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Authors

Hays, Ron D
Slaughter, Mary
Rodriguez, Anthony
et al.

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Analyses of Cross-Sectional Data to Link the PEG With the Patient Reported Outcomes Measurement and Information System (PROMIS) Global Physical Health Scale

Ron D. Hays,^{*} Mary Slaughter,[†] Anthony Rodriguez,[‡] Maria Orlando Edelen,[§] and Patricia M. Herman[†]

^{*}Division of General Internal Medicine and Health Services Research, UCLA Department of Medicine, Los Angeles, California, [†]RAND Corporation, Behavioral and Policy Sciences, Santa Monica, California, [‡]RAND Corporation, Behavioral and Policy Sciences, Boston, Massachusetts, [§]Patient Reported Outcomes, Value and Experience (PROVE) Center, Department of Surgery, Brigham and Women's Hospital, Boston, Massachusetts

Abstract: It is challenging to synthesize findings across studies of pain impact. This study develops a link to estimate the Patient-Reported Outcomes Measurement Information System (PROMIS) global health measure from the 3-item Pain intensity, interference with Enjoyment of life, interference with General activity (PEG) scale. The PROMIS and PEG items were administered to 795 adults (average age = 51; 54% female, 79% White). We estimated correlations among the PEG and PROMIS items and conducted factor analysis to identify the best subset of PROMIS items for linking to the PEG. An item response theory graded response model was estimated to link the PEG with the 4-item PROMIS global physical health scale. A categorical single-factor model and a bifactor model provided support for a single dimension for the PEG and PROMIS global physical health items. The product-moment correlation between estimated PROMIS global physical health scale from the PEG and the actual global physical health score was .74. The mean difference between estimated PROMIS global physical health scale score from the PEG and the observed global physical health score was less than a T-score point. This study makes it possible to estimate the average global physical health for group-level comparisons in research that includes the PEG.

Perspective: This article describes an empirical link of the PEG to the PROMIS global physical health scale that makes it possible to estimate the average global physical health in studies that include the PEG. This link can facilitate comparisons among studies that have not administered the PEG or the PROMIS global health scale.

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Key words: Pain Intensity, interference with Enjoyment of life, interference with General Activity, patient-reported outcomes measurement information system, linking, item response theory, group comparisons.

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The RAND Human Subjects Protection Committee determined that these secondary analyses of existing data are exempt on August 21, 2019 (RAND IRB Number 0000051).

The authors have no conflicts of interest to declare.

Address reprint requests to Ron D. Hays, PhD, Division of General Internal Medicine and Health Services Research, UCLA Department of Medicine, 1100 Glendon Avenue Suite 850, Los Angeles, CA, USA. E-mail: drhays@ucla.edu
 1526-5900/\$36.00

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Generic self-report health measures are by design intended to be applicable to the general population. Because of the general applicability of these measures across different people, they can be used to estimate relative burden of different conditions and different treatments. Some generic measures focus on specific symptoms such as pain while others assess higher-order concepts such as global physical and mental health. An extensive body of research has been conducted with adults having chronic pain using a wide variety of pain-targeted and global health outcome measures.¹¹ The National Institutes of Health Pain Consortium's Research Task Force on chronic low back pain noted that because of variations in study design and measures used it is "difficult to compare epidemiologic data and studies of similar or competing interventions, replicate findings, pool data from multiple studies, resolve conflicting conclusions, develop multidisciplinary consensus, or even achieve consensus within a discipline regarding interpretation of findings"⁶ (p. 1250).

When 2 measures are correlated with one another and define an underlying continuum, they can be empirically linked on a common metric.^{7,28} A linkage can be done between 2 global measures. For example, the PROMIS global physical and mental health scores can be estimated from the Veterans RAND 12-item general health survey because they were empirically linked.²⁹ Or the linkage can be between different measures of the same symptom such as depression.⁵ In addition, generic measures of a specific domain can be linked with disease-targeted measures as was the PROMIS physical function scale with the Functional Assessment of Cancer Therapy.¹³

While assessing pain and other specific symptoms is critically important when examining individuals with chronic low back pain and other conditions, information about global health can also be useful for researchers and clinicians. Global health scores for a group of patients with a certain condition can be compared to the general population and to patients with other condition to assess the relative burden of the condition. The Patient-Reported Outcomes Measurement Information System (PROMIS) global health instrument is an outcome measure endorsed by the International Consortium for Health Outcomes Measurement.²⁵ The 10 PROMIS global health items impose limited respondent burden as they can be administered in 2 minutes or less. Support for the reliability and validity of the PROMIS global physical and mental health scales is accumulating.^{1,8,14,30}

One measure increasingly used to assess pain in outcomes research is the Pain intensity, interference with Enjoyment of life, interference with General activity (PEG), which is a 3-item subset of the Brief Pain Inventory (BPI).¹⁸ The developers reported internal consistency reliability of .73 and .89 in 2 samples and comparable construct validity to the full BPI.¹⁸

Prior work documents statistically significant and noteworthy associations between the PEG and some PROMIS measures. In a sample of 300 primary care patients, the PEG correlated .46 to .51 with PROMIS-29 depression, fatigue, sleep disturbance and fatigue scales and .86 with pain interference.¹⁹ But the PEG has not yet been linked to a global health measure.

This paper describes the development of a linkage from the PEG to the PROMIS global physical health measure using data collected in the development and evaluation of the PROMIS measures.^{2,8}

Methods

Sample

As part of the PROMIS wave 1 data collection, a sub-sample of participants responded to every candidate item of a PROMIS measure and all items of one or more "legacy instruments" that measured the same or a similar concept. Individuals who responded to the PROMIS

Table 1. Characteristic of the Overall Sample (n = 21,133) and those Administered the PEG Items (n = 795)

VARIABLE	OVERALL SAMPLE	PEG SUBGROUP
Age means (SD, range)	53 (17, 18–100)	51 (18, 18–90)
Female (%)	52%	54%
Race		
White (%)	82%	79%
Black (%)	9%	8%
Other (%)	9%	13%
Spanish (%)	9%	11%
Education		
< High school (%)	2%	2%
High school graduate (%)	16%	15%
Some college (%)	39%	33%
College degree (%)	24%	29%
Advanced degree (%)	19%	21%
Marital Status		
Married or living with partner (%)	66%	64%
Never married (%)	15%	18%
Separated, divorced or widowed (%)	19%	18%
Hypertension (%)	41%	37%
Arthritis (%)	26%	22%
Depression (%)	26%	22%
Anxiety (%)	18%	14%
Migraines (%)	17%	14%
Cancer (%)	17%	9%
Asthma (%)	16%	15%
Diabetes (%)	13%	9%
Chronic obstructive pulmonary disease (%)	11%	4%
Angina (%)	10%	5%
Coronary artery disease (%)	6%	3%
Congestive heart failure (%)	5%	2%
Myocardial infarction (%)	6%	3%
Liver disease (%)	4%	2%
Kidney disease (%)	3%	2%

global health scale also completed the PEG. This is a secondary analysis of cross-sectional data collected from 795 adults (54% female) who completed the PEG and PROMIS global health items (Table 1).

The average age was 51 and the majority were White (79%), had some college or higher education (83%), and were married or living with a partner (64%). The characteristics of the subsample that was administered the PEG were like the overall PROMIS wave 1 sample but had fewer chronic conditions.

Measures

PEG. The 3 PEG items are 1) What number best describes your pain on average in the past week? 2) What number best describes how, during the past week, pain has interfered with your enjoyment of life? 3) What number best describes, how, during the past week, pain has interfered with your general activity? PEG response options range from 0 to 10, with 10 indicating the most severe pain. The PEG scale score is the mean of the 3 items and has a possible range of 0 to 10.

PROMIS Global Health. This set of 10 items includes 4 items used in scoring the global physical health scale, 4 items used in scoring the global mental health scale, a general health item and a general activity item.

The 4 PROMIS items used in scoring the global physical health scale (PROMIS item names provided within parentheses) are 1) "In general, how would you rate your physical health?" (global03) 2) "To what extent are you able to carry out your everyday physical activities such as walking, climbing stairs, carrying groceries, or moving a chair?" (global06) 3) "How would you rate your pain on average?" (global07) 4) "How would you rate your fatigue on average?" (global08). Three of these 4 PROMIS items are administered with 5 response options and the other item (global07) is administered with a 0 (no pain) to 10 (worst pain imaginable) response scale. Based on the Sheehan Disability Scale and the Flushing Symptom Questionnaire,²² the latter item is recoded to 5 categories (5 = no pain; 4 = 1–3; 3 = 4–6; 2 = 7–9; 1 = worse pain imaginable) before scoring the global physical health scale. All 4 items are coded so a higher score represents better global physical health.

The 4 PROMIS global mental health items are 1) "In general, would you say your quality of life is" (global02) 2) "In general, how would you rate your mental health, including your mood and your ability to think?" (global04) 3) "In general, how would you rate your satisfaction with your social activities and relationships?" (global05) 4) "How often have you been bothered by emotional problems such as feeling anxious, depressed or irritable?" (global10). All 4 of these PROMIS items are administered with 5 response options and coded so a higher score represents better global mental health. Internal consistency reliability of the 4-item global physical health and mental health scales were .81 and .86, respectively.⁹ The global physical and mental health scale scores are estimated using an item-response theory graded response

model and transformed to have a mean of 50 and SD of 10 in the U.S. general population.⁸

Two of the PROMIS global items are not used in scoring the global physical and mental health scales: 1) "In general, would you say your health is" (global01); and 2) "In general, please rate how well you carry out your usual social activities and roles. This includes activity at home, at work, and in your community, and responsibilities as a parent, child, spouse, employee, friend, etc." (global09). Global01 has been administered on several nationally representative health surveys and can be used to estimate the global physical health scale.¹⁰

Analysis Plan

We estimate means for the PEG score and the PROMIS global physical and mental health scale scores for descriptive purposes. We also report correlations between the PEG scale and the PROMIS global physical health and mental health scales. To identify the subset of PROMIS global health items best suited for linking to the PEG, we begin by estimating product-moment correlations among the 3 PEG and 10 PROMIS global health items and conducting an exploratory factor analysis. Based on the correlations and the exploratory factor analysis, we evaluate a single-factor categorical confirmatory factor analytic model for the PEG items and the subset of PROMIS global health items identified in the above analyses to be most strongly associated with the PEG items. Because Mplus software only allows up to 10 categories per item, we collapsed responses of 9 and 10 (worse pain) into a single category for this analysis. We evaluate fit with the comparative fit index (CFI), the standardized root mean squared residual (SRMR) and the root mean square error of approximation (RMSEA). Good model fit is indicated by a CFI of about .95 or above, a SRMR of about .08 or less, and an RMSEA of about .06 or less.¹² In addition, we estimate a bifactor model to obtain an indication of general factor saturation (omega hierarchical, ω_h) that represents the percent of variance in unit-weighted total scores attributed to individual differences on the general factor. Values $\geq .80$ are suggestive of essential unidimensionality.²⁴

Next, we fit an item-response theory graded response model²⁶ for the PEG items and the PROMIS global physical health items (the PROMIS global health items identified in the above analyses to be most strongly associated with the PEG items) using a single group design with common-item equating.¹⁷ To do this, items are calibrated in a single run with PROMIS item parameters fixed at their previously estimated values and the PEG item parameters freely estimated.¹⁶ PEG items were reversed for this calibration so that a higher score indicate less pain. This fixed item calibration of PROMIS global physical health items yields PEG item parameters on the PROMIS metric. We use the polytomous version of the Lord and Wingersky²⁰ algorithm that computes the probability of each successive response recursively based on previously computed likelihoods³¹ to map the PEG scale score to the PROMIS global physical health

4 The Journal of Pain

scale. Finally, we estimate the product-moment correlation of the linked PEG scores to actual PROMIS global physical health scores and report the mean and standard deviation of the difference.

Analyses were conducted using SAS,²⁷ Mplus,²¹ R,²³ and PROSetta Stone⁴ software: <https://www.prosetta.stone.org>.

Results

The mean PEG scale score in our sample was 1.82 (SD = 2.18; range: 0–10), much lower than the mean of 6.1 found in a study of 500 adults with musculoskeletal pain.¹⁸ The PROMIS global physical health score was equal to that of the U.S. general population mean: 50.14 (SD = 8.41; range: 22–67); as was the PROMIS global mental health score of 49.97 (SD = 8.46). Internal consistency reliability of the PROMIS global physical health and PEG scales were .77 and .91, respectively.

Correlations among the PEG items and PROMIS global health items (Table 2) ranged from .29 (Global05 and PEG1) to .77 (Global07 and PEG1). We provide the correlations for the 2 PROMIS global health items not used in scoring the global physical and mental health scales (global01 and global09) for completeness, but we do not include them in subsequent analyses because they are redundant with the items used in the scales (ie, locally dependent). For example, global01 correlated .90 with global03.

Factor Analysis

An exploratory factor analysis was conducted on the 3 PEG items and 8 PROMIS global health items used in scoring the 4-item global physical health scale and the

PEG Link to PROMIS Physical Health

4-item global mental health scale. Two principal components eigenvalues exceeded 1 (Guttman's weakest lower bound): the first 3 eigenvalues were 5.67, 1.67 and .83. A scree plot of eigenvalues from a common factor analysis with squared multiple correlations as communality estimates suggested 2 factors (Fig 1). Next, we estimated a principal factor analysis Promax rotated 2-factor solution with squared multiple correlations as prior communality estimates (Table 3). The 3 PEG items did not load on the mental health factor but loaded on the global physical health factor with standardized factor pattern loadings ranging from .78 to .90. Hence, we limit subsequent analyses to the PEG and the 4 global physical health items.

A 1-factor categorical confirmatory model for the PEG items and the 4 global physical health items fit the data well according to 2 indices of practical fit (CFI = .981; SRMR = .037) and the RMSEA was = .159. Standardized factor loadings ranged from .64 to .94. All residual correlations were less than .18. The bifactor model provided support for essential unidimensionality with ω_h of .80 (explained common variance = .74), RMSEA = .042, and standardized factor loadings on the general factor ranging from .51 to .89. All loadings on the general factor easily exceeded the corresponding loadings on the group factors.

Linking

The correlation of the PEG scale was -.77 ($n = 790$) with the PROMIS global physical health scale and -.47 ($n = 791$) with the PROMIS global mental health scale. The correlation between the PEG scale and the PROMIS global physical health scale adjusted for unreliability was .92.

Table 2. Product-Moment Correlations Among 13 Items

	1	2	3	4	5	9	6	10	8	7	PEG1	PEG2
2	.69											
3	.90	.70										
4	.50	.64	.51									
5	.49	.68	.51	.68								
9	.63	.67	.63	.61	.64							
6	.58	.50	.58	.34	.35	.58						
10	.34	.48	.35	.66	.56	.50	.26					
8	.53	.50	.53	.48	.44	.60	.48	.48				
7	.47	.41	.47	.32	.31	.46	.52	.30	.48			
PEG1	-.47	-.42	-.45	-.32	-.29	-.45	-.54	-.28	-.46	-.77		
PEG2	-.46	-.47	-.48	-.41	-.38	-.50	-.55	-.39	-.48	-.62	.72	
PEG3	-.47	-.47	-.46	-.38	-.30	-.51	-.63	-.32	-.48	-.68	.76	.84

1 = Global01: In general would you way your health is. . .

2 = Global02: In general, would you say your quality of life is. . .

3 = Global03: In general, how would you rate your physical health?

4 = Global04: In general, how would you rate your mental health?

5 = Global05: In general, how would you rate your satisfaction with social activities and relationships?

6 = Global06: To what extent are you able to carry out your everyday physical activities?

7 = Global07: How would you rate your pain on average? (Note that the 0-10 response scale is recoded to 5 categories: 0 (no pain) -> 5; 1-3 -> 4; 4-6 -> 3; 7-9 -> 2; 10 (worst pain imaginable)-> 1.

8 = Global08: How would you rate your fatigue on average?

9 = Global09: In general, please rate how well you carry out your usual social activities and roles?

10 = Global10: How often have you been bothered by emotional problems?

PEG1: What number best describes your pain on average in the past week?

PEG2: What number best describes how, during the past week, pain has interfered with your enjoyment of life?

PEG3: What number best describes how, during the past week, pain has interfered with your general activity?

Note: PROMIS global physical health items are global03, global06, global07, and global08.

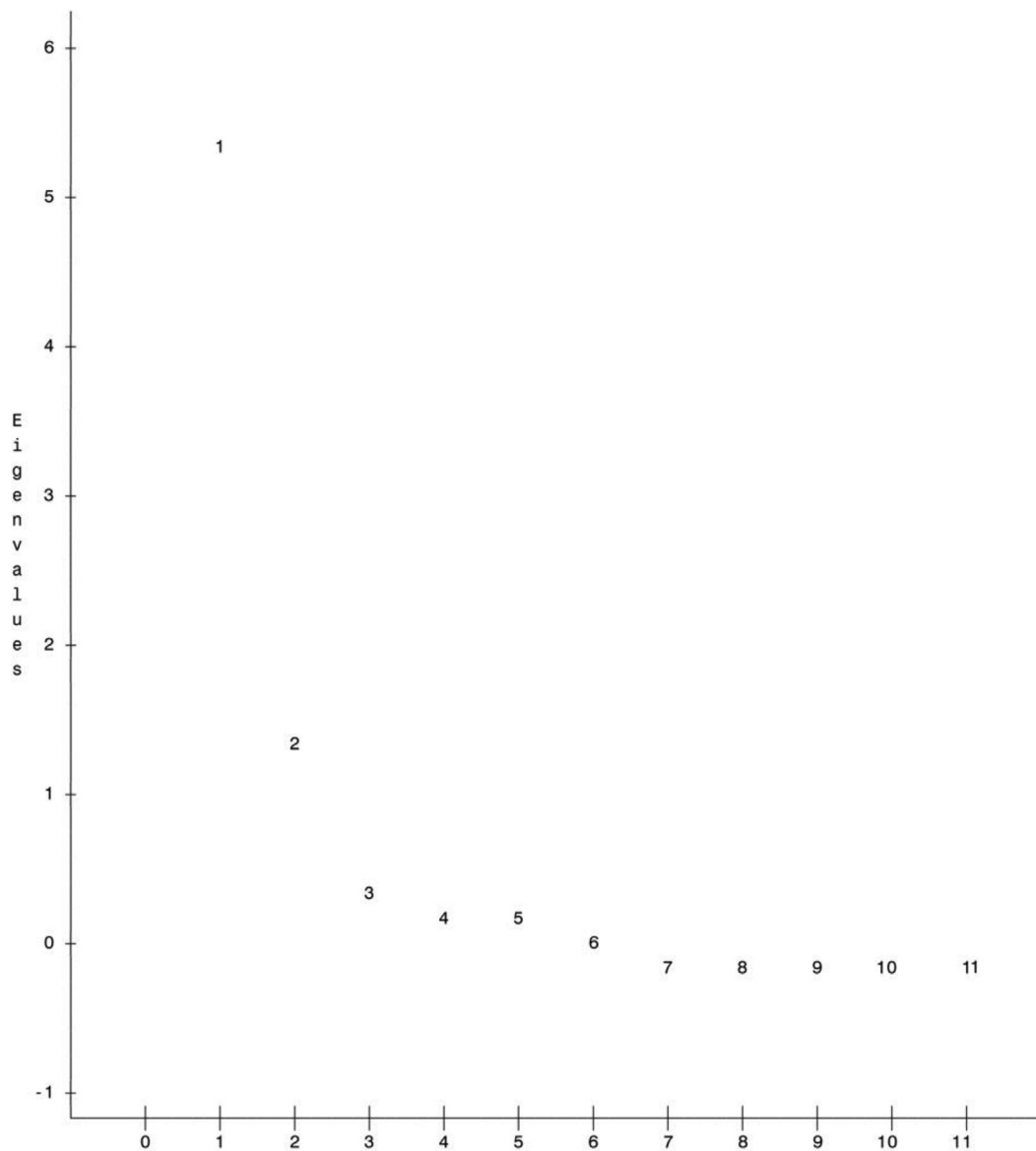


Figure 1. Scree plot of common factor analysis eigenvalues from common factor analysis with squared multiple correlations as communality estimates.

Table 4 gives the graded response model item parameters from the combined PEG and PROMIS global physical health concurrent calibration. The PEG had larger slopes than the PROMIS global physical health items, indicating that the PEG items more strongly represented the common factor defined by the 7 items. The number of thresholds is one less than the number of response categories for each item. The thresholds indicate that 3 of the PROMIS items (global03 global07, global08) represented the positive range of physical health (1 SD and higher) better than did the PEG items. That is, the PEG item thresholds top out at between $-.0251$ and $.6468$.

Table 5 presents the crosswalk from the mean and summed PEG scores (scored in the usual direction, with a higher score representing more pain) to PROMIS global physical health T-scores. For example, a PEG score of 0 (lowest level of pain) is mapped to a PROMIS global physical health score of 61.6 while a PEG mean score of 10 (summed score of 30; most pain) is associated with a

PROMIS global physical health score of 20.7. A PEG mean score of 1 (summed score of 3) is consistent with PROMIS global physical health scores near the U.S. general population mean of 50.

The product-moment correlation between the estimated PROMIS global physical health scale based on the PEG link and the actual PROMIS global physical health scores was $.74$. The mean for the estimated PROMIS global physical health score (ie, linked score from the PEG) was less than a T-score point ($.48$) different from the actual PROMIS global physical health score (50.62 vs 50.14) and the standard deviation of the difference was 6.20 .

Discussion

This study provides a crosswalk that allows the PROMIS global physical health scale to be estimated

Table 3. PROMAX Rotated Two-Factor Pattern (Loadings > = .30)

ITEM	PHYSICAL HEALTH	MENTAL HEALTH
PEG3	-.90	
PEG1	-.88	
Global07	.80	
PEG2	-.78	
Global06	.66	
Global03	.30	.50
Global08	.32	.42
Global04		.82
Global05		.79
Global02		.69
Global10		.69

Global02: In general, would you say your quality of life is . . .
 Global03: In general, how would you rate your physical health?
 Global04: In general, how would you rate your mental health?
 Global05: In general, how would you rate your satisfaction with social activities and relationships?
 Global06: To what extent are you able to carry out your everyday physical activities?
 Global07: How would you rate your pain on average?
 Global08: How would you rate your fatigue on average?
 Global10: How often have you been bothered by emotional problems?
 PEG1: What number best describes your pain on average in the past week?
 PEG2: What number best describes how, during the past week, pain has interfered with your enjoyment of life?
 PEG3: What number best describes how, during the past week, pain has interfered with your general activity?
 Note: Estimated correlation = 0.53 between physical and mental health.

from the PEG. In this study, the correlation between estimated PROMIS global health linked scores based on PEG items and actual scores ($r = .74$) exceeded the correlation reported by Schalet et al.²⁹ between the PROMIS global physical health scale and the Veterans RAND-12 physical component summary score ($r = 0.69$). Those authors suggested that the size of the correlation could be due to the breadth of the construct of global physical health. In the current study, the mean estimated PROMIS global physical health score was less than a T-score point different from the actual PROMIS global physical health score. This indicates that the mean

PROMIS global physical health scale can be accurately estimated from the PEG.

The link between the PEG and the PROMIS global physical health scales is useful for studies where the PEG has been administered but a global health measure has not. In these studies, global physical health can be estimated to provide information about how the sample compares to the U.S. general population and other subgroups. For example, the mean PEG scale score of 6.1 in Study 1 of the Krebs et al¹⁸ article corresponds to a PROMIS global physical health score of about 37 (worse than the overall U.S. general population mean). While it is preferable to administer the PROMIS global health measure directly, there is often competing needs in research and clinical practice as well as concerns about response burden.

It is important to note that there is more error when estimating scores from a link than when the scores are directly measured. That is, PROMIS physical health estimated from the PEG linked scores is less accurate than PROMIS physical health scale scored directly from the PROMIS items. In addition, we recommend that the estimated PROMIS global physical health score only be used for group-level comparisons because the error in estimating individual PROMIS global physical health scores is much higher. Further, the association between linked and actual scores may vary by characteristics of the population. Thus, it is always better to have administered and scored the PROMIS global physical health items directly. But when that is not possible, estimating the PROMIS global physical health scale provides useful comparative information.

The current study adds to existing linkages of PROMIS measures with other measures. Investigators who have administered the PEG can estimate the PROMIS global physical health scale using the link provided in Table 5. Future research is needed to evaluate how well the link from the PEG scale to the PROMIS global physical health scale generalizes to other samples and settings. It may also be valuable to compare

Table 4. Item Parameters for Global Physical Health (Fixed) and PEG (Estimated)

	GLOBAL03	GLOBAL06	GLOBAL07	GLOBAL08	PEG1	PEG2	PEG3
Slope	2.2257	2.8809	1.6799	1.8319	3.4354	4.5180	5.6266
Threshold 1	-2.3068	-3.0148	-4.1331	-3.4747	-3.3014	-2.1862	-2.3795
Threshold 2	-1.0357	-1.9551	-1.9869	-2.0584	-2.6493	-1.8582	-2.0505
Threshold 3	.1876	-1.1949	-.8116	-.4829	-2.2348	-1.6345	-1.6988
Threshold 4	1.4917	-.5224	.9227	1.1009	-1.8155	-1.3604	-1.4124
Threshold 5					-1.4190	-1.2225	-1.1787
Threshold 6					-1.0226	-1.0634	-.9921
Threshold 7					-.7234	-.9009	-.8175
Threshold 8					-.2984	-.6993	-.5919
Threshold 9					.0856	-.3913	-.3137
Threshold 10					.6468	-0.0251	-0.0081

Global03: In general, how would you rate your physical health?
 Global06: To what extent are you able to carry out your everyday physical activities?
 Global07: How would you rate your pain on average?
 Global08: How would you rate your fatigue on average?
 PEG1: What number best describes your pain on average in the past week?
 PEG2: What number best describes how, during the past week, pain has interfered with your enjoyment of life?
 PEG3: What number best describes how, during the past week, pain has interfered with your general activity?
 Note: For the item calibration shown here, PEG items were reversed scored so that a higher score represents less pain and interference.

Table 5. Estimated PROMIS Global Physical Health Score From PEG Score

PEG MEAN SCORE	PEG SUM SCORE	PROMIS GLOBAL PHYSICAL HEALTH	STANDARD ERROR
0	0	61.6	5.8
1/3	1	55.0	3.4
2/3	2	52.5	3.0
1	3	50.7	2.8
4/3	4	49.1	2.6
5/3	5	47.9	2.5
2	6	46.8	2.4
7/3	7	45.8	2.3
8/3	8	44.9	2.3
9/3	9	44.1	2.3
10/3	10	43.3	2.2
11/3	11	42.5	2.2
14	12	41.8	2.2
13/3	13	41.0	2.2
14/3	14	40.3	2.2
5	15	39.6	2.2
16/3	16	38.9	2.2
17/3	17	38.2	2.2
6	18	37.4	2.2
19/3	19	36.6	2.2
20/3	20	35.8	2.2
7	21	34.9	2.2
22/3	22	34.0	2.2
23/3	23	33.0	2.3
8	24	32.0	2.3
25/3	25	30.8	2.3
26/3	26	29.5	2.4
9	27	28.0	2.6
28/3	28	26.2	2.8
29/3	29	24.0	3.2
10	30	20.7	4.1

Note: Estimated using PROSetta Stone software.

the link developed here with other linking methods.²⁸ But, it was noted that “when the dis-attenuated correlation between instruments is .90 or higher, the results of each method are expected to converge and the differences among them will probably be inconsequential at the group level. In this circumstance, unidimensional item response theory linking provides the benefit of creating a bi-directional link, as well as simplicity”²⁸ (p. 740). In this study, the correlation between the PEG scale and the PROMIS global physical health scale adjusted for unreliability was .92.

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8 The Journal of Pain

PEG Link to PROMIS Physical Health

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