American Pain Society
RESEARCH
EDUCATION
TREATMENT
ADVOCACY
PUBLISHED BY ELSEVIER

The Journal of Pain, Vol 19, No 3 (March), 2018: pp 317-329
Available online at www.jpain.org and www.sciencedirect.com

Dimensionality and Reliability of the Central Sensitization Inventory in a Pooled Multicountry Sample

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Received May 22, 2017; Revised November 4, 2017; Accepted November 9, 2017.
This project was funded in part by the Instituto de Salud Carlos III through the Network for Prevention and Health Promotion in Primary Care (RD16/0007/0012). J.V.L. has a "Miguel Servet" research contract from the Instituto de Salud Carlos III (CP14/00087).
The authors have no conflicts of interest to declare.
Supplementary data accompanying this article are available online at www.jpain.org and www.sciencedirect.com.

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1526-5900/$36.00

https://doi.org/10.1016/j.jpain.2017.11.006

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Abstract: **Central sensitization (CS) involves the amplification of neural signaling within the central nervous system, which evokes pain hypersensitivity. The Central Sensitization Inventory (CSI) assesses 25 overlapping health-related symptom dimensions that have been reported to be associated with CS-related disorders. Previous studies have reported satisfactory test-retest reliability and internal consistency, but factor analyses have exhibited conflicting results in different language versions. The purpose of this cross-sectional study was to thoroughly examine the dimensionality and reliability of the CSI, with pooled data from 1,987 individuals, collected in several countries. The principal component analysis suggested that 1 general factor of CS best described the structure. A subsequent confirmatory factor analysis revealed that a bifactor model, which accounted for the covariance among CSI items, with regard to 1 general factor and 4 orthogonal factors, fit the CSI structure better than the unidimensional and the 4-factor models. Additional analyses indicated substantial reliability for the general factor (ie, Cronbach $\alpha = .92$; $\omega = .95$; and ω hierarchical = .89). Reliability results for the 4 specific factors were considered too low to be used for subscales. The results of this study clearly suggest that only total CSI scores should be used and reported.**

Perspective: ***As far as we know, this is the first study that has examined the factor structure and reliability of the CSI in a large multicountry sample. The CSI is currently considered the leading self-report measure of CS-related symptoms worldwide.***

Key words: *Central Sensitization Inventory, central sensitization, central sensitivity syndrome, chronic pain, psychometrics, multicountry sample.*

Central sensitization (CS) has been defined as an amplification of neural signaling within the central nervous system, which evokes pain hypersensitivity.[51] CS has been proposed as an underlying mechanism for many pain-related conditions, including fibromyalgia, irritable bowel syndrome, temporomandibular joint disorder, headache, and spinal pain disorders.[6,21,39,48,56] CS-related pain disorders often share other common secondary symptoms, such as insomnia, feeling "unrefreshed" after sleeping, difficulty concentrating, and fatigue.[53,54] More recently, CS has been tied to various other conditions in which pain is not a primary symptom, including post-traumatic stress disorder, multiple chemical sensitivity, restless leg syndrome,[54] and overactive bladder.[36] It has also been suggested that CS is not only associated with pain hypersensitivity, but can also involve hypersensitivity to lights, sounds, fragrances, skin irritants, bodily sensations, and stress-evoking life events.[13,53,54] It was within this framework that the Central Sensitization Inventory (CSI) was developed.

The CSI was designed as a screening instrument to help identify if a patient's presenting symptoms may be related to CS, or indicate a CS-related disorder.[26] A recent systematic review of 14 CSI studies, which were determined to have good to excellent quality of evidence, concluded that the CSI generates reliable and valid data to quantify the severity of CS-related symptoms.[40] A cutoff score of 40 has been recommended for screening purposes,[27,30,32] and 5 severity levels have been proposed for clinical interpretation.[28] CSI total scores have been shown to discriminate between chronic pain and control subjects, and between chronic pain subgroups with, and without objective CS-related diagnoses.[11,22,23,26-28,33] Higher CSI scores have been associated with higher scores on other validated, pain-related, self-report measures,[22,27-29,47] CS-related clinical symptoms,[12,20,24] as well as objective biological markers of CS.[2,11] Higher scores have been shown to predict decreased quality of life and longer length of hospital stay after spinal fusion.[5] CSI scores have also been reported to be responsive to functional restoration treatment in a group of chronic spinal pain patients.[29] In addition, the CSI has also been recommended as one component of a classification algorithm for differentiating CS pain from neuropathic and nociceptive pain.[30,32]

The original English version of the CSI has been cross-culturally adapted and published into various European, Asian, and South American languages.[7,11,14,22,23,33] It has shown satisfactory psychometric results for test-retest reliability (intraclass correlation coefficient ranging from .88 to .97), and Cronbach α (ranging from .88 to .91).[7,11,14,22,23,26,33] However, factor analyses from the different published-language versions of the CSI have produced some conflicting results. Some groups have determined a 4-factor structure[11,22,23,26,33] and some have determined a unidimensional structure.[14] In addition, although the same 4 factors were identified in these previous studies, some differences were found in which items loaded on each of the factors and with some items that did not load well on any of the factors. Table 1 shows a comparison of the psychometric results from published subject samples.

On the basis of previous results, the factor structure of the CSI remains unresolved. Therefore, the aim of the

Table 1. Descriptive Data and Psychometric Properties of the CSI From Previously Published Studies (2012–2017)

	English (CSI-En)[26]	*Dutch (CSI-D)*[23]	*Spanish (CSI-Sp)*[14]	*French (CSI-Fr)*[33]	*Brazilian Portuguese (CSI-BP)*[11]	*Serbian (CSI-Serb)*[22]	*Gujarati (CSI-G)*[7]
Chronic pain patients (n)	n = 105*	n = 368	n = 395	n = 40	n = 222*	n = 355	n = 31
CSI total score, mean (SD)	CSI = 41.6 to 58.2 (10.5–14.9)	CSI = 43.9 (17.7)	CSI = 24.6 (12.0)	CSI = 68.8 (13.5)	CSI = 39.5 to 58.3 (15.5–16.5)	CSI = 38.3 (15.7)	CSI = 44.2 (13.8)
Healthy controls (n)	n = 40	n = 49	n = 0	n = 40 (+ 40 acute)†	n = 63	n = 34	n = 0
CSI total score mean (SD)	CSI = 28.9 (13.5)	CSI = 21.55 (10.9)	n/a	CSI = 24.6 (10.8)	CSI = 37.14 (15.0)	CSI = 20.9 (9.1)	n/a
Test-retest	r = .82	ICC = .88/.91	ICC = .91	ICC = .91/.94	ICC = .91	ICC = .95	ICC = .97
Internal consistency (Cronbach α)	α = .88	α = .91	α = .87	α = .96 to .97	α = .91	α = .91	α = .91
Factor analysis solution	EFA‡ = 4 factors (with eigenvalues >1) explaining 53.4% of the variance (items 1, 5, and 14 did not load on any of the factors)	EFA/CFA = 4 factors (items 1, 5, 22, 23, and 24 did not load on any of the factors)	EFA = 1 factor explaining 25.9 % of the variance	CFA = 4 factors (items 1, 5, and 14 did not load on any of the factors)	CFA = 4 factors (with eigenvalues >1) explaining 49% of the variance (item 14 did not load on any of the factors)	CFA = 4 factors (with eigenvalues >1) explaining 50.6% of the variance. All items were retained	Not assessed

Abbreviations: CSI-BP, Brazilian Portuguese CSI; CSI-D, Dutch CSI; CSI-En, English CSI; CSI-Fr, French CSI; CSI-G, Gujarati CSI; CSI-Serb, Serbian CSI; CSI-Sp, Spanish CSI; EFA, exploratory factor analysis; ICC, intraclass correlation coefficient; n/a, not applicable.

*Subjects were divided into separate clinical subgroups, so means for the total sample were not available.

†An acute "sprained ankle" group was included in this "healthy control" section.

‡Additional subjects were included in the EFA (210 chronic pain patients and 159 normative subjects).

present investigation was to determine the dimensionality and reliability of the CSI in a large, heterogeneous, subject sample. It is hoped that the results will provide guidance on the proper interpretation of CSI scores. A consortium of research groups from The Netherlands, Belgium, Spain, France, Italy, Serbia, Brazil, and the United States pooled CSI data from 1,987 individuals to accomplish this goal.

Methods

Subjects

CSI results from 2,093 subjects, representing 7 countries, were pooled into a single database. Each subject agreed to participate by signing an informed consent. Because of some missing item responses, 109 patients were eliminated, leaving 1,987 total subjects for analyses. Each study site also obtained separate institutional review board (IRB) approval. Data collection in The Netherlands was carried out during standard physical therapy sessions, which is exempted from a review board approval under the Dutch law. However, all Dutch study participants did sign written informed consent to use their data in the present study. Data collection in Belgium was covered by an approval of the medical ethical committee of the University Hospital Ghent. Data collection in France was approved by the IRB at Comité d'Ethique Hospitalo-Facultaire, Cliniques Universitaires Saint-Luc. Data collection in Brazil was approved by the local ethics committee at Postgraduate Research Group at Hospital de Clínicas de Porto Alegre. Data collection in Serbia was approved by the Ethical Board of Clinical Centre of Vojvodina. Data collection in Italy was approved by the Internal Ethical Board of the Department of Internal Medicine at the University of Genova. Data collection in Spain was approved by the Tribunal of Review of Human Subjects at the University of Malaga. All data from the U.S. sample were collected as part of the patients' standard medical files, with Health Insurance Portability and Accountability Act protection of deidentified data. Therefore, the study was granted exemption status by the IRB at the University of Texas at Arlington.

Table 2 provides demographic data (gender and age) and descriptions of the subject samples. Most subjects had chronic pain conditions, with various diagnoses. Chronic pain was defined in the present study as pain beyond 3 months of onset. To increase the variability of the pooled sample, 192 nonclinical subjects were also included. Diagnostic groups are known to score higher on the CSI, and healthy subjects are known to score lower. Including both types of subjects resulted in the widest possible distribution of CSI scores in the pooled sample for the analyses of dimensionality and reliability. Two recruitment methods were used. The Dutch, English, Serbian, and Spanish clinical samples were recruited consecutively among patients referred for assessment and treatment in local treatment facilities. The Brazilian, French, and Italian clinical samples, and all of the pain-free subjects, were recruited through local advertisements. These subjects were accepted into the study if they met specific diagnostic criteria, as shown in Table 2. A large proportion of subjects had been study participants in previously published CSI validation reports (Table 1). Some additional subjects were included in the Dutch and English samples. The Italian sample in the present study had not been previously published.

The CSI

The original English version of the CSI is shown in Supplementary Appendix 1. Part A of the CSI assesses 25 overlapping somatic and emotional health-related symptom dimensions that have been reported in previous studies to be associated with CS-related disorders. Responses are recorded about the frequency of each symptom, with a Likert scale from 0 (never) to 4 (always), resulting in a total possible score of 100. Higher scores indicate a higher degree of self-reported symptomatology. Part B (which is not scored) assesses 7 CS-related disorders (tension headaches/migraines, fibromyalgia, irritable bowel syndrome, restless leg syndrome, temporomandibular joint disorder, chronic fatigue syndrome, and multiple chemical sensitivities), and 3 associated diagnoses (depression, anxiety/panic attacks, and neck injury). Subjects are asked: 1) if they have previously been diagnosed by a doctor with each of the disorders, and 2) what year they were diagnosed. Only Part A was used for the present study. Multiple-language versions of the CSI, in pdf form, can be found at www.pridedallas.com/questionnaires.

Statistical Analyses

Descriptive statistics were calculated for each CSI item (range, 0–4) in the entire subject sample, including mean, SD, skewness, kurtosis, and corrected item total correlations. Univariate values, approaching at least 2.0 for skewness and 7.0 for kurtosis, were used to determine substantial univariate nonnormality.[49]

Before assembling the multicultural data set, it was important to test whether the subsamples were homogeneous concerning the structure of the CSI items represented by the covariances or correlations. A test of the equality of the covariance matrices was computed to evaluate the equality of the CSI items before pooling the data from different studies. The 7 subsamples of the total data set were tested for heterogeneity and were found to be homogeneous (root mean square error of approximation [RMSEA] = .062, 90% confidence interval [CI], .059–.065).

For dimensionality analyses, the multicountry sample was randomly divided into 2 subsamples for the purpose of cross-sample validation (stratified randomization according to cultural CSI version), allowing for principal component analysis (PCA) with 1 subsample (n = 1,049), and confirmatory factor analysis (CFA) with the other (n = 1,044). No statistically significant differences were found between the 2 subsamples in the CSI total scores (subsample 1 = 38.10 ± 17.86 vs subsample 2 = 37.70 ± 17.85; $P = .620$).

Table 2. Description of the Samples

Subject Sample	*Description*	*Demographic Characteristics*	*Recruitment Method*
CSI-Brazilian Portuguese Total N = 285 PCA = 143 CFA = 142	Chronic pain patients with diagnoses of: 1. fibromyalgia (n = 73) 2. myofascial pain syndrome (n = 65) 3. chronic tension type headache (n = 53) 4. osteoarthritis (n = 31) Pain-free control subjects (n = 63)	Mean age = 45.34 ± 15.06 years 82.1% Female	A nonconsecutive sample of clinical subjects was recruited from local community care units, an institutional chronic pain clinic, via referrals from other hospital units, and phone and newspaper. Volunteers were determined eligible for participation the study on the basis of diagnostic criteria for the 4 patient subgroups. The recruitment process was done in conjunction with other randomized controlled trials run at the Hospital de Clínicas de Porto Alegre, Porto Alegre, Brazil. Pain-free control subjects were recruited from the general population, also using public advertisements. A standard screening questionnaire was performed to identify volunteers who were free of any acute or chronic pain
CSI-Dutch Total N = 414 PCA = 205 CFA = 209	Chronic musculoskeletal pain subjects with various diagnoses (n = 365) Control subjects (n = 49)	Mean age = 42.08 ± 13.54 years 70% Female	Clinical subjects were recruited consecutively among referrals for assessment and treatment in 3 different pain treatment centers: 1) Transcare, Transdisciplinary pain management center, Groningen, The Netherlands; 2) Inter-fysio, Physical therapy practice, Groningen, The Netherlands; and 3) multidisciplinary pain center at the University Hospital of Ghent, Ghent, Belgium. Healthy control subjects were recruited from the general population. Volunteers were included in the study if they were not diagnosed with any central sensitivity syndrome and had no long-term pain complaints during the past 5 years
CSI-English Total N = 451 PCA = 226 CFA = 225	Chronic musculoskeletal pain disorder subjects with various injury-related diagnoses	Mean age = 45.66 ± 12.0 years 25.7% Female	Clinical subjects were recruited consecutively among referrals for assessment and treatment at the Productive Rehabilitation Institute of Dallas for Ergonomics, in Dallas, Texas, an interdisciplinary community-based functional restoration treatment program
CSI-French Total N = 120 PCA = 62 CFA = 58	Three subject groups included: 1. Fibromyalgia (n = 40) 2. Acute ankle sprain (<6 weeks; n = 40) 3. Healthy controls (n = 40)	Mean age = 42.76 ± 9.73 88.3% Female	A nonconsecutive sample of clinical subjects was recruited from advertisements at the Multidisciplinary Pain Clinic at the Cliniques Universitaires Saint-Luc, Brussels, Belgium. Volunteers were determined eligible for participation the study on the basis of diagnostic criteria for the two patient subgroups. A sample of healthy subjects, who reported no pain lasting more than 24 hours during the previous 6 months, were recruited among the researchers' acquaintances
CSI-Italian Total N = 220 PCA = 110 CFA = 110	Chronic pain subjects with 1 or more of the following diagnoses: 1. Low back pain (n = 76) 2. Temporomandibular disorders (n = 37) 3. Hand osteoarthritis (n = 43) 4. Rheumatoid arthritis (n = 44) 5. Fibromyalgia (n = 20)	Mean age = 54.5 + 15.5 78.8% Female	A nonconsecutive sample of clinical subjects was recruited in 2 clinical settings: a physiotherapy private practice in Bologna, Italy, and the Rheumatology Clinical Operational Unit of the IRCCS—Ospedale San Martino in Genova, Italy. Volunteers were determined eligible for participation the study on the basis of diagnostic criteria for the 5 patient subgroups
CSI-Serbian Total N = 212 PCA = 106 CFA = 106	Chronic pain subjects with various diagnoses	Mean age = 52.08 ± 12.61 years 68.4% Female	Clinical subjects were recruited consecutively among referrals for assessment and treatment at a medical rehabilitation program at the Medical Rehabilitation Clinic in the Clinical Centre of Vojvodina, Vojvodina, Serbia
CSI-Spanish Total N = 391 PCA = 197 CFA = 194	Chronic musculoskeletal pain subjects with various diagnoses	Mean age = 54.48 + 13.60 years 44.4% Female	Clinical subjects were recruited consecutively among referrals for assessment and treatment at a community-based physiotherapy program at the Malaga University, Malaga, Spain

To evaluate the suitability of the CSI data for factor analysis, the Kaiser–Mayer–Olkin[19] Measure of Sampling Adequacy (>.70) and the Bartlett Test of Sphericity[4] ($P < .05$) were computed. To make the results comparable with those originally reported by Mayer et al,[26] a PCA with oblique PROMAX rotation was used. The following set of rules helped to determine the optimal number of components to retain[45]: Kaiser criterion for components with eigenvalues >1.0, the ratio of the eigenvalue of the first and second unrotated component ≥4.0,[34] Cattell Scree Test, and individual item loadings ≥.40. We did not make imputation of missing values. The analyses were computed with only the participants who had answered all items (n = 954).

Three-factor structures were tested in the CFA. First tested was the 1-factor model. The second tested was the original 4-factor model,[26] with a "physical symptoms" factor (items 1, 2, 5, 6, 8, 9, 12, 14, 17, 18, and 22), an "emotional distress" factor (items 3, 13, 15, 16, 23, and 24), a "headache/jaw symptoms" factor (items 4, 7, 10, 19, and 20), and a "urological symptoms" factor (items 11, 21, and 25). Finally, a bifactor structure was fitted, examining whether the CSI could be modeled using a general factor of "CS-related symptoms," measured for all CSI items, and 4 specific factors, measured according to item subsets. A bifactor approach helps to determine whether the CSI items are multidimensional, allowing the computation of subscale scores, or whether the items are mainly unidimensional, for which only 1 total score should be computed and reported.[37,38] To justify multidimensionality, and the computation of subscale scores, factors must be mutually uncorrelated and must explain unique variance among the items, beyond the general factor. One of the main utilities of the bifactor model approach is the capacity to "tease apart" general as well as specific factors influencing a group of symptoms or experiences. Analysis of a bifactor model determines the common variance (Explained Common Variance [ECV] index), which is the ratio of variance explained by the general factor divided by the variance explained by the general plus the group factors. For example, an ECV of .75 means that the general factor explains 75% of the common variance extracted, with 25% of the common variance spread across specific factors. Higher ECV values indicate a more robust general factor. The difference between the standardized loadings in the 1-factor model, and the standardized loadings for the general factor of the bifactor model, were also determined.

In ordinal items with a non-normal distribution, such as those in the CSI, it may be expected that the matrix of covariances will underestimate the true amount of relations among items. Therefore, we proceeded to estimate the models from the matrix of polychoric correlations, which estimate the linear relationship between unobserved continuous variables with only observed ordinal data. Polychoric correlations are on the basis of the premise that the observed ordinal values are due to an unobserved underlying continuous distribution.[16] Mean and variance-corrected weighted least squares (WLSMV) was applied to test the fit of the 3-factor models. Besides the χ^2 test, the following fit indices were analyzed (the values in parentheses denote goodness-of-fit standards: the Tucker–Lewis index [TLI] and the comparative fit index [CFI] ≥ .95 indicate an acceptable fit, and ≥ .97 indicate a good fit), and the RMSEA with 90% confidence intervals (RMSEA ≤ .08 indicates an acceptable fit and ≤ .05 indicates a good fit).[41,42] Model comparisons were performed on the basis of a practical improvement in a model-fit approach (TLI difference ≥ .01).[17] In addition, to compare the goodness-of-fit of the tested models, we computed the difftest, which is available in the case of WLSMV estimation in Mplus version 7.4 (Muthén & Muthén, Los Angeles, CA). A difftest procedure is used to obtain a correct χ^2 difference test when the WLSMV estimation method is used, because the difference in χ^2 values for 2 nested models using WLSMV χ^2 values is not distributed as χ^2. The "LISTWISE = ON" command in Mplus (Muthén & Muthén) was used to delete incomplete cases from the CFA.[3] The CFA was computed with only the participants who had answered all items (n = 1,033).

Cronbach α coefficient, which reflects the average intercorrelations among items, was computed for the CSI total score and subscales in the entire sample. In addition, 2 types of unbiased alternative measures of construct reliability were computed for bifactor models: ω and ω hierarchical (ω-h),[9] which are considered superior to Cronbach α coefficient.[55] The ω estimates the reliability of a latent factor combining the general and specific factor variance, whereas ω-h estimates the reliability of a latent factor with all other latent construct variance removed. According to Shrout and Lane,[43] a reliability of: .00 to .10 indicates virtually no reliability; .11 to .40, slight; .41 to .60, fair; .61 to .80, moderate; and .81 to 1.0; substantial reliability.

SPSS version 22.0 (IBM Corp, Armonk, NY) and Mplus version 7.4 (Muthén & Muthén) were used to conduct the statistical analyses.

Results

Descriptive Statistics

The mean CSI total score for the entire sample was 37.9 (SD = 17.85, range = 0–96). Additional descriptive statistics are shown in Table 3. None of the items had questionable univariate normality on the basis of their skewness or kurtosis values. All items obtained a corrected item total correlation that was higher than the "rule of thumb" minimum value of .25.[15] The mean percentage of missing values according to item was 1.19% (range = .8%–2.2%).

PCA

The Kaiser-Meyer-Olkin (KMO) measure yielded a coefficient of .947, and the Bartlett test of sphericity produced a figure of 9,396,792 ($P < .0001$), indicating that the sampling adequacy was excellent, and the correlation matrix was suitable for factor analysis. The first PCA (n = 954 after listwise deletion) revealed 4 factors with

Table 3. Mean, SD, Skewness, Kurtosis, and r_{tot} for all CSI Items (Range = 0–4) in the Pooled Sample

CSI Items	Mean	SD	Skewness	Kurtosis	R_{TOT}
1. I feel unrefreshed when I wake up in the morning	2.13	1.20	–.10	–.81	.51
2. My muscles feel stiff and achy	2.46	1.15	–.35	–.68	.64
3. I have anxiety attacks	1.07	1.18	.71	–.63	.60
4. I grind or clench my teeth	1.18	1.31	.68	–.86	.40
5. I have problems with diarrhea and/or constipation	1.36	1.21	.53	–.70	.53
6. I need help in performing my daily activities	1.19	1.28	.68	–.72	.58
7. I am sensitive to bright lights	1.29	1.32	.64	–.79	.53
8. I get tired very easily when I am physically active	2.15	1.28	–.08	–1.04	.71
9. I feel pain all over my body	1.59	1.32	.38	–.99	.68
10. I have headaches	1.70	1.08	.18	–.69	.51
11. I feel discomfort in my bladder and/or burning when I urinate	.62	.98	1.59	1.86	.45
12. I do not sleep well	2.16	1.21	–.06	–.90	.56
13. I have difficulty concentrating	1.83	1.13	.11	–.67	.64
14. I have skin problems such as dryness, itchiness, or rashes	1.29	1.26	.61	–.75	.42
15. Stress makes my physical symptoms get worse	2.11	1.34	–.12	–1.11	.66
16. I feel sad or depressed	1.52	1.11	.35	–.50	.63
17. I have low energy	2.01	1.13	.00	–.70	.70
18. I have muscle tension in my neck and shoulders	2.46	1.22	–.41	–.73	.59
19. I have pain in my jaw	.73	1.08	1.36	.83	.45
20. Certain smells, such as perfumes, make me feel dizzy and nauseated	.85	1.14	1.19	.44	.41
21. I have to urinate frequently	1.48	1.23	.40	–.84	.38
22. My legs feel uncomfortable and restless when I am trying to go to sleep at night	1.55	1.39	.35	–1.18	.58
23. I have difficulty remembering things	1.64	1.15	.24	–.70	.58
24. I suffered trauma as a child	.69	1.13	1.54	1.28	.47
25. I have pain in my pelvic area	1.10	1.35	.84	–.65	.49

Abbreviation: r_{tot}, corrected item total correlations.
NOTE: The SE of skewness was .054. The SE of kurtosis was .107.

eigenvalues > 1.0. The first component explained 36.1% of the variance, whereas the other 3 components explained 6.3%, 5.0%, and 4.7% of the variance, respectively (eigenvalues of the 4 components were 9.01, 1.59, 1.26, and 1.18, respectively). The ratio between the first and second factor (= 5.67) and the scree plot suggested that 1 factor may be sufficient to capture the essence of the CSI. A second PCA yielded a 1-factor solution (accounting for 36.10% of total variance), with the 25 items loading strongly on the factor (all $\lambda \geq .40$). As shown in Table 3, factor loadings for the 1-factor model ranged from .40 (item 4 "I grind or clench my teeth") to .75 (item 8 "I get tired very easily when I am physically active").

CFA

The results of the CFAs are also presented in Table 4. The χ^2 statistic for the set of factor models was significant ($P < .001$) in all cases (1-factor model $\chi^2_{275} = 2{,}250.223$; 4-factor model $\chi^2_{269} = 1{,}717.485$; bifactor model $\chi^2_{250} = 1{,}229.674$], suggesting a poor model fit. This result is not surprising because the χ^2 is highly sensitive and even small differences in model fit are statistically significant. In general, the CFA indicated that the bifactor model was the best model for the multicountry sample. The 1-factor model fit the data reasonably well, with 2 indices indicating an acceptable fit (CFI = .91 and TLI = .90), and 1 index an almost adequate fit (RMSEA = .08; 95% CI, .08–.09). The 4-factor model fit the data better than the unidimensional model (CFI = .93, TLI = .93, RMSEA = .07, 95% CI = .07–.08, ΔTLI = .03). The difftest procedure confirmed that the model containing 4 latent first ordered factors yielded better fit to the data than the 1-factor model ($\Delta\chi^2$ test = 357.114, df = 6, $P < .0001$). Standardized factor loadings for the 4-factor model ranged from .48 (item 14) to .82 (item 8). The 4 latent factors were highly and significantly correlated in the sample (r for physical symptoms and emotional distress = .85, r for physical symptoms and headache/jaw symptoms = .78, r for physical symptoms and urological symptoms = .70, r for emotional distress and headache/jaw symptoms = .82, r for emotional distress and urological symptoms = .63, r for headache/jaw symptoms and urological symptoms = .68). Finally, the bifactor model showed the best fit across all indices, compared with the previously estimated unidimensional and 4-factor model (CFI = .96, TLI = .95, RMSEA = .06, 95% CI, .06–.07). This model containing 1 global and 4 specific latent factors resulted in a significantly better fit to the current data than the 1-factor model ($\Delta\chi^2$ test = 881.067, df = 25, $P < .0001$, ΔTLI = .05). Regarding the comparison of the bifactor model with the 4-factor model, computation of $\Delta\chi^2$ was not possible because of the singular matrix during the computation process. The TLI difference between these models was .02, which exceeded the practical significance criterion of .01.

For illustrative purposes, the bifactor model is shown in Fig 1. Items from all domains tended to be more strongly related to the general 'CS-related symptoms' factor than the specific factors (see Fig 1 and Table 4 for

Table 4. Item Content, Mean, SD, and λ of the CSI Items

	Subsample 1 (N = 954) PCA		*Subsample 2 (N = 1,033) CFA*										
CSI Item	*Mean (SD)*	*λ*	*Mean (SD)*	*1F λ*	*F1 λ*	*F2 λ*	*F3 λ*	*F4 λ*	*GEN*	*S1 λ*	*S2 λ*	*S3 λ*	*S4 λ*
1. I feel unrefreshed when I wake up in the morning	2.13 (1.20)	.56	2.14 (1.19)	.55	.56				.48	.34			
2. My muscles feel stiff and achy	2.47 (1.15)	.68	2.44 (1.16)	.73	.74				.60	.57			
3. I have anxiety attacks	1.06 (1.16)	.64	1.06 (1.18)	.68		.72			.71		-.12		
4. I grind or clench my teeth	1.14 (1.31)	.40	1.18 (1.30)	.49			.56		.48			.32	
5. I have problems with diarrhea and/or constipation	1.36 (1.21)	.58	1.35 (1.20)	.57	.58				.60	-.01			
6. I need help in performing my daily activities	1.14 (1.28)	.65	1.21 (1.27)	.67	.69				.60	.36			
7. I am sensitive to bright lights	1.32 (1.34)	.56	1.25 (1.30)	.58			.67		.58			.29	
8. I get tired very easily when I am physically active	2.16 (1.26)	.75	2.15 (1.31)	.80	.82				.73	.39			
9. I feel pain all over my body	1.58 (1.34)	.72	1.58 (1.31)	.73	.75				.63	.44			
10. I have headaches	1.70 (1.07)	.58	1.69 (1.09)	.54			.62		.55			.13	
11. I feel discomfort in my bladder and/or burning when I urinate	.59 (.95)	.49	.63 (.97)	.48				.65	.47				.88
12. I do not sleep well	2.14 (1.21)	.62	2.14 (1.20)	.63	.64				.58	.29			
13. I have difficulty concentrating	1.86 (1.10)	.70	1.79 (1.15)	.70		.75			.69		.40		
14. I have skin problems such as dryness, itchiness, or rashes	1.30 (1.26)	.45	1.28 (1.27)	.47	.48				.52	-.15			
15. Stress makes my physical symptoms get worse	2.09 (1.33)	.68	2.13 (1.36)	.73		.78			.77		-.03		
16. I feel sad or depressed	1.50 (1.09)	.68	1.51 (1.10)	.72		.77			.75		-.03		
17. I have low energy	2.01 (1.11)	.74	2.01 (1.14)	.78	.81				.75	.26			
18. I have muscle tension in my neck and shoulders	2.50 (1.22)	.64	2.42 (1.23)	.60	.62				.56	.25			
19. I have pain in my jaw	.73 (1.09)	.48	.70 (1.05)	.54			.61		.52			.51	
20. Certain smells, such as perfumes, make me feel dizzy and nauseated	.88 (1.18)	.42	.83 (1.11)	.52			.60		.51			.33	
21. I have to urinate frequently	1.45 (1.24)	.44	1.48 (1.21)	.39				.52	.39				.33
22. My legs feel uncomfortable and restless when I am trying to go to sleep at night	1.57 (1.38)	.62	1.49 (1.41)	.66	.67				.60	.32			
23. I have difficulty remembering things	1.63 (1.13)	.62	1.62 (1.15)	.62		.66			.60		.62		
24. I suffered trauma as a child	.71 (1.15)	.54	.69 (1.11)	.54		.57			.56		-.01		
25. I have pain in my pelvic area	1.11 (1.36)	.56	1.12 (1.35)	.52				.69	.52				.16

Abbreviations: λ, factor loading; 1F, 1-factor model; F1, "physical symptoms"; F2, "emotional distress"; F3, "headache/jaw symptoms"; F4, "urological symptoms"; GEN, general "CS-related symptoms" factor in the bifactor model; S1-S4, specific factors in the bifactor model.

standardized factor loading estimates), with factor loadings on the general factor ranging from .39 (item 21 "I have to urinate frequently") to .77 (item 15 "Stress makes my physical symptoms get worse") (Fig 1). Only one-half of the items for the specific "emotional distress" factor showed factor loadings > .4. Item 5 (diarrhea/constipation) had a nonsignificant loading on its specific "physical symptoms" factor, and a high loading on the general "CS-related symptoms" factor.

Overall, the general "CS-related symptoms" factor accounted for 37.1% of the shared variance among symptoms from the physical symptoms domain, whereas the specific "physical symptoms" factor accounted for 11.3% of variance among these symptoms. There was a greater difference for the symptoms from the "emotional distress" domain, with the general factor explaining 46.7% of shared variance among these symptoms, and the specific "emotional distress" factor accounting for 9.2% of their variance. For the symptoms from the "headache/jaw" and "urological symptoms" factors, the general factor accounted for 28.0% and 21.3% of shared variance among these symptoms, respectively, whereas these specific factors accounted for 15.8% and 30.3% of their variance, respectively. The ECV index was .67, which indicated that the general factor explained 67% of the common variance. Therefore, the results indicated that the CSI had a strong general "CS-related symptoms" factor, and the common variance was mainly unidimensional.[37] Regarding the difference between the standardized loadings in the 1-factor model and the standardized loadings for the general factor of the bifactor model, the mean relative bias was .02 (SD = .05), which indicated that the relative difference in parameter estimates between the unidimensional and bifactor model was very small. In other words, there was an absence of biasing effects if we forced a unidimensional model to our multidimensional data.

Internal Consistency/Reliability

Overall, the internal consistency for the CSI total score was excellent (Cronbach α = .92). Using the .80 cutoff criterion established by Carmines and Zeller,[10] 2 of the 4 CSI subscales were internally consistent ("physical symptoms" = .88, and "emotional distress" = .83), whereas the other 2 subscales had a modest internal consistency ("headache/jaw symptoms" = .67, and "urological symptoms" = .57).

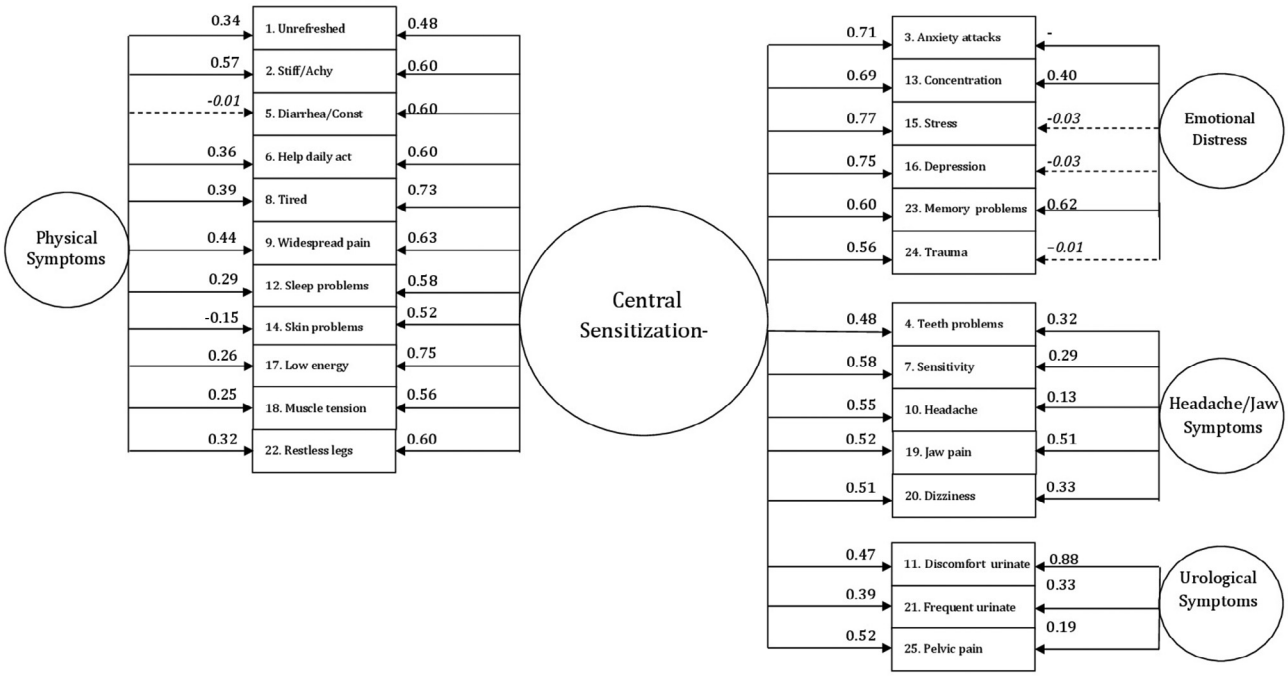

Figure 1. The CSI bifactor structure. Nonsignificant factor loadings are given in italic and indicated by dashed lines.

The ω indicator showed some similar results to those observed in the Cronbach α results. The latent general "CS-related symptoms" factor (.95) and the specific "physical symptoms" (.90) and "emotional distress" (.87) factors showed substantial reliability. The ω indicator for the "headache/jaw symptoms" and "urological symptoms" was moderate (.76 and .72, respectively). In contrast, coefficient ω-h oscillated from virtually no reliability (.03) in the case of "emotional distress," to slight for the other specific factors ("physical symptoms" = .16, "headache/jaw symptoms" = .20, "urological symptoms" = .36). This coefficient indicated substantial reliability only for the general "CS-related symptoms" factor (.89).

Discussion

It has become increasingly recognized that CS is a contributing factor in many chronic pain conditions, including fibromyalgia, irritable bowel syndrome, temporomandibular joint disorder, headache, and spinal pain disorders.[21,39,48,56] The CSI was originally designed as a screening instrument to help identify when a patient's clinical presentation may be CS-related and to help guide the provider in appropriate evaluation and identification of the underlying problem(s). Biopsychosocial interventions, including cognitive-behavioral, physical therapies, and targeted drug therapies, have been recommended for treating CS-related disorders.[1,31] Expensive diagnostic testing (such as colonoscopy, cardiac catheterizations, or imaging) and invasive medical interventions (such as surgical procedures or implantable devices) are often superfluous and counterproductive for this clinical population.

Although the CSI does not directly measure CS, it has been reported to correlate significantly with CS-related clinical variables. Higher total CSI scores have been reported to be associated with higher pain intensity[20,29] and wider pain distribution.[24,47] Chronic pain samples, with presumably higher levels of CS (such as a fibromyalgia diagnosis and/or multiple central sensitivity syndromes) have been shown to score higher on the CSI than chronic pain subjects with presumably less CS (such as chronic regional and/or fewer central sensitivity syndromes),[11,22,26,27] acute pain subjects (such as acute ankle sprain),[33] and pain-free comparison subjects.[11,22,23,26,33] Finally, associations have been reported between CSI scores and biological markers of CS, including brain gamma amino butyric acid levels[2] and brain-derived neurotrophic factor.[11]

To shed light on the dimensionality and scoring of the CSI, the present study examined the goodness of fit of 3-factor models, including a 1-factor model (obtained in the PCA), a 4-factor model,[26] and a bifactor model. The unidimensional as well as the 4-factor models fit the pooled data well, but the CFA robustly revealed that the bifactor model provided the best fit. This bifactor solution indicates that the dimensions of the CSI have important common features from the general "CS-related symptoms" factor, as well as some unique features from the specific factors. All of the items loaded onto the specific "physical symptoms," "headache/jaw symptoms," and "urological symptoms" factors, after partialing out the general factor influence. However, only one-half of the items for the specific "emotional distress" factor met our stated criteria, and showed factor loadings > .4, suggesting that this factor might be reduced to a "cognitive problems" factor, with concentration and memory problems as its hallmark. Most of the CSI items (23 of 25) obtained higher factor loadings on the global CSI factor than on their respective specific factors. Overall, the factor analyses indicated that the general factor was

primarily responsible for item score variation, suggesting that the latent structure of the CSI is mainly unidimensional. Notwithstanding, the superiority of the tested bifactor model may be a result of "overfitting." Some experts on psychometrics advise that "demonstrating the fit of a bifactor model, relative or absolute, is therefore not sufficient evidence to validate the latent variable."[8]

It should be noted that this is the first study to assess the dimensionality of the CSI with a bifactor model, which has been shown to be a useful methodological approach for different purposes in some recent studies.[25,50,52] For example, Xie et al[52] tested a bifactor model of the Hospital Anxiety and Depression Scale that separated the general distress component of depression as well as anxiety symptoms from their specific characteristics (anhedonia and arousal, respectively) in 503 patients with chronic pain symptoms. As expected, significant correlations existed between pain severity and anxiety, as well as depression scores, under the classical 2-factor model. Interestingly, using the bifactor model, distress scores and pain severity were significantly correlated, whereas the specific factors of anxiety and depression were not significantly correlated with pain severity. In other words, the authors showed, by means of a fine-grained methodological approach (bifactor model) that general distress was responsible for the common link between pain and depression/anxiety symptoms. Using the same bifactor approach, Luciano et al[25] showed that the Hospital Anxiety and Depression Scale "general distress" and "depression" latent factors had high stability over time in fibromyalgia patients, whereas the stability of the "anxiety" factor was moderate over time. Finally, some research groups have even proposed a bifactor conceptualization of psychopathology comorbidity, in which an orthogonal general psychopathology factor saturates all diagnoses, in addition to internalizing/distress/fear and externalizing factors.[18]

Besides the factor analyses conducted in the present investigation, we examined the reliability of the CSI total score and the specific factor scores. The internal consistency for the total score was excellent. The specific "physical symptoms" and "emotional distress" factors had good reliability, but the "headache/jaw symptoms" and "urological symptoms" factors obtained somewhat lower than optimal α values. The modest α values obtained in these subscales were expected, because Cronbach α is affected by the length of the scale.[44] If subscales are too short, the value of α is reduced. Therefore, to increase α values, more intercorrelated items testing the same construct could be added to both subscales. In addition to Cronbach α, 2 additional measures of construct reliability, ω and ω-h,[9] were computed. These tests are considered superior to the Cronbach α coefficient.[55] The ω indicator (testing the reliability of a latent factor, after combining the general and specific factor variance) showed some results similar to those observed in the Cronbach α results. The latent general "CS-related symptoms" factor and the specific "physical symptoms" and "emotional distress" factors showed substantial reliability. The ω indicator for the "headache/jaw symptoms" and "urological symptoms" was moderate. In contrast, coefficient ω-h (which estimates the reliability of a latent factor with all other latent construct variance removed) showed virtually no reliability in the specific "emotional distress" factor and only slight reliability in the other specific factors. The ω-h coefficient indicated substantial reliability only for the general "CS-related symptoms" factor. Because the bifactor model supports the idea that the dimensions of the CSI have important common features, and some unique features, it may be tempting for clinicians to report and interpret subscale scores. On the basis of the reliability analyses, however, we discourage the use of subscales and recommend that only total scores be reported.

In any large investigation of this type, there are usually certain limitations. There were some in the present work. Because of space and in some cases sample size limitations, we did not test factorial invariance formally across country, gender, age groups, diagnosis, etc. Therefore, this is a pending issue in the CSI that future studies could address. Because of the unavailability of longitudinal data across the different cultural versions of the CSI, we were unable to examine responsiveness, stability, smallest detectable change, or minimal clinical important change for scoring the CSI in the pooled sample. The pooled data in the present study represented a very heterogeneous sample, with a wide variety of diagnoses, as well as nonclinical subjects, representing many cultures, which were reflected in the broad range of total scores, from 0 to 96. More research is needed to better understand how the CSI behaves psychometrically with specific populations, in specific cultures, and diagnostic subgroups. For instance, an important finding that merits replication is that certain specific factors captured some additional variance not accounted for by the general factor, whereas the "emotional distress" variance seemed to be tapped primarily by the general factor. Further psychometric research is also needed to examine the predictive validity of the CSI modeled as unidimensional (usual standard practice), and the predictive validity of the global "CS-related symptoms" factor when the specific factors are controlled for within the bifactor approach. Additional studies with longitudinal data are also needed to better determine if the general and specific CSI factors are stable over time, as has been performed in other lines of research with bifactor models.[18,25] Finally, the analyses reported in this study offer no means to gauge the quality of individual CSI items and response options across different levels of CS. The use of methods on the basis of item response theory[46] might provide detailed information about the functioning of each CSI item and would allow assessment of differential item functioning. We encourage the use of this methodology in future psychometric analyses of the CSI.

To sum up, although the CSI is still in its infancy, the present study has provided important information for the use of this measure in research and clinical practice. The analysis of its exact dimensionality, in a large and heterogeneous subject sample, has allowed us to determine that just 1 total score is needed for the proper interpretation of a subject's status. Reliability indices

indicated that the general "CS-related symptoms" factor was highly reliable, whereas the 4 specific factors were not sufficiently reliable to warrant computation of subscales scores in subsequent research and clinical practice. In other words, despite the multidimensionality of the CSI items, the total score reliably reflects variation on symptoms of general CS if we have in mind the ω hierarchical values of the general factor in the bifactor model. Therefore, it seems reasonable to compute the total score by summing the ratings on the 25 items because of the moderate to large item loadings on the global factor. In contrast, it is not recommended that subscale scores be computed separately because their variance is tapped primarily by the general construct of CS and the 4 specific dimensions showed low reliability. However, as pointed out by Reise et al,[35] even when a unidimensional model in a measure might be good enough for practical purposes, there might be occasions in which complex multidimensional models should be considered; for example, for testing unique associations of the general and the 4 specific factors with relevant external criteria (functional impairment, quality of life, well-being, etc), which could not be made in the present work.

Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jpain.2017.11.006.

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