authors created a variance decomposition graph which helps to interpret the decomposition of variance components into general and specific factors for researchers who are less familiar with structural equation modeling.

Applications

The results clearly showed that the Birmingham-IBS symptom questionnaire is also suitable to assess IBS related symptom severity in persons who may show some IBS symptoms but do not fulfill the diagnostic criteria of a full IBS. In practice, one should inspect all of the three sub scales (i.e., diarrhea, constipation, pain) of the questionnaire and not only the summary score.

Peer review

A well conceived and implemented study to show that IBS symptoms occur in healthy individuals not amounting to a diagnosis of IBS.

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