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Validity, Reliability, and Differential Item Functioning of English and French Versions of the 10-Item Connor-Davidson Resilience Scale in Systemic Sclerosis: A Scleroderma Patient-Centered Intervention Network Cohort Study

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Validity, Reliability, and Differential Item Functioning of English and French Versions of the 10-Item Connor-Davidson Resilience Scale in Systemic Sclerosis: A Scleroderma Patient-Centered Intervention Network Cohort Study

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Objective. Some individuals with systemic sclerosis (SSc) report positive mental health, despite severe disease manifestations, which may be associated with resilience, but no resilience measure has been validated in SSc. This study was undertaken to assess the validity, reliability, and differential item functioning (DIF) between English- and French-language versions of the 10-item Connor-Davidson Resilience Scale (CD-RISC-10) in SSc.

Methods. Eligible participants were enrolled in the Scleroderma Patient-centered Intervention Network Cohort and completed the CD-RISC-10 between August 2022 and January 2023. We used confirmatory factor analysis (CFA) to evaluate the CD-RISC-10 factor structure and conducted DIF analysis across languages with Multiple Indicators Multiple Causes models. We tested convergent validity with another measure of resilience and measures of self-esteem and depression and anxiety symptoms. We assessed internal consistency and test-retest reliability using Cronbach's alpha and intraclass correlation coefficient (ICC).

Results. A total of 962 participants were included in this analysis. CFA supported a single-factor structure (Tucker-Lewis index = 0.99, comparative fit index = 0.99, root mean square error of approximation = 0.08 [90% confidence interval (90% CI) 0.07, 0.09]). We found no meaningful DIF. Internal consistency was high ($\alpha = 0.93$ [95% CI 0.92, 0.94]), and we found that correlations with other measures of psychological functioning were moderate to large ($|r| = 0.57$ – 0.78) and confirmed study hypotheses. The scale showed good 1–2-week test-retest reliability (ICC 0.80 [95% CI 0.75, 0.85]) in a subsample of 230 participants.

Conclusion. The CD-RISC-10 is a valid and reliable measure of resilience in SSc, with score comparability across English and French versions.

INTRODUCTION

Systemic sclerosis (SSc; scleroderma) is a rare, chronic autoimmune disorder characterized by vascular abnormalities

and fibrosis of the skin and internal organs, including the gastrointestinal (GI) tract, lungs, heart, and kidneys (1,2). Disease manifestation is heterogeneous, and the disease course is unpredictable (1,3). Researchers have estimated the standardized mortality rate

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SIGNIFICANCE & INNOVATIONS

- Some individuals with severe systemic sclerosis (SSc) burden and high levels of pain, fatigue, and sleep disturbance report positive mental health, which may be associated with resilience.
- This is the first study to validate a resilience scale in SSc and the first to compare measurements for English and French versions of the 10-item Connor-Davidson Resilience Scale (CD-RISC-10).
- The CD-RISC-10 had good reliability and validity, and measurement properties were comparable for English- and French-language participants.
- The CD-RISC-10 can be used to evaluate resilience in individuals with SSc, including in international studies with English- and French-language participants.

to be almost 3 times as high as sex- and age-matched peers (4), and individuals with SSc report substantially lower quality of life compared to those with other rheumatic diseases (5) and the general population (6). Symptoms often include impaired function and mobility, breathing problems, GI symptoms, fatigue, pain, pruritus, sleep disturbances, body image distress from disfigurement (e.g., skin tightening, pigment changes, hand contractures, telangiectasias), and reduced mental health (3,7–10).

A recent cross-sectional study (Wojeck et al, unpublished observations) of >2,000 participants in the Scleroderma Patient-centered Intervention Network (SPIN) Cohort found that 5 latent classes characterized patterns of patient-reported outcomes, including fatigue, sleep, pain, anxiety symptoms, and depression symptoms (members of the SPIN investigators are shown in Appendix A). Participants were separated into four classes: low, normal, high, and very high symptom severity, and levels of patient-reported symptoms in these classes closely correlated with the severity or presence of specific disease manifestations. The fifth class, however, identified individuals with high fatigue, sleep, and pain symptoms but low mental health problems, even though members of this class had underlying disease burdens similar to the high class. The difference between individuals in this class and others with similarly severe SSc might be associated with resilience (11,12).

Research has defined resilience as positive adjustment or the ability to preserve or restore mental health despite adverse circumstances (13,14). Psychological factors associated with resilience include self-efficacy, self-esteem, optimism, hardiness, determination, an internal locus of control, and a sense of self-empowerment and mastery (11,12). Individuals with chronic medical conditions who score higher on resilience measures report lower anxiety and depression symptoms and better quality of life

(11,12). In addition, researchers have found that intervention strategies that enhance resilience and adaptive coping improve psychological adaptation and reduce symptom burden (15).

No resilience measure has been validated in scleroderma, and there are no studies of resilience in individuals with SSc. A methodologic review (16) of tools to measure resilience reported that >15 scales had been developed and that, based on a set of predefined criteria to assess overall quality and usability, the 25-item Connor-Davidson Resilience Scale (CD-RISC) (17) was among 3 measures with the strongest ratings for measurement properties. It was the only measure that researchers had successfully used to evaluate change in response to an intervention. Researchers originally developed the CD-RISC in English and simultaneously validated it in a general population sample, primary care outpatients, mixed psychiatry outpatients, anxiety patients, and individuals with post-traumatic stress disorder (17). The 10-item short version of the scale, the CD-RISC-10, which researchers initially validated in English-speaking undergraduate students (18), reduces burden on study participants and has similar measurement properties as the CD-RISC (16,19). Additionally, compared to the original CD-RISC, the factor structure of the 10-item version may be more stable across studies and different cultural groups (20). The CD-RISC-10 has been validated in multiple languages (21,22), including French (21), and is therefore well-suited for use in international cohorts.

The objectives of the present study were to evaluate the validity and reliability of the 10-item CD-RISC-10 for use in SSc by 1) testing its unidimensional structure; 2) performing a differential item functioning (DIF) analysis to identify possible differences in measurement properties between English- and French-language respondents and assess the magnitude of any DIF; 3) evaluating internal consistency and test-retest reliability; and 4) evaluating convergent validity by comparing scores to another measure of resilience: the 14-item Resilience Scale (RS14) (23), a measure of self-esteem: the Rosenberg Self-Esteem Scale (24), and measures of depression and anxiety symptoms: Patient Reported Outcomes Measurement Information System (PROMIS) Anxiety 4a version 2.0 and PROMIS Depression 4a version 2.0 scales (25). For convergent validity, we hypothesized that the CD-RISC-10 would moderately to highly correlate with all other measures and that the magnitude of correlation with the RS14, another measure of resilience, would be the largest.

PATIENTS AND METHODS

We evaluated cross-sectional data collected from the regular SPIN Cohort assessments to evaluate English- (18) and French-

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language (21) versions of the CD-RISC-10 for factor structure, language-based DIF, internal consistency reliability, and convergent validity. We administered the CD-RISC-10 a second time to a subset of participants 1–2 weeks after their first assessment to assess test–retest validity. A protocol was published online prior to study initiation (<https://osf.io/dx3b6/>). We reported the study consistent with the COnsensus-based Standards for the selection of health status Measurement Instruments (COSMIN) reporting guideline for studies on properties of patient-reported outcome measures (26).

Participants and procedure. The SPIN Cohort (27,28) is a convenience sample of participants recruited from 47 sites in 7 countries (Australia, Canada, France, Mexico, Spain, the UK, and the US). To be eligible for the SPIN Cohort, participants must be ≥ 18 years old, fluent in English, French, or Spanish, have access to and be able to respond to questionnaires via the internet, and meet the 2013 American College of Rheumatology/EULAR criteria for SSc (29) verified by a physician at a SPIN site. Participants are invited to participate in the SPIN Cohort by attending physicians or nurse coordinators at recruiting sites. Site personnel obtain written informed consent, including consent to be contacted by the SPIN team about additional studies, and submit an electronic medical form to enrol participants. Participants then receive an email with a unique, secure link to complete baseline measurements online in English, French, or Spanish. Subsequent online assessments are conducted by SPIN at 3-month intervals (27,28). The study included SPIN participants who completed all study measures in English or French during a regular assessment between August 2022 and January 2023, when the CD-RISC-10 was included in the SPIN Cohort. We did not include Spanish-language participants in this study because there were not enough individuals to conduct all study analyses.

To examine test–retest reliability, we administered the CD-RISC-10 to a subsample of participants 1–2 weeks following routine cohort assessment. We invited English- and French-speaking SPIN Cohort participants who completed the CD-RISC-10 as part of their regular SPIN Cohort assessment by email 7 days later (30,31) to complete the scale a second time via the online survey website Qualtrics. Invited participants had access to the questionnaire for 7 days, and they completed the retest assessments between 7 and 14 days after the initial assessment. We sent a reminder email to nonresponders 4 days after the initial invitation. As an incentive, we randomly selected 10 questionnaire respondents to win an Amazon gift card worth \$100 CAD or the equivalent in their local currency. We emailed invitations until we reached our targeted sample size for test–retest reliability.

The SPIN Cohort study was approved by the Research Ethics Committee of the Centre intégré universitaire de santé et de services sociaux du Centre-Ouest-de-l'Île-de-Montréal (approval no. MP-05-2013-150) and by the ethics committees of all recruiting sites. The present study was approved as an amendment.

Measures. At baseline, SPIN Cohort participants report sociodemographic variables, including race or ethnicity, country, language, education, and marital status. Physician-reported data from the baseline data assessment included age, sex, height, weight, date of initial onset of non-Raynaud's phenomenon symptoms, SSc subtype, presence of GI involvement, digital ulcers anywhere on the fingers, current tendon friction rubs, presence of joint contractures, history of renal crisis, presence of pulmonary arterial hypertension, presence of interstitial lung disease, presence of primary biliary cirrhosis, and presence of overlap syndromes (rheumatoid arthritis, Sjögren's syndrome, systemic lupus erythematosus, idiopathic inflammatory myositis, autoimmune thyroid disease).

CD-RISC-10. CD-RISC-10 scores reflect multiple aspects of resilience, including flexibility, self-efficacy, regulation of emotion, optimism, and the ability to maintain focus under stress. Items assess the ability to tolerate and cope with experiences such as change, personal problems, illness, pressure, failure, and painful feelings (18). Item response options range from 0 (not true at all) to 4 (true nearly all the time). Participants respond to each statement in reference to the previous month. Evaluators score the scale by totalling item scores, resulting in possible scores of 0–40, with higher scores reflecting greater resilience. The correlation of the CD-RISC-10 with the 25-item CD-RISC was 0.92 in a sample of >500 undergraduate students (18). Researchers have validated a French version of the scale (21).

RS14. The 25-item Resilience Scale (RS25) was initially developed by researchers in a sample of older women who had recently experienced but successfully coped with a loss (e.g., loss of a spouse) (32). The scale received the second-highest score level in the review of resilience measures (16) and the highest possible rating for content and construct validity. The shortened form of the RS25, the RS14 (23), is based on a 1-factor structure and focuses on aspects of resilience such as self-reliance, purpose, equanimity, perseverance, and authenticity. Items are rated using a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Evaluators sum item scores to a total (possible range 14–98), and higher scores reflect greater resilience. Researchers have validated the RS14 in numerous populations. It exhibits similar measurement properties compared to the original Resilience Scale, including evidence of high reliability and good validity in clinical and nonclinical settings (23). The correlation of the RS14 with the original 25-item Resilience Scale was 0.97 in a sample of 776 middle-aged and older adults (23). A French version of the scale has been validated by researchers (33).

Rosenberg Self-Esteem Scale. The RSES (24) assesses self-esteem, which reflects confidence in one's abilities or worth. It measures both positive and negative feelings about oneself. Researchers originally developed the scale in a sample of high school juniors and seniors (24). Since then, the scale has been applied in studies across a wide range of samples and has

demonstrated high reliability and good validity (34). The scale contains 10 items rated on a 4-point Likert scale, with response options from 0 (strongly disagree) to 3 (strongly agree). Evaluators calculate scoring the scale by first reverse scoring the negatively worded items (items 2, 5, 6, 8, and 9) and then totalling item scores, resulting in a possible range of 0 to 30, with higher scores reflecting greater self-esteem. Researchers previously validated a French version of the scale (35).

PROMIS Depression 4a version 2.0 and PROMIS Anxiety 4a version 2.0. The PROMIS Depression 4a version 2.0 and PROMIS Anxiety 4a version 2.0 scales (25) measure patient-reported depression and anxiety symptoms over the previous 7 days. Participants rate 4 statements for each domain on a 5-point scale ranging from 1 (“never”) to 5 (“always”). The sum of item scores for each domain yields a score ranging from 4 to 20, which is converted by evaluators into a T score adjusted to the US general population (mean \pm SD 50 \pm 10). Higher scores indicate greater severity of depression or anxiety symptoms. The SPIN research team previously validated the English and French versions of PROMIS Depression 4a version 2.0 and PROMIS Anxiety 4a version 2.0 in SSc (36).

Statistical analysis. We calculated descriptive sample statistics as the mean \pm SD for continuous variables and frequencies and percentages for categorical variables for the total sample and separately for the English- and French-speaking samples.

CFA. We conducted a CFA to evaluate the single-factor structure of the CD-RISC-10 (18). Item responses for the CD-RISC-10 are ordinal Likert data. We modelled the responses using a weighted least squares estimator, a diagonal weight matrix, and robust standard errors. We used the Tucker–Lewis Index (TLI), comparative fit index (CFI), and root mean square error of approximation (RMSEA) to assess model fit. Well-fitting models are indicated by a TLI and CFI of ≥ 0.95 and RMSEA of ≤ 0.06 (37), although a CFI of ≥ 0.90 and an RMSEA of ≤ 0.08 (38) are often regarded as indicators of acceptable model fit. We used modification indices to identify pairs of items for which model fit would improve if error estimates were freed to covary and for which there were theoretically justifiable shared method effects (e.g., similar wording) if the original model did not achieve adequate model fit.

DIF analysis. We performed a DIF analysis using the Multiple Indicators Multiple Causes (MIMIC) model to identify possible differences in measurement properties between English and French versions of the CD-RISC-10. DIF analysis compares patterns of item responses in subgroups and tests whether individuals with similar levels of a latent construct respond to each item similarly, regardless of group affiliation. For DIF assessment, MIMIC models are based on structural equation models, in which the group variable (English versus French) is added to the basic CFA model as an observed variable. Thus, the base MIMIC model consists of the CFA factor model with the additional regression of the latent factor on group to control for group differences at the latent factor level.

We then identified DIF by first separately regressing items, one at a time, on group. If there was DIF for ≥ 1 item in this first step, the item with the largest magnitude of statistically significant DIF was considered to have DIF, and the link between the language group variable and that item was included in the model. In a second step, we again separately regressed remaining items on language group one at a time and included the item with the largest DIF in the model. This procedure was repeated until none of the remaining items showed significant DIF. Once all items with significant DIF had been identified, the potential magnitude of DIF items collectively was evaluated by comparing the difference of the latent factor between language groups in the baseline CFA model and after controlling for DIF. Because we did not encounter DIF of a meaningful magnitude, item analyses and reliability and convergent validity were done with the whole sample and not separated by language.

Item analyses. We reported the mean \pm SD, item intercorrelations, and item–rest correlations for each item of the CD-RISC-10. The item–rest correlation is the correlation of an item score with the total score after removing the item from the total score. In addition, we examined floor and ceiling effects, defined as $\geq 15\%$ of the participants having the lowest or highest possible score (39).

Reliability and convergent validity. We computed Cronbach’s alpha to determine internal consistency (40) and the intraclass correlation coefficients (ICC) to measure test–retest reliability (41). We chose the ICC as the measure of test–retest reliability because it reflects both the degree of correlation and agreement between measurements (42). We calculated ICC estimates and 95% confidence intervals (95% CIs) based on absolute agreement and a 2-way mixed-effects model.

To examine the convergent validity of the CD-RISC-10, we formulated hypotheses regarding the direction and magnitude of Pearson’s correlations with other outcome measures a priori based on existing evidence from convergent validity comparisons for the CD-RISC-10 (20). The magnitude of correlations was interpreted as small ($|r| \leq 0.3$), moderate ($0.3 < |r| < 0.5$), or large ($|r| \geq 0.5$) (43). We hypothesized that all correlations between measures would be moderate to large and that the CD-RISC-10 would be more strongly related to another resilience measure, the RS14, than with other measures. We conducted CFA and DIF using Mplus version 7 (44). All other statistical analyses were performed using SPSS version 29 (45).

Sample size calculation. *Confirmatory factor analysis.* Recommendations for CFA sample size vary. In the present study, we performed a single-factor CFA with 10 indicators using a sample that we expected would include $\sim 1,000$ participants. This number substantially exceeds the minimum number recommended by all established recommendations and standards (46–48) for a sample size necessary to achieve excellent agreement between true model characteristics and estimates.

Convergent validity. Stable estimates of correlations are typically achieved with a sample size of ≥ 250 , although smaller

correlations require larger samples. To assess a Pearson's correlation with a 95% CI with a width of 0.10, a sample size of ≥ 403 is required for a correlation of 0.30, and a size of ≥ 275 is required for a correlation of 0.50 (40).

Test-retest reliability. Although an ICC value of 0.70 is considered acceptable for test-retest reliability, a coefficient close to or exceeding 0.80 is preferable (49). A test-retest sample size of 200 individuals would be required for a precision level of 95% CI with a width of 0.10 for an estimated ICC of 0.80 (31). Therefore, we aimed for a retest sample size of 200 participants.

RESULTS

Sample characteristics. In total, 962 participants completed all items of the CD-RISC-10, RS14, RSES, and PROMIS Depression 4a version 2.0 and PROMIS Anxiety 4a version 2.0.

Sociodemographic and disease characteristics were similar across English- and French-language samples, as shown in Table 1. The total sample consisted of 848 female participants (88%) with a mean \pm SD age of 61.1 ± 11.6 years. Mean \pm SD time since onset of first non-Raynaud's phenomenon symptoms was 15.7 ± 9.6 years, and 345 individuals had diffuse SSc (36%). Participants were from France (37%), Canada (26%), the US (25%), the UK (9%), and Australia (2%). Just over half (549 [57%]) completed assessments in English.

CD-RISC measurement properties. *Confirmatory factor analysis.* The results of the CFA are shown in Table 2. In the initial CFA, the model fit for the hypothesized single-factor model was somewhat suboptimal (TLI 0.97, CFI 0.98, RMSEA 0.11). Our examination of modification indices showed that freeing the error terms of items 1 and 2 to covary would improve model fit. Items

Table 1. Sample sociodemographic and disease characteristics for the full sample and by assessment language*

Characteristics	Full sample (n = 962)		English (n = 549)		French (n = 413)	
	No.	Mean \pm SD or no. (%)	No.	Mean \pm SD or no. (%)	No.	Mean \pm SD or no. (%)
Sociodemographic variables						
Age, years	962	61.1 \pm 11.6	549	62.4 \pm 10.7	413	59.4 \pm 12.5
Female sex	962	848 (88)	549	488 (89)	413	360 (87)
White race or ethnicity	955	816 (85)	546	471 (86)	409	345 (84)
Nationality	962		549		413	
Canada		254 (26)		197 (36)	57	57 (14)
US		245 (25)		245 (45)	–	–
UK		85 (9)		85 (16)	–	–
France		358 (37)		2 (<1)	356	356 (86)
Australia		20 (2)		20 (4)	–	–
Language, English language speaking	962	549 (57)				
Education, years	960	15.1 \pm 3.6	549	15.6 \pm 3.0	411	14.4 \pm 4.1
Marital status single	960	106 (11)	549	54 (10)	411	52 (13)
BMI, kg/m ²	962	25.1 \pm 5.2	549	25.6 \pm 5.4	413	24.4 \pm 5.0
Disease characteristics						
Time since first non-Raynaud's symptom	892	15.7 \pm 9.6	505	17.6 \pm 9.9	387	13.3 \pm 8.8
Diffuse subtype	955	345 (36)	543	221 (41)	412	124 (30)
Gastrointestinal involvement	962	828 (86)	549	480 (88)	413	348 (84)
Digital ulcers	914	124 (14)	513	72 (14)	401	52 (13)
Current tendon friction rubs	846	86 (10)	468	46 (10)	378	40 (11)
Large joint contractures (moderate or severe)	891	98 (11)	499	41 (8)	392	57 (15)
Small joint contractures (moderate or severe)	906	224 (25)	504	107 (21)	402	117 (29)
History of SSc renal crisis	945	40 (4)	539	25 (5)	406	15 (4)
Interstitial lung disease	941	296 (32)	534	159 (30)	407	137 (34)
Pulmonary arterial hypertension	931	70 (8)	525	41 (8)	406	29 (7)
Primary biliary cirrhosis	926	18 (2)	527	10 (2)	399	8 (2)
Any overlap syndrome†	962	195 (20)	549	113 (21)	413	82 (20)
Psychological assessments						
CD-RISC-10	962	27.8 \pm 7.3	549	28.6 \pm 7.2	413	26.8 \pm 7.18
RS14	962	78.6 \pm 15.1	549	80.2 \pm 14.3	413	76.6 \pm 15.9
Rosenberg Scale	962	20.8 \pm 5.5	549	21.6 \pm 5.7	413	19.9 \pm 5.2
PROMIS Depression	962	51.5 \pm 9.2	549	50.6 \pm 9.0	413	52.8 \pm 9.4
PROMIS Anxiety	962	53.6 \pm 9.8	549	52.8 \pm 9.6	413	54.6 \pm 10.0

* BMI = body mass index; CD-RISC-10 = 10-item Connor-Davidson Resilience Scale; PROMIS = Patient Reported Outcomes Measurement Information System; RS14 = 14-item Resilience-Scale; SSc = systemic sclerosis.

† Participant had ≥ 1 of the following disease: rheumatoid arthritis, Sjögren's syndrome, systemic lupus erythematosus, or idiopathic inflammatory myositis.

Table 2. Factor loadings on the CD-RISC-10*

Item†	CFA factor loading‡	95% CIs
1. I am able to adapt when changes occur	0.76	0.73, 0.80
2. I can deal with whatever comes my way	0.87	0.85, 0.89
3. I try to see the humorous side of things when I am faced with problems	0.74	0.71, 0.77
4. Having to cope with stress can make me stronger	0.76	0.74, 0.80
5. I tend to bounce back after illness, injury, or other hardships	0.84	0.82, 0.86
6. I believe I can achieve my goals, even if there are obstacles	0.85	0.83, 0.87
7. Under pressure, I stay focused and think clearly	0.83	0.80, 0.85
8. I am not easily discouraged by failure	0.70	0.67, 0.73
9. I think of myself as a strong person when dealing with life's challenges and difficulties	0.87	0.85, 0.89
10. I am able to handle unpleasant or painful feelings like sadness, fear, and anger	0.83	0.81, 0.86

* 95% CI = 95% confidence interval; CD-RISC-10 = 10-item Connor-Davidson Resilience Scale; CFA = confirmatory factor analysis.

† On a 5-point scale, where 0 = not true at all and 4 = true nearly all the time.

‡ Error terms of items 1 and 2 were freed to covary.

1 and 2 evaluate how well individuals can adapt to changes or deal with things coming their way, which are closely related experiences. Therefore, we refitted the model to allow the error terms of these items to covary, resulting in good fit (TLI 0.99, CFI 0.99, RMSEA 0.08).

DIF analysis. The 1-factor model, which included regression of the latent resilience factor on language, demonstrated good fit (TLI 0.99, CFI 0.99, RMSEA 0.07). Baseline CFA model parameters before correcting for DIF are shown in Table 3. We identified 6 items with statistically significant language-based DIF. Compared to English-language participants, French-language participants had higher scores than would be expected on item 3 ($\beta = 0.14$

[95% CI 0.04, 0.23]) and item 9 ($\beta = 0.13$ [95% CI 0.04, 0.21]) and lower scores on item 1 ($\beta = -0.17$ [95% CI $-0.27, -0.08$]), item 4 ($\beta = -0.12$ [95% CI $-0.23, -0.03$]), item 5 ($\beta = -0.22$ [95% CI $-0.32, -0.14$]), and item 6 ($\beta = -0.17$ [95% CI $-0.26, -0.08$]). The difference between the 2 language groups (English and French) on the mean latent factor level was not meaningfully different between the model with DIF adjustment (standardized mean differences [SMD] 0.31 [95% CI 0.17, 0.43]) and without adjustment (SMD 0.26 [95% CI 0.13, 0.37]) (see Table 3).

Item analysis. The mean item and total CD-RISC-10 scores in the full sample are shown in Table 4. Mean item scores ranged from 2.5 for item 4 ("Having to cope with stress can

Table 3. Factor loading for the CD-RISC-10 in combined English and French samples and DIF evaluation*

Item	Base model†		DIF-corrected model‡	
	CFA factor loading	95% CIs	CFA factor loading	95% CIs
Items				
1. I am able to adapt when changes occur	0.77	0.74, 0.79	0.77	0.74, 0.79
2. I can deal with whatever comes my way	0.87	0.85, 0.88	0.87	0.85, 0.88
3. I try to see the humorous side of things when I am faced with problems	0.74	0.70, 0.76	0.74	0.70, 0.76
4. Having to cope with stress can make me stronger	0.76	0.74, 0.79	0.76	0.74, 0.79
5. I tend to bounce back after illness, injury, or other hardships	0.84	0.82, 0.86	0.84	0.82, 0.86
6. I believe I can achieve my goals, even if there are obstacles	0.85	0.83, 0.87	0.85	0.83, 0.87
7. Under pressure, I stay focused and think clearly	0.82	0.80, 0.84	0.82	0.80, 0.84
8. I am not easily discouraged by failure	0.70	0.66, 0.72	0.70	0.66, 0.72
9. I think of myself as a strong person when dealing with life's challenges and difficulties	0.87	0.85, 0.89	0.87	0.85, 0.89
10. I am able to handle unpleasant or painful feelings like sadness, fear, and anger	0.83	0.81, 0.85	0.83	0.81, 0.85
Direct effects on items attributable to the French language				
1. I am able to adapt when changes occur	-	-	-0.17	-0.27, -0.08
3. I try to see the humorous side of things when I am faced with problems	-	-	0.14	0.04, 0.23
4. Having to cope with stress can make me stronger	-	-	-0.12	-0.23, -0.03
5. I tend to bounce back after illness, injury, or other hardships	-	-	-0.22	-0.32, -0.14
6. I believe I can achieve my goals, even if there are obstacles	-	-	-0.17	-0.26, -0.08
9. I think of myself as a strong person when dealing with life's challenges and difficulties	-	-	0.13	0.04, 0.21
Standardized mean difference (English and French) on latent resilience factor	0.26	0.13, 0.37	0.31	0.17, 0.43

* 95% CI = 95% confidence interval; CD-RISC-10 = 10-item Connor-Davidson Resilience Scale; CFA = confirmatory factor analysis.

† Unstandardized model with fixed variance and regression of the latent resilience factor on language, not corrected for differential item functioning (DIF).

‡ Unstandardized model with fixed variance and regression of the latent resilience factor on language, corrected for DIF on items 1, 3, 4, 5, 6, and 9.

Table 4. Characteristics of the CD-RISC-10*

Item	Mean \pm SD score [†]	Item-rest correlation
Individual scores		
1. I am able to adapt when changes occur	3.1 \pm 0.84	0.70
2. I can deal with whatever comes my way	2.9 \pm 0.86	0.80
3. I try to see the humorous side of things when I am faced with problems	2.7 \pm 0.97	0.67
4. Having to cope with stress can make me stronger	2.5 \pm 1.00	0.69
5. I tend to bounce back after illness, injury, or other hardships	3.0 \pm 0.88	0.75
6. I believe I can achieve my goals, even if there are obstacles	2.8 \pm 0.88	0.76
7. Under pressure, I stay focused and think clearly	2.6 \pm 0.97	0.75
8. I am not easily discouraged by failure	2.6 \pm 0.98	0.62
9. I think of myself as a strong person when dealing with life's challenges and difficulties	3.0 \pm 0.92	0.78
10. I am able to handle unpleasant or painful feelings like sadness, fear, and anger	2.7 \pm 0.97	0.75
Total score	27.8 \pm 7.3	–

* CD-RISC-10 = 10-item Connor-Davidson Resilience Scale.

[†] On a 5-point scale, where 0 = not true at all and 4 = true nearly all the time.

make me stronger”) to 3.1 for item 1 (“I am able to adapt when changes occur”). Correlations between items ranged from $r = 0.44$ ($P < 0.001$ for items 3 and 8) to $r = 0.73$ ($P < 0.001$ for items 1 and 2). Item–rest correlations ranged from $r = 0.62$ (item 8) to $r = 0.80$ (item 2). There were 2 participants (0.2%) with the lowest possible score (score of 0) on the scale and 48 participants (5.0%) with the highest possible score (score of 40). Item response frequencies are shown in Supplementary Table 1 (available on the *Arthritis Care & Research* website at <http://onlinelibrary.wiley.com/doi/10.1002/acr.25139/abstract>).

Reliability. Cronbach's alpha was 0.93 (95% CI 0.92, 0.94). We assessed test–retest reliability in a subsample of 230 participants, whose characteristics were similar compared to the full sample (for subsample sociodemographic and medical data, see Supplementary Table 2, available at <http://onlinelibrary.wiley.com/doi/10.1002/acr.25139/abstract>), resulting in an ICC of 0.80 (95% CI 0.75, 0.85), indicating good 1–2-week test–retest reliability.

Convergent validity. As shown in Table 5, there were moderate-to-large correlations between the CD-RISC-10 and measures of resilience (RS14), self-esteem (RSES), depression (PROMIS depression 4a version 2.0), and anxiety (PROMIS anxiety 4a version 2.0). All correlations were consistent with convergent validity hypotheses.

DISCUSSION

We tested the unidimensional structure of the CD-RISC-10, examined whether there were meaningful differences in measurement properties between English- and French-language versions of the scale, and evaluated internal consistency, test–retest reliability, and convergent validity. We found that the hypothesized single-factor structure of the scale fit well, supporting the use of a single total score for the CD-RISC-10 scale. There was statistically significant DIF for 6 items between English- and French-language participants. However, the cumulative effect of DIF was minimal and did not meaningfully influence estimates of differences in resilience between English- and French-language respondents in unadjusted models (SMD 0.26 [95% CI 0.17, 0.43]) versus DIF-adjusted models (SMD 0.31 [95% CI 0.17, 0.43]), allowing us to conclude that CD-RISC-10 scores of English- and French-language participants can be compared and aggregated without concerns of language-based bias.

Internal consistency reliability ($\alpha = 0.93$ [95% CI 0.92, 0.94]) and test–retest reliability (ICC 0.80 [95% CI 0.75, 0.85]) were good, and there were no floor or ceiling effects. In addition, indices of convergent validity were consistent with study hypotheses; CD-RISC-10 correlated moderately to highly with all measurements (RSES $r = 0.69$; PROMIS depression $r = -0.60$; PROMIS

Table 5. Correlation of measures using the CD-RISC-10 to assess convergent validity*

Convergent validity [†]	Pearson correlation	95% CIs
Large positive correlation		
Resilience (RS14)	0.78	0.76, 0.81
Moderate-to-large positive correlation		
Self-esteem (Rosenberg Self-esteem Scale)	0.69	0.65, 0.72
Moderate-to-large negative correlation		
Depression (PROMIS Depression)	–0.60	–0.64, –0.56
Anxiety (PROMIS Anxiety)	–0.57	–0.61, –0.52

All hypotheses were confirmed. 95% CI = 95% confidence interval; CD-RISC-10 = 10-item Connor-Davidson Resilience Scale; PROMIS = Patient Reported Outcomes Measurement Information System; RS14 = 14-item Resilience-Scale.

[†] Magnitude of correlations was defined as small ($|r| \leq 0.3$), moderate ($0.3 < |r| < 0.5$), or large ($= |r| \geq 0.5$).

anxiety $r = -0.57$) and the magnitude of correlation with the RS14, another measure of resilience, was the largest ($r = 0.78$).

Researchers initially validated the CD-RISC-10 in a sample of 1,743 undergraduate students from the US (18). The present study is the first to validate the scale among individuals with SSc and, to our knowledge, the first comparison of measurement properties between English- and French-language versions. The overall outcomes of our study were consistent with results from previous studies that examined measurement properties of the CD-RISC scale in other samples, including among individuals with chronic diseases (18,21,22). We believe that this is the first study to examine language-based DIF in the CD-RISC-10.

Our findings have important implications for research. We found that the CD-RISC-10 provides a valid and reliable method for evaluating resilience in individuals with SSc. A previous study (Wojack et al, unpublished observations) used latent profile analysis and found that some individuals with SSc report positive mental health, despite experiencing severe disease manifestations and high levels of pain, fatigue, and sleep disturbance, which could be associated with resilience (11,12). Resilience, using the CD-RISC-10, should be compared between classes of individuals with SSc who differ in mental health despite having similar disease burdens to further elucidate the possible role of resilience in the mental health of individuals with SSc. We plan to conduct these analyses in a second study, using a sample from the SPIN Cohort. In addition, researchers could conduct similar analyses in other chronic illness populations.

The results of our DIF analysis demonstrate the comparability and combinability of CD-RISC-10 scores across English and French languages in SSc, presenting opportunities for broader utilization in international patient cohorts, including the SPIN Cohort (27,28). Among individuals with chronic medical conditions, intervention strategies that improve resilience and adaptive coping have been found to be effective in improving psychological adaptation and reducing symptom burden (15). The CD-RISC-10 presents a valid outcome measure for testing similar interventions in SSc.

Our study has several notable strengths, including its international cohort with participants from 47 clinical sites, its large sample size, its assessment of test-retest reliability, and the comparison of measurement properties in English- and French-language participants with SSc. There are also limitations to consider. First, the SPIN Cohort is a convenience sample of individuals with SSc receiving treatment at SPIN recruiting centers who can complete online measures, since SPIN collects data digitally only. However, a comparison with the European Scleroderma Trials and Research Cohort and the Canadian Scleroderma Research Group Cohort indicated broad comparability of participant characteristics, which supports generalizability in SSc (27). Second, the examination of DIF was limited to English- and French-language versions of the CD-RISC-10 and adults with SSc, and the generalizability of the results to other populations is

not known. Third, the MIMIC approach for DIF evaluates uniform, but not nonuniform, DIF.

Overall, the results of this study indicate that the CD-RISC is a valid and reliable measure of resilience in English and French languages in SSc, supporting its use as an outcome measure to assess resilience in this population. In addition, we found DIF to be negligible, suggesting that CD-RISC-10 scores are comparable across English- and French-language versions.

AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be submitted for publication. Dr. Thombs had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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