RESEARCH ARTICLE

Open Access

Cross-cultural adaptation and validation for central sensitization inventory: based on Chinese patients undergoing total knee arthroplasty for knee osteoarthritis

Chao Xu[1,2†], Shuxin Yao[2†], Wei Wei[3†], Haiyue Zhang[1], Jianbing Ma[2*] and Lei Shang[1*]

Abstract

Background This study was conducted to develop a simplified Chinese version of the central sensitization inventory (CSI-CV) and to evaluate its reliability and validity.

Methods The CSI-CV was developed through a process involving the translation and back translation of the original CSI. Subsequently, experts reviewed and revised the content of the items to ensure their appropriateness. A total of 325 patients with knee osteoarthritis (KOA), who were scheduled to undergo total knee arthroplasty (TKA), completed the CSI-CV at a prominent orthopedic center in Xi'an, China. Afterward, a random selection of 100 participants was chosen for retesting after one week. The reliability and validity of the inventory were evaluated through exploratory factor analysis, correlation coefficient calculation and other methods.

Results The CSI-CV consists of 25 items in five dimensions (emotional distress, headache and jaw symptoms, physical symptoms, urological symptoms, and fatigue and sleep problems). The cumulative variance contribution rate was 75.3%, the Cronbach's α coefficient was 0.83, the Guttman split-half reliability coefficient was 0.88 and the intraclass correlation coefficient was 0.965. The CSI-CV scores correlated moderately with the total scores of the brief pain inventory (r = 0.506), Western Ontario and McMaster Universities Osteoarthritis Index (r = 0.466) and EuroQoL Group's five-dimension questionnaire (r = 0.576).

Conclusions The findings demonstrate that the CSI was successfully trans-culturally adapted into a simplified Chinese version (CSI-CV) that was reliable and valid for Chinese-speaking patients who awaiting TKA for KOA.

Keywords Central sensitization inventory, Central sensitization, Knee osteoarthritis, Psychometrics, Total knee arthroplasty, Chinese

[†]Chao Xu, Shuxin Yao and Wei Wei have contributed equally to this manuscript.

*Correspondence:
Jianbing Ma
drmajianbing@163.com
Lei Shang
shanglei@fmmu.edu.cn
Full list of author information is available at the end of the article

Xu *et al. Journal of Orthopaedic Surgery and Research*   (2023) 18:960

Page 2 of 11

Background

Knee osteoarthritis (KOA) is one of the most common degenerative diseases in elderly populations, resulting in chronic persistent pain and functional disability [1]. The average crude prevalence of KOA among individuals aged over 55 years was 13.2% between the years 2008 and 2017 in China [2]. Despite the recognized effectiveness of total knee arthroplasty (TKA) as a surgical intervention for end-stage KOA, a notable percentage (approximately 10–20%) of patients still report dissatisfaction [3]. Persistent unexplained pain following TKA has emerged as one of the strongest factors associated with this dissatisfaction [4].

Over the past few decades, the concept of central sensitization (CS) has been developed. It is defined as an enhanced responsiveness of nociceptive neurons in the central nervous system to their normal or subthreshold afferent input [5]. CS has been recognized as a significant risk factor for persistent pain and patient dissatisfaction after TKA [6–12]. Therefore, assessing the patient's CS status before surgery is essential to enable early intervention if necessary [13].

Several attempts have been made to objectively quantify CS, such as Quantitative Sensory Testing (QST) [14, 15] and (f)MRI [16, 17]. While these tools can provide valuable information, they are often complex, time-consuming, and expensive [18]. To address these limitations, researchers are investigating the feasibility of utilizing more accessible and cost-effective methods, such as the central sensitization inventory (CSI). CSI is a self-report questionnaire, which identifies key symptoms associated with CS and quantifies the severity of these symptoms [19]. The questionnaire consists of two parts, Part A assesses 25 CS-related symptoms regarding the patient's current conditions, while Part B investigates whether the patient has or had 10 central sensitivity syndromes (CSS) (fibromyalgia, chronic fatigue syndrome, temporomandibular joint disorder, irritable bowel syndrome, migraine or tension headaches, multiple chemical sensitivities, and restless leg syndrome, neck injuries, anxiety or panic attacks, depression) [19].

The CSI has been translated and validated in multiple countries for patients with chronic pain resulting from various causes [19–32]. Previously, Feng et al. translated and validated the traditional Chinese version of the CSI in Hong Kong [23]. Traditional Chinese is written and spoken in regions like Hong Kong, Macau, Taiwan, and Singapore. Simplified Chinese is the predominant official language in mainland China. This linguistic diversity reflects the cultural and geographical variations [33]. The majority of individuals in mainland China may encounter difficulties when it comes to reading and writing in traditional Chinese [33, 34]. Consequently, there is a pressing need to translate and culturally adapt the simplified Chinese version of the CSI. As such, the objective of this study is to translate, cross-culturally adapt, and validate the psychometric properties of the CSI in mainland Chinese KOA patients scheduled to undergo TKA. The aim is to establish a robust foundation for the application of the CSI in preoperative screening specifically for TKA procedures.

Materials and methods

The medical ethics committee of Honghui Hospital approved this prospective observational study (No. 202105010). All experiments were performed in accordance with the Declaration of Helsinki. All participants provided written informed consent.

Translation and cross-cultural adaptation

To culturally adapt the CSI, a translation and back-translation approach was employed [35]. Initially, the CSI was translated from English to simplified Chinese by two native Chinese speakers: an orthopedic surgeon proficient in English and a professional standard translator. The translation preserved the original English version's items and scoring instructions without any modifications. An experienced cross-cultural adaptation expert collaborated with the two translators to merge their translations into a unified version. Following that, two other English-speaking individuals with no medical background independently retranslated the preliminary unified version back into English. Back translation is an effectiveness verification process aimed at ensuring that the translated version accurately conveys the same item content as the original version. This step frequently highlights any ambiguities or unclear phrasing in the translation [36]. To further refine the simplified Chinese version of the CSI, a pretest was conducted with 50 elderly patients suffering from end-stage KOA. Their feedback was collected and considered during the reconciliation process, comparing the back-translated version with the original version. Subsequently, all researchers involved in the study deliberated upon the testing issues and developed the final version of the simplified Chinese CSI (CSI-CV).

Participants

Between July 2021 and December 2022, patients with end-stage KOA who were scheduled to undergo TKA were recruited from the Department of Knee Joint Surgery at Honghui Hospital in Xi'an City, Shaanxi Province, China. The inclusion criteria for this study were as follows: (a) patients older than 18 years old with end-stage KOA who were scheduled to undergo primary unilateral TKA; (b) whose cognitive level meets the requirements for completing the questionnaire; (c) who were fluent

Xu *et al. Journal of Orthopaedic Surgery and Research*   (2023) 18:960

Page 3 of 11

in Mandarin at a conversational level; and (d) who consented to participate. Exclusion criteria were: (a) patients with a history of other vascular, nerve, muscle, and bone diseases that affect movement or produce pain symptoms, such as hemiplegia, fractures, ligament injuries, lower extremity vascular injuries, etc.; (b) Patients who have previously undergone TKA; (c) patients with serious diseases that affect daily life, such as coronary heart disease, asthma, mental illness, etc.

The self-assessment questionnaires were administered by a trained interviewer who instructed the participants to independently complete the questionnaire before TKA. After receiving the completed questionnaires, a thorough review was conducted to identify any missing items. In instances where items were found to be missing, participants were kindly requested to provide the necessary answers [37]. To ensure consistency, standardized instructions were given to participants regarding how to complete the missing items [22]. To evaluate test–retest reliability, 100 patients from the first interview were randomly selected and were asked to complete the CSI-CV again within an interval of 1 weeks, before TKA.

Questionaries

All patients were required to complete the questionnaires as briefly described below.

Demographic information

Every participant was required to fill out the general demographic information questionnaire, which included age, body mass index, gender, employment status, living situation and educational level.

The CSI-CV

The CSI-CV consists of two sections: Part A and Part B [19]. Part A evaluates 25 symptom items. Participants rate the frequency of each symptom using a Likert scale ranging from 0 (never) to 4 (always), resulting in a total possible score of 100. Higher scores indicate a greater self-reported symptom burden. To aid clinical interpretation, five severity levels have been recommended: subclinical (0–29), mild (30–39), moderate (40–49), severe (50–59), and extreme (60–100) [38].

Part B is not scored and focuses on assessing 10 CSS-related diagnoses. Participants are asked two questions: (1) whether they have been previously diagnosed with each of these disorders by a doctor, and (2) the year of diagnosis.

The EuroQol five-dimensional questionnaire (EQ-5D)

The EQ-5D is a self-administered measurement instrument used to assess health-related quality of life. It comprises five domains (mobility, self-care, functional activity, pain/discomfort, and anxiety/depression) and is measured on a five-grade scale: no difficulties, slight difficulties, moderate difficulties, severe difficulties, and extremely severe difficulties [39, 40].

The brief pain inventory (BPI)

The BPI consists of two main scores: the pain severity score and the pain interference score [41]. The pain severity score is determined by four items that measure the patient's "most severe", "least severe" and "average" pain experienced in the past 24 h, as well as their current pain at the time of completing the questionnaire. Each item is rated on a scale of 0 to 10, ranging from "no pain" to "the most severe pain imaginable".

The pain interference score is calculated based on seven items that evaluate the extent to which pain affects various aspects of life. Each item is rated on a scale of 0 to 10, ranging from "no interference" to "complete interference".

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)

The WOMAC is divided into three domains: stiffness (two items), pain (five items), and physical function (17 items) [42]. Each item is rated on a scale of 0 to 10. The scores from the three domains are then combined to generate a total score, with higher scores indicating increased pain, stiffness, and impaired function.

Sample size determination

To determine the appropriate sample size, we followed the recommendations for conducting factor analysis. These recommendations suggest having 4 to 10 participants per item [43] and a total sample size of more than 100 participants [44]. Therefore, the final sample size of this study was determined to be ≥ 250 cases.

Statistical analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the participants, with the mean and SD calculated for continuous variables, and percentages calculated for categorical variables. The Kolmogorov–Smirnov test was used to assess the normality of the CSI-CV, EQ-5D, WOMAC, and BPI total scores. T-tests and one-way analysis of variance (ANOVA) with Bonferroni correction were employed to compare CSI-CV scores across subjects with different characteristics. This analysis aimed to assess the discriminant validity of the scale. All statistical analyses were conducted using SPSS 24.0 (Chicago, IL). The significance level was set at 0.05.

Xu *et al. Journal of Orthopaedic Surgery and Research* (2023) 18:960

Page 4 of 11

Structural validity

Since the factorial structure of the CSI has been shown to vary in different language versions [20–30], structural validity of the CSI-CV was investigated with an exploratory approach to assess the number of factors. The adequacy for these analyses was calculated by the Kaiser–Meyer–Olkin test and Bartlett's test of sphericity. An exploratory factor analysis (EFA) was conducted with the maximum likelihood method using a promax rotation. Factors were considered for eigenvalues > 1.0. The cut-off for the loadings should be set at 0.4 [45].

Criterion validity

The Pearson correlation coefficient was used to test the criterion validity of the CSI-CV with the EQ-5D, WOMAC and BPI. The correlation levels were set as follows: > 0.81, very strong correlation; 0.61–0.80, strong correlation; 0.41–0.60, moderate correlation; 0.21–0.40, weak correlation; and < 0.20, none or very weak correlation [46]. Before this analysis, based on assessment of the content of the items on the scales, we hypothesized that the CSI-CV scores correlated moderately with the total scores of the EQ-5D, WOMAC and BPI.

Internal consistency and test–retest reliability

Internal consistency indicates how closely related a set of items is as a group, which is usually measured by Cronbach's α coefficients. The coefficient α was set as follows: < 0.70, poor or unacceptable; 0.70–0.79, fair; 0.80–0.89, good; and ≥ 0.90, excellent [47]. Test–retest reliability was assessed using the intraclass correlation coefficient (ICC), which was derived from a 2-way analysis of variance in a random effect model. ICC values between 0.5 and 0.75 indicated moderate reliability, values between 0.75 and 0.9 indicated good reliability, and values greater than 0.9 suggested excellent reliability [48]. Guttman's split-half reliability coefficients were calculated to evaluate scale reliability and equivalence [37]. It is recommended that the interval between repeated measurements should be 1–2 weeks [49]. We decided to send the questionnaire again after an interval of 7 days.

Item screening

Items were screened based on their factor loadings of item scores and Cronbach's α coefficient. Item deletion was contemplated if the item's factor loading was less than 0.4, and the Cronbach's α coefficient of the entire scale increased after removing the item compared to before its removal [37].

Measurement error

Standard error of measurement (SEM) is an indicator of absolute reliability [49]. The most common calculation method for this statistic is the following equation: $SEM = SD \cdot \sqrt{(1 - R)}$, SD = the sample standard deviation, and R = the calculated ICC [50].

Smallest detectable change

The smallest detectable change (SDC) reflects the smallest within-person change in score, calculated using the formula $SDC_{(95\% \, CI)} = 1.96 \cdot \sqrt{2} \cdot SEM$ [49].

Feasibility

Each participant was queried about any challenges encountered while completing the questionnaire. The feasibility was assessed by considering the percentage of participants who did not respond to certain items, as well as the overall time taken to complete the questionnaire.

Results

Participants

A total of 325 patients were included in the study. The demographic data of all the participants are shown in Table 1.

Cross-cultural adaptation and Item screening results

The forward and backward translations of the CSI into simplified Chinese were successfully completed, as described in Additional file 1, without encountering any major issues. All item's factor loadings were above 0.4

Table 1 Demographic data of participants

Items	Participants ($n = 325$)
Age (SD, range)	65.6 years (6.5, 45.0 to 79.0)
Body mass index (SD, range)	26.1 kg/m^2 (2.9, 19.0 to 32.0)
Gender	
Male	96 (29.5%)
Female	229 (70.5%)
Employment status	
In work	210 (64.6%)
Be unemployed	20 (6.2%)
Retired	95 (29.2%)
Living situation	
Living alone	80 (24.6%)
With spouse	220 (67.7%)
With children	25 (7.7%)
Education	
Primary school or below	138 (42.5%)
Middle school	122 (37.5%)
High school or above	65 (20.0%)

SD standard deviation

Table 2 Prevalence rates of CS severity levels and frequency of diagnoses

CSI-CV score	N (%)
Subclinical (0–29)	168 (51.7)
Mild (30–39)	119 (36.6)
Moderate (40–49)	18 (5.5)
Severe (50–59)	17 (5.2)
Extreme (> 60)	3 (0.9)
Diagnoses	
Restless leg syndrome	1 (0.3)
Chronic fatigue syndrome	2 (0.6)
Fibromyalgia	6 (1.8)
Temporomandibular joint disorder	0 (0)
Migraine or tension headaches	5 (1.5)
Irritable bowel syndrome	4 (1.2)
Multiple chemical sensitivities	1 (0.3)
Neck injury (including whiplash)	4 (1.2)
Anxiety or panic attacks	4 (1.2)
Depression	18 (5.5)

CS central sensitization, *CSI-CV* simplified Chinese version of the Central Sensitization Inventory

(Table 3). Additionally, the Cronbach's α coefficient for the scale did not increase after removing any item. Therefore, no item needed to be removed following the screening process.

Prevalence

The CSI scores among the 325 patients ranged from 8 to 62, with a mean of 29.6 (SD = 10.1). Of the 325 patients, 168 patients indicated subclinical, 119 patients indicated mild, and 38 patients indicated moderate or higher severity. As shown in Table 2, of the total 325 patients, 35 (10.8%) patients were diagnosed with CS-related diseases. Patients diagnosed with only one CSS (25 patients, 47.2 ± 6.9) or 2 CSSs (10 patients, 54.4 ± 4.9) scored higher on the CSI than those with no CSS diagnosis (290 patients, 27.2 ± 7.5; $P < 0.01$).

Structural validity

The results of the Kaiser–Meyer–Olkin test (0.784) and the Bartlett's test of sphericity ($P < 0.001$) confirmed that the data was suitable for factor analysis. EFA and screen plot (Fig. 1) resulted in a five-factor model. The eigenvalues of the Factor 1 to Factor 5 were 6.58, 5.62, 2.70, 2.10 and 1.83, and the variance contribution rates of the Factor 1 to Factor 5 were 26.32%, 22.49%, 10.80%, 8.38%
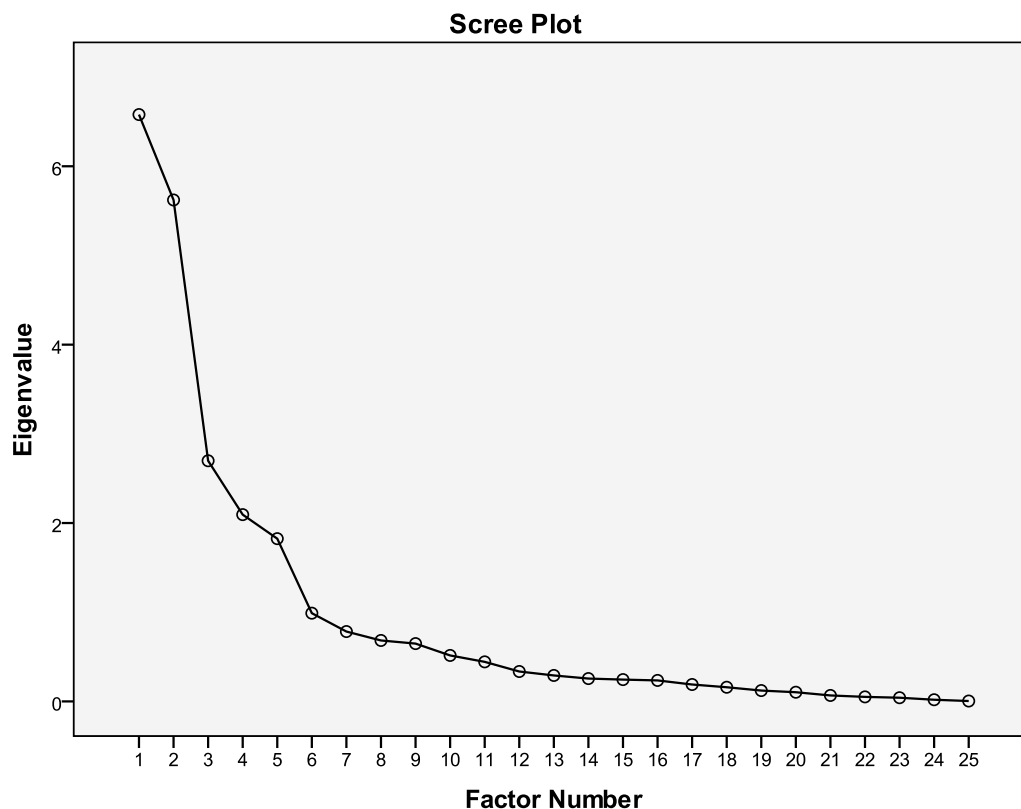

Fig. 1 Scree plot of exploratory factor analysis

Table 3 Factor loadings of the EFA with promax rotation

Item no.	Question	F1	F2	F3	F4	F5	Original version [19]	Hongkong version [23]
5	Diarrhea/constipation	0.939					F3	Not loading
16	Sad or depressed	0.938					F1	F1
6	Need help with daily activity	0.935					F3	Not loading
15	Stress makes symptoms worse	0.930					F1	Not loading
13	Difficulty concentrating	0.929					F1	F1
3	Anxiety attacks	0.908					F1	F1
24	Trauma as a child	0.768					F1	Bladder and teeth grinding disorders
23	Poor memory	0.697					F1	Concentration and memory problem
19	Pain in jaw		0.955				F2	Not loading
7	Sensitive to bright lights		0.927				F2	Hypersensitivity syndrome
4	Grind/clench teeth		0.922				F2	Bladder & teeth grinding disorders
10	Headaches		0.896				F2	Not loading
17	Low energy			0.854			F3	Concentration and memory problem
2	Muscles stiff/achy			0.769			F3	F3
14	Skin problems			0.709			F3	Not loading
20	Certain smells make dizzy			0.676			F2	Not loading
9	Pain all over body			0.591			F3	F3
18	Tension neck and shoulder			0.512			F3	F3
11	Bladder/urination pain				0.907		F4	Bladder & teeth grinding disorders
25	Pelvic pain				0.896		F4	Not loading
21	Urinate frequently				0.822		F4	Hypersensitivity syndrome
22	Restless legs					0.857	F3	Not loading
12	Do not sleep well					0.807	F3	Not loading
8	Easily tired with physical activity					0.741	F3	F3
1	Unrefreshed in morning					0.565	F3	Not loading

EFA exploratory factor analysis, *F1* Emotional Distress, *F2* Headache and Jaw Symptoms, *F3* Physical Symptoms, *F4* Urological Symptoms, *F5* Fatigue and Sleep Problems

and 7.30%, respectively. The cumulative variance contribution rate was 75.3%. The factors matrix is presented in Table 3. Items 3, 5, 6, 13, 15, 16, 23 and 24 were loaded on factor 1, which was named "Emotional Distress". Factor 2 consisted of items 4, 7, 10 and 19, and was named "Headache and Jaw Symptoms". Factor 3 consisted of items 2, 9, 14, 17, 18 and 20, and was named "Physical Symptoms". Factor 4 consisted of items 11, 21 and 25, and was named "Urological Symptoms". Factor 5, consisting of items 1, 8, 12, and 22, exhibited a significant association with fatigue and sleep-related difficulties. Consequently, we appropriately labeled this factor as "Fatigue and Sleep Problems".

Criterion validity

The correlations between the CSI-CV and EQ-5D, BPI and WOMAC were showed in Table 4. As hypothesized, the results revealed positive correlations between CSI-CV scores and the scores of EQ-5D, BPI, and WOMAC.

Table 4 Results of bivariate correlations between CSI-CV and related scales

Variance	Mean (SD)	Correlation coefficient	*P*-value
Health-related QOL (EQ-5D)	13.1 (3.6)	0.576	< 0.001
BPI	43.4 (17.0)	0.506	< 0.001
WOMAC	91.5 (39.1)	0.466	< 0.001

SD standard deviation

Internal consistency and test–retest reliability

The CSI-CV exhibited a strong level of internal consistency (Cronbach's α = 0.83), with individual factor scores ranging from 0.76 to 0.98. Furthermore, the Guttman split-half reliability coefficient was determined to be 0.88, with individual factor scores ranging from 0.59 to 0.92. These findings indicate that each item within the measure showed significant correlation with the overall factor being assessed. Test–retest reliability was excellent with

Xu *et al. Journal of Orthopaedic Surgery and Research*   (2023) 18:960

Page 7 of 11

Table 5 Cronbach's α, intraclass correlation coefficients, and Guttman split-half coefficient of test–retest reliability

Item no.	Questions	Cronbach's α	ICC	Guttman split-half coefficient
Sum	Total score	0.83	0.965	0.88
Factor 1	Emotional Distress	0.96	0.965	0.92
Factor 2	Headache and Jaw Symptoms	0.98	0.948	0.98
Factor 3	Physical Symptoms	0.79	0.910	0.79
Factor 4	Urological Symptoms	0.86	0.971	0.78
Factor 5	Fatigue and Sleep Problems	0.76	0.966	0.71

ICC intraclass correlation coefficients

an ICC of 0.965. All factors of the CSI had an excellent ICC greater than 0.90. The SEM was 1.89 points (Table 5).

SDC

The SDC, representing the smallest change of value for a scale that could be considered an actual change rather than measurement of error, was 5.22 points.

Feasibility

All participants completed Part A of the CSI-CV without any difficulties, and there were no issues with missing or multiple answers. However, it is worth noting that some patients experienced difficulties in completing Part B. These challenges were attributed to their limited familiarity with certain diagnoses. The average time for completing the questionnaires was 6.4 ± 1.3 min.

Discriminant validity

There was no significant difference in CSI scores between two groups of patients of different ages. The total scores of the CSI-CV differed significantly according to gender, employment status, living situation and education. The results indicated that women scored significantly higher than men on the CSI-CV scale. Additionally, unemployed individuals obtained significantly higher scores compared to working individuals and retirees. Furthermore, individuals living alone achieved significantly higher scores than those living with their spouse or children. Lastly, individuals with lower education levels obtained significantly higher scores compared to those with higher education levels (Table 6).

Discussion

The objective of this study was to develop a culturally adapted simplified Chinese version of the CSI and assess its psychometric properties among patients undergoing TKA for KOA. Among these patients, there is considerable variation in the presence and intensity of CS. Previous research has shown that CS predicts poor treatment outcomes in TKA patients [6–10]. This emphasizes the critical importance of individualized assessments to precisely evaluate each patient's condition [51]. Such screening can

Table 6 CSI-CV scores in different populations

Factor		N	Total score of CSI	*P* value
Age	≥ 70 years old	121	30.0 ± 9.4	0.545
	< 70 years old	204	30.5 ± 10.5	
Gender	Male	96	27.5 ± 8.1[a]	0.018
	Famale	229	30.4 ± 10.8[a]	
Employment status	In work	210	30.2 ± 9.1[a]	< 0.001
	Be unemployed	20	43.4 ± 10.7[a]	
	Retired	95	25.3 ± 9.3[a]	
Living situation	Living alone	80	31.6 ± 11.1[a]	0.035
	With spouse	220	29.2 ± 9.9	
	With children	25	26.0 ± 7.3[a]	
Education	Primary school or below	138	31.9 ± 10.1[a]	0.001
	Middle school	122	27.5 ± 10.3[a]	
	High school or above	65	28.4 ± 9.0	

Values are expressed as means ± standard deviation. [a] Items with significant differences. *P* value represents the comparison result of T-tests or ANOVA with Bonferroni correction

Xu *et al. Journal of Orthopaedic Surgery and Research*   (2023) 18:960

Page 8 of 11

provide valuable information that enables early intervention [13] before or intensive treatment after TKA. Furthermore, by identifying CS in KOA patients before surgery, surgeons can engage in shared decision-making with patients, discussing the potential implications of CS on their postoperative recovery and setting realistic expectations [5, 52, 53].

In our study, EFA revealed a 5-factor model for the CSI-CV, which aligns with the findings from the Japanese [20] and French [31] versions. However, the English version demonstrated a 4-factor model [19], the Spanish version showed a 1-factor model [27], and the Korean version resulted in a 6-factor model [30].

Table 3 displays the factor loading of each item across different versions of the CSI. The observed variations in the factor structure between this study and previous studies conducted with other language versions [19, 27, 30] underscore the influence of cultural and linguistic factors on the conceptualization of CS in different populations [20, 30]. These findings emphasize the importance of adapting assessment tools to specific cultural settings to ensure their validity and reliability in measuring the construct of interest [20].

The ICC indicated that the CSI-CV has excellent reliability, at 0.965. The results corroborated earlier reports on English (0.817) [19], Japanese (0.85) [20], Korean (0.941) [30], French (0.91) [31] and Brazilian (0.91) [32] versions. In addition, the CSI-CV demonstrated good criterion validity when compared to the BPI, the WOMAC, and the EQ-5D. The level of correlation observed was similar to that of the Korean and Japanese versions of the CSI [20, 30]. All of these findings collectively support the strong psychometric properties of the CSI-CV.

The CSI-CV exhibited a high level of internal consistency with a Cronbach's alpha of 0.83. Additionally, the 25 sub-items displayed high Cronbach's α values ranging from 0.82 to 0.83. These values were consistent with the English (0.87) [19], Japanese (0.89) [20], Korean (0.94) [30], Spanish (0.87) [27], and Italian (0.87) [29] versions. This indicates that the CSI remains stable internal consistency across different cultural contexts.

Only a few of the initial validation studies [22, 25, 26] computed the SEM and the SDC. The SEM values ranged from 0.31 [25] to 4.14 [22], while the SDC values ranged from 0.86 [25] to 11.48 [22]. In this study, the values for SEM and SDC are 1.89 and 5.22, respectively, falling between the two ranges mentioned. The differences in these values could be attributed to specific factors. In the Nepali study [25], participants were provided with baseline measurement values during the follow-up, and the CSI was administered face-to-face. These factors may have influenced participant responses and introduced potential biases. Conversely, the longer interval between

measurements in the German study [22] could have minimized memory effects, potentially increasing the values of SEM and SDC. Based on the current findings, any change score greater than 5.2 units (out of 100) may be considered a true change for the CSI-CV.

In addition to its psychometric properties, the feasibility of the CSI-CV was also evaluated in this study. The time required to complete the CSI-CV was found to be relatively short, with participants spending an average of 6.4 ± 1.3 min to complete the questionnaire. The brevity of the CSI-CV allows for efficient administration, reducing participant burden and increasing the likelihood of compliance.

The CSI scores in the present study ranged from 8 to 62, with a mean of 29.6 ± 10.1. These scores were lower than those reported in Germany (43.6 ± 15.0) [22], Korea (33.4 ± 15.7) [30], Serbia (38.3 ± 15.7) [26], Italy (35.3 ± 14.6) [29], Brazil (45.4 ± 17.4) [32], and Hong Kong of China (36.4 ± 13.1) [23]. On the other hand, the scores in this study were higher compared to the Japan [20] and Nepal [25] studies. In addition, in the present study, the proportion of CSS diagnoses was found to be 10.8%, which is lower than the proportions reported in most studies conducted in other areas ranging from 13 [23] to 56% [29].

These variations in CSI scores and the prevalence of CSS diagnoses can be attributed to various factors, such as cultural, racial, and medical differences among the patient populations [51]. Cultural and societal attitudes towards mental health can influence patients' willingness to acknowledge and disclose their own mental sensitivities. In this study, the patients were recruited from underdeveloped inland areas in northwest China, where a relatively conservative social atmosphere may discourage individuals from openly admitting their mental health issues. Additionally, limited access to advanced medical resources has led to underdiagnosis of CSS in many patients. These disparities underscore the importance of exercising caution when interpreting scale scores in diverse cultural contexts, and suggest that the clinical threshold for identifying CS may need to be adjusted to accommodate the unique social environment in China [23].

Furthermore, it is important to note that the present study focused specifically on patients undergoing TKA due to KOA. This distinguishes it from previous studies that included a broader range of conditions such as musculoskeletal pain, fibromyalgia, and acute injury pain [20–30]. The specific patient population targeted in this study may have contributed to the observed differences in CSI-CV scores.

The CSI total score exhibits a substantial disparity among individuals with different demographic

Xu *et al. Journal of Orthopaedic Surgery and Research*   (2023) 18:960

Page 9 of 11

characteristics. Specifically, women tend to have significantly higher CSI scores compared to men, aligning with previous research findings indicating that women with acute pain are more likely to experience persisting pain [51, 54]. Furthermore, unemployed individuals, those living alone, and those with lower education levels also display higher CSI scores, likely due to the increased economic and social pressures they face. Consequently, it is imperative that healthcare professionals prioritize these specific groups and offer proactive measures, such as early interventions like Duloxetine [13, 55, 56] or Pregabalin [57–59] during the perioperative period.

Numerous limitations of the present study should be acknowledged. Firstly, all participants were recruited from a single hospital, predominantly representing patients in northwestern China. Given the vast land area of China, the generalizability of the findings to other regions of mainland China may be limited. Secondly, the assessment of CSS was based on self-report questionnaires, which introduces the potential for response bias. Thirdly, we did not directly measure CS using QST in our study. Further research is required to investigate the validation of the CSI-CV, which could involve incorporating QST as a complementary measure. Lastly, the study did not include healthy individuals, warranting future research to investigate whether the CSI-CV can effectively differentiate individuals with and without CS.

Conclusions

In conclusion, the linguistic translation and cultural adaptation of the CSI from the original English version to simplified Chinese were successfully completed, ensuring the equivalence of all items. The CSI-CV demonstrated strong psychometric properties, including reliability, validity, and ease of understanding. These findings provide robust evidence supporting the use of the CSI-CV as a reliable instrument for screening CS in Chinese-speaking patients with KOA prior to undergoing TKA.

Abbreviations

CSI-CV	Simplified Chinese version of the central sensitization inventory
KOA	Knee osteoarthritis
TKA	Total knee arthroplasty
EFA	Exploratory factor analysis
CS	Central sensitization
QST	Quantitative sensory testing
CSI	Central sensitization inventory
CSS	Central sensitivity syndromes
EQ-5D	The EuroQol Five-Dimensional Questionnaire
BPI	Brief Pain Inventory
WOMAC	The Western Ontario and McMaster Universities Osteoarthritis Index
ANOVA	One-way analysis of variance
ICC	Intraclass correlation coefficient
SEM	Standard error of measurement
SDC	Smallest detectable change
SD	Standard deviation

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The medical ethics committee of Honghui Hospital approved this prospective observational study (No. 202105010). All experiments were performed in accordance with the Declaration of Helsinki. All participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Health Statistics, Faculty of Preventive Medicine, Fourth Military Medical University, No.169. Changle West Rd, Xi'an, Shaanxi, China. [2]Department of Knee Joint Surgery, Honghui Hospital, Xi'an Jiaotong University, No. 555 Youyi East Rd, Xi'an, Shaanxi, China. [3]Department of Orthopedics, 989th Hospital of PLA, No. 2 Huaxia West Rd, Luoyang, Henan, China.

References

1. Zhou G, Zhao M, Wang X, et al. Demographic and radiographic factors for knee symptoms and range of motion in patients with knee

Xu *et al. Journal of Orthopaedic Surgery and Research*   (2023) 18:960

Page 10 of 11

osteoarthritis: a cross-sectional study in Beijing, China. BMC Musculoskelet Disord. 2023;24(1):378.

2. Chen H, Wu J, Wang Z, et al. Trends and patterns of knee osteoarthritis in China: a longitudinal study of 17.7 million adults from 2008 to 2017. Int J Environ Res Public Health. 2021;18(16):8864.

3. DeFrance MJ, Scuderi GR. Are 20% of patients actually dissatisfied following total knee arthroplasty? A systematic review of the literature. J Arthroplasty. 2023;38(3):594–9.

4. Kim MS, Kim JJ, Kang KH, et al. Diagnosis of central sensitization and its effects on postoperative outcomes following total knee arthroplasty: a systematic review and meta-analysis. Diagnostics (Basel). 2022;12(5):1248.

5. Nijs J, Leysen L, Vanlauwe J, et al. Treatment of central sensitization in patients with chronic pain: time for change? Expert Opin Pharmacother. 2019;20(16):1961–70.

6. Kazarian GS, Anthony CA, Lawrie CM, et al. The impact of psychological factors and their treatment on the results of total knee arthroplasty. J Bone Joint Surg Am. 2021;103(18):1744–56.

7. Sasaki E, Kasai T, Araki R, et al. Central sensitization and postoperative improvement of quality of life in total knee and total hip arthroplasty: a prospective observational study. Prog Rehabil Med. 2022;7:20220009.

8. Koh HS, Choi YH, Park D, et al. Association between pain catastrophizing and central sensitization among patients with severe knee osteoarthritis awaiting primary total knee arthroplasty. Orthopedics. 2022;45(4):197–202.

9. Kim MS, Koh IJ, Sohn S, et al. Central sensitization is a risk factor for persistent postoperative pain and dissatisfaction in patients undergoing revision total knee arthroplasty. J Arthroplasty. 2019;34(8):1740–8.

10. Kim MS, Koh IJ, Choi KY, et al. Minimal clinically important differences for patient-reported outcomes after TKA depend on central sensitization. J Bone Joint Surg Am. 2021;103(15):1374–82.

11. Koh IJ, Kang BM, Kim MS, et al. How does preoperative central sensitization affect quality of life following total knee arthroplasty? J Arthroplasty. 2020;35(8):2044–9.

12. Kim SH, Yoon KB, Yoon DM, et al. Influence of centrally mediated symptoms on postoperative pain in osteoarthritis patients undergoing total knee arthroplasty: a prospective observational evaluation. Pain Pract. 2015;15(6):e46-53.

13. Koh IJ, Kim MS, Sohn S, et al. Duloxetine reduces pain and improves quality of recovery following total knee arthroplasty in centrally sensitized patients: a prospective, randomized controlled study. J Bone Joint Surg Am. 2019;101(1):64–73.

14. Rankin J, Rudy-Froese B, Hoyt C, et al. Quantitative sensory testing protocols to evaluate central and peripheral sensitization in knee OA: a scoping review. Pain Med. 2022;23(3):526–57.

15. Zafereo J, Wang-Price S, Kandil E. Quantitative sensory testing discriminates central sensitization inventory scores in participants with chronic musculoskeletal pain: an exploratory study. Pain Pract. 2021;21(5):547–56.

16. den Boer C, Dries L, Terluin B, et al. Central sensitization in chronic pain and medically unexplained symptom research: a systematic review of definitions, operationalizations and measurement instruments. J Psychosom Res. 2019;117:32–40.

17. Soni A, Wanigasekera V, Mezue M, et al. Central sensitization in knee osteoarthritis: relating presurgical brainstem neuroimaging and PainDETECT-based patient stratification to arthroplasty outcome. Arthritis Rheumatol. 2019;71(4):550–60.

18. Treede RD. The role of quantitative sensory testing in the prediction of chronic pain. Pain. 2019;160(Suppl 1):S66–9.

19. Mayer TG, Neblett R, Cohen H, et al. The development and psychometric validation of the central sensitization inventory. Pain Pract. 2012;12(4):276–85.

20. Tanaka K, Nishigami T, Mibu A, et al. Validation of the Japanese version of the central sensitization inventory in patients with musculoskeletal disorders. PLoS ONE. 2017;12(12): e188719.

21. Turczyn P, Kosińska B, Janikowska-Hołoweńko D, et al. Translation and cross-cultural adaptation of the Polish central sensitization inventory. Reumatologia. 2019;57(3):129–34.

22. Klute M, Laekeman M, Kuss K, et al. Cross-cultural adaptation and validation of the German central sensitization inventory (CSI-GE). BMC Musculoskelet Disord. 2021;22(1):708.

23. Feng B, Hu X, Lu WW, et al. Cultural validation of the Chinese central sensitization inventory in patients with chronic pain and its predictive ability of comorbid central sensitivity syndromes. J Pain Res. 2022;15:467–77.

24. Kregel J, Vuijk PJ, Descheemaeker F, et al. The Dutch central sensitization inventory (CSI): factor analysis, discriminative power, and test-retest reliability. Clin J Pain. 2016;32(7):624–30.

25. Sharma S, Jha J, Pathak A, et al. Translation, cross-cultural adaptation, and measurement properties of the Nepali version of the central sensitization inventory (CSI). BMC Neurol. 2020;20(1):286.

26. Knezevic A, Neblett R, Jeremic-Knezevic M, et al. Cross-cultural adaptation and psychometric validation of the Serbian version of the central sensitization inventory. Pain Pract. 2018;18(4):463–72.

27. Cuesta-Vargas AI, Roldan-Jimenez C, Neblett R, et al. Cross-cultural adaptation and validity of the Spanish central sensitization inventory. Springerplus. 2016;5(1):1837.

28. Bilika P, Neblett R, Georgoudis G, et al. Cross-cultural adaptation and psychometric properties of the Greek version of the central sensitization inventory. Pain Pract. 2020;20(2):188–96.

29. Chiarotto A, Viti C, Sulli A, et al. Cross-cultural adaptation and validity of the Italian version of the central sensitization inventory. Musculoskelet Sci Pract. 2018;37:20–8.

30. Kim MS, Koh IJ, Kim CK, et al. Cross-cultural adaptation and validation of the Korean version of the central sensitization inventory in patients undergoing total knee arthroplasty for knee osteoarthritis. PLoS ONE. 2020;15(12): e242912.

31. Pitance L, Piraux E, Lannoy B, et al. Crosscultural adaptation, reliability and validity of the French version of the central sensitization inventory. Manual Ther. 2016;25:e83–4.

32. Caumo W, Antunes LC, Elkfury JL, et al. The central sensitization inventory validated and adapted for a Brazilian population: psychometric properties and its relationship with brain-derived neurotrophic factor. J Pain Res. 2017;10:2109–22.

33. Yang L, Suttiwong J, Fu Y, et al. The simplified Chinese version of the Knee Injury and Osteoarthritis Outcomes Score (KOOS) in individuals with knee osteoarthritis for mainland China: the study of reliability and validity. J Patient Rep Outcomes. 2023;7(1):80.

34. Fu L, Hu Y, Lu Z, et al. Validation of the simplified Chinese version of the memorial symptom assessment scale-short form among cancer patients. J Pain Symptom Manag. 2018;56(1):113–21.

35. Guillemin F, Bombardier C, Beaton D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. J Clin Epidemiol. 1993;46(12):1417–32.

36. Beaton DE, Bombardier C, Guillemin F, et al. Guidelines for the process of cross-cultural adaptation of self-report measures. Spine. 2000;25(24):3186–91.

37. Zhang H, Yang X, Xu T, et al. Preliminary evaluation of the Chinese version of the Baby Eating Behaviour Questionnaire. Child Care Health Dev. 2021;47(5):627–34.

38. Neblett R, Hartzell MM, Mayer TG, et al. Establishing clinically relevant severity levels for the central sensitization inventory. Pain Pract. 2017;17(2):166–75.

39. Weng G, Hong Y, Luo N, et al. Comparing EQ-5D-3L and EQ-5D-5L in measuring the HRQoL burden of 4 health conditions in China. Eur J Health Econ. 2023;24(2):197–207.

40. Luo N, Liu G, Li M, et al. Estimating an EQ-5D-5L value set for China. Value Health. 2017;20(4):662–9.

41. Poquet N, Lin C. The brief pain inventory (BPI). J Physiother. 2016;62(1):52.

42. Clement ND, Bardgett M, Weir D, et al. What is the minimum clinically important difference for the WOMAC Index after TKA? Clin Orthop Relat Res. 2018;476(10):2005–14.

43. Wilson C, Voorhis SV, Morgan B. Understanding power and rules of thumb for determining sample sizes. Tutor Quant Methods Psychol. 2007;3(2):43–50.

44. Terwee CB, Mokkink LB, Knol DL, et al. Rating the methodological quality in systematic reviews of studies on measurement properties: a scoring system for the COSMIN checklist. Qual Life Res. 2012;21(4):651–7.

45. Costello AB, Osborne J. Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. Pract Assess Res Eval. 2005;10(1):7.

46. Cao S, Liu N, Li L, et al. Simplified Chinese version of University of California at Los Angeles Activity Score for arthroplasty and

arthroscopy: cross-cultural adaptation and validation. J Arthroplasty. 2017;32(9):2706–11.

47. Cicchetti DV. Guidelines, criteria, and rules of thumb for evaluating nor-med and standardized assessment instruments in psychology. Psychol Assess. 1994;6(4):284–90.

48. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016;15(2):155–63.

49. Terwee CB, Bot SDM, Boer MRD, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol. 2007;60(1):34–42.

50. Atkinson DG, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med. 1998;26(4):217–38.

51. Nijs J, George SZ, Clauw DJ, et al. Central sensitisation in chronic pain conditions: latest discoveries and their potential for precision medicine. Lancet Rheumatol. 2021;3(5):e383–92.

52. Arendt-Nielsen L, Morlion B, Perrot S, et al. Assessment and manifestation of central sensitisation across different chronic pain conditions. Eur J Pain. 2018;22(2):216–41.

53. Zhang A, Lee YC. Mechanisms for joint pain in rheumatoid arthritis (RA): from cytokines to central sensitization. Curr Osteoporos Rep. 2018;16(5):603–10.

54. Holley AL, Wilson AC, Palermo TM. Predictors of the transition from acute to persistent musculoskeletal pain in children and adolescents: a prospective study. Pain. 2017;158(5):794–801.

55. Kim MS, Koh IJ, Sung YG, et al. Preemptive duloxetine relieves post-operative pain and lowers wound temperature in centrally sensitized patients undergoing total knee arthroplasty: a randomized, double-blind, placebo-controlled trial. J Clin Med. 2021;10(13):2809.

56. Yuan M, Tang T, Ding Z, et al. Analgesic effect of perioperative duloxetine in patients after total knee arthroplasty: a prospective, randomized, double-blind, placebo-controlled trial. BMC Musculoskelet Disord. 2022;23(1):242.

57. Akdoğan M, Ütebey G, Atilla HA, et al. Effects of preoperative pregabalin on postoperative pain control in total knee arthroplasty surgery. J Inves-tig Surg. 2021;34(8):848–52.

58. Dong J, Li W, Wang Y. The effect of pregabalin on acute postoperative pain in patients undergoing total knee arthroplasty: a meta-analysis. Int J Surg. 2016;34:148–60.

59. Yajima M, Sugimoto M, Sugimura YK, et al. Acetaminophen and pre-gabalin attenuate central sensitization in rodent models of nociplastic widespread pain. Neuropharmacology. 2022;210: 109029.

Publisher's Note