Original experimental

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The validity of pain intensity measures: what do the NRS, VAS, VRS, and FPS-R measure?

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Abstract

Background and aims: The Numerical Rating Scale (NRS), Visual Analogue Scale (VAS), Verbal Rating Scale (VRS), and Faces Pain Scale-Revised (FPS-R) are valid measures of pain intensity. However, ratings on these measures may be influenced by factors other than pain intensity. The purpose of this study was to evaluate the influence of non-pain intensity factors on the pain intensity scales.
Methods: We administered measures of pain intensity (NRS, VAS, VRS, FPS-R), pain unpleasantness, catastrophizing, depressive symptoms, and pain interference to 101 individuals with chronic lower back or knee pain. Correlation analyses examined the associations among the pain intensity scales, and regression analyses evaluated the contributions of the non-pain intensity factors (depressive symptoms, and pain unpleasantness, catastrophizing, and interference) to the VAS, VRS, and FPS-R ratings, while controlling for NRS, age, and gender.
Results: Although the NRS, VAS, VRS, FPR-S, scales were strongly associated with one another, supporting their validity as measures of pain intensity, regression analyses showed that the VRS also reflected pain interference, the FPS-R also reflected pain unpleasantness, and the VAS was not associated with any of the additional non-pain intensity factors when controlling for NRS, age, and gender.
Conclusions: The VAS appears to be most similar to the NRS and less influenced by non-pain intensity factors than the VRS or FPS-R. Although the VRS and FPS-R ratings both reflect pain intensity, they also contain additional information about pain interference and pain unpleasantness, respectively. These findings should be kept in mind when selecting pain measures and interpreting the results of research studies using these scales.
Implications: The influence of pain interference and pain unpleasantness on VRS and FPS-R, respectively should be kept in mind when selecting pain measures and interpreting the results of research studies using these scales.

Keywords: pain assessment; pain intensity; pain rating; psychosocial factors.

1 Introduction

Four commonly used pain intensity scales are the Numerical Rating Scales (NRSs), the Visual Analogue Scales (VASs), the Verbal Rating Scales (VRSs), and the Faces Pain Rating Scales (FPSs) [1, 2]. There is a general consensus that NRSs have more validity and more strengths than other scales [2–8]. However, there are situations where a VAS, VRS, or FPS may be more appropriate [9–17].

Pain intensity measures may be influenced by non-pain intensity factors. Qualitative studies have reported that some individuals consider non-pain intensity factors when rating pain intensity [18, 19]. It is also possible that the non-pain intensity factors that contribute to intensity ratings differ between scales. For example, researchers have traditionally graded pain intensity as reflected by the VRS with respect to pain's interference with function [20–22]. It is possible that patients use a similar approach, and that VRS ratings may be influenced more strongly by pain interference than NRS ratings.

Also, VRSs and measures for pain interference and catastrophizing are assessed by questionnaires that depend heavily on verbal descriptions, as opposed to numbers. Therefore, VRSs may be more strongly associated with measures of pain catastrophizing and interference than NRSs. Preliminary support for this idea comes from a study which found that a composite score containing information about pain interference, pain catastrophizing, and other factors was associated with VRS ratings over and above the variance explained by NRS among adults with physical disabilities and chronic pain

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[23]. However, to our knowledge, this finding has not yet been replicated in additional pain populations.

Although the Faces Pain Scale – Revised (FPS-R) [24] was developed to measure pain intensity with a goal of minimizing affect cues, it is less strongly correlated with NRSs than other intensity measures [11, 25–27]. This may be due to the possibility that the facial expressions are viewed by respondents as representing emotional distress [28–30]. The FPS-R may therefore be more influenced by emotional distress than NRSs. However, to our knowledge, this possibility has not yet been examined.

As a measure with less verbal cues than VRS or affect-related cues than FPS-R, the VAS is more strongly associated with NRS than either VRS or FPS-R [4, 11, 31]. The VAS, like the NRS, may therefore be a more "pure" measure of pain intensity.

Information regarding whether pain intensity measures are influenced by non-pain intensity factors should be taken into account when selecting and interpreting measures. The objective of this study was therefore to examine whether VRS, FPS-R, and VAS ratings are associated with non-pain intensity factors. We hypothesized that the association between NRS and VAS would be stronger than the associations between these measures and a VRS or FPS-R. We also hypothesized that the VRS would be significantly associated with pain interference and pain catastrophizing, the FPS-R would be significantly associated with depressive symptomatology and pain unpleasantness, and the VAS would not be associated with any of these non-pain intensity factors, when controlling for NRS ratings.

2 Materials and methods

2.1 Participants

A convenience sample of 101 individuals with chronic pain were recruited through referrals from the National University Hospital's (NUH) in Singapore: the Orthopedic Spine Clinic, the Anesthesia Pain Clinic and the Rheumatology Clinic. Participants were patients of the study's referring physicians who were attending their medical appointments. Doctors referred participants who met the following inclusion criteria: (1) having a diagnosis of either primarily chronic (pain lasting for ≥3 months) low back or chronic knee pain; (2) reporting an average low back/knee pain intensity of 4 or greater on a 0–10 NRS; (3) being at least 21 years old; and (4) being able to read, speak, and write in English. Exclusion criteria were: (1) having cognitive impairments (e.g. dementia, intellectual disability) that would interfere with the ability to provide informed consent and complete the study measures; and (2) severe psychiatric or psychological problems that would interfere with participation.

2.2 Procedures

Potential participants were identified by NUH physicians and then screened again for eligibility by a research assistant stationed temporarily at the clinics. The research assistant described the study procedures to the potential participants, and those that were interested and were eligible were asked to sign an informed consent form. Participants were then asked to complete a packet of paper-and-pencil questionnaires assessing the study variables, described below. Ethical approval was obtained from the National Healthcare Group Domain Specific Review Board.

2.3 Measures

2.3.1 Average pain intensity

Four measures were used to assess average pain intensity: (1) a 0–10 NRS; (2) a Visual Analog Scale (VAS); (3) a VRS; and (4) the FPS-R [24]. With the NRS, participants were asked to rate their average pain intensity over the last 7 days by selecting a single number from 0 to 10. With the VAS, participants were asked to make a hatch mark on a 100 mm line that represents their average pain intensity over the last 7 days. With the FPS-R, participants were asked to rate their average pain over the last 7 days by selecting one of six line drawings of faces expressing an increasing level of pain intensity. These were then converted to a numerical score for each face (i.e. 0, 2, 4, 6, 8, or 10), depending on the face selected. The end-point descriptors for the NRS, VAS, and FPS-R were "*No pain*" (0, 0 mm, and the face representing no pain, respectively) and "*The most intense pain imaginable*" (10, 100 mm, and the face representing the most intense pain level, respectively). Finally, with the VRS, participants were asked to select one of four descriptors that represent four different levels of pain intensity (i.e. "*None*", "*Mild*", "*Moderate*", and "*Severe*"). Each of these measures of pain intensity have a great deal of support for their reliability and validity when used with adults [2, 11, 32].

2.3.2 Pain unpleasantness

Participants were asked to rate their average pain unpleasantness over the last 7 days by selecting a single number

from 0 to 10. The end-point descriptors were "*Not unpleasant*" (0) and "*The most unpleasant pain imaginable*" (10). This measure has been found to possess good convergent and discriminant validity, and sensitivity to change [33].

2.3.3 Depressive symptomatology

Depressive symptoms were assessed using the Patient Health Questionnaire-9 (PHQ-9) [34]. The PHQ-9 asks respondents to rate the frequency of nine symptoms of depression over the past 2 weeks on 4-point Likert scales (with anchors: "*Not at all*" to "*Nearly every day*") that reflect the nine DSM-IV criteria for major depression [35]. PHQ-9 scores can range from 0 to 27, with higher scores representing greater symptom severity. This scale has been widely used in clinical and research settings and thus much evidence supporting its validity is available [36–38]. Also, a strong correlation between Beck's Depression Inventory II and the PHQ-9 has been reported, $r = 0.84$, $p < 0.001$ suggesting good convergent validity [39]. The reliability (internal consistency) of the PHQ-9 in the current sample was excellent (Cronbach's $\alpha = 0.92$).

2.3.4 Catastrophizing

Pain catastrophizing was assessed using the 13-item Pain Catastrophizing Scale [40]. This scale asked participants to rate the degree to which they have catastrophizing thoughts and feelings when experiencing pain on 5-point Likert scales. A total score is computed by summing the responses to each item which can range from 0 to 52, with higher scores representing greater use of catastrophic thinking in response to pain. The PCS has been shown to have concurrent and discriminant validity, and high test-retest reliability over a 6-week period [40–42]. In the current sample, the internal consistency of the PCS was found to be excellent (Cronbach's $\alpha = 0.96$).

2.3.5 Pain interference

Pain interference was measured using the four-item Pain Interference Short Form of the Patient-Reported Outcomes Measurement Information System (PROMIS) [43]. The items selected asked participants to rate the magnitude of pain interference with day-to-day activities, work around the home, ability to participate in social activities, and enjoyment of life. Each question is rated on a 5-point Likert scale ("*Not at all*" to "*Very much*"), and the responses to the items are summed to create a raw score that can range from 4 to 20. Like all PROMIS measures, the Pain Interference raw score can be converted to a standardized t-score representing the domain of interest, with a mean of 50 and standard deviation of 10 in the normative sample [43]. In the current sample, the internal consistency of the 4-item scale was found to be excellent (Cronbach's $\alpha = 0.90$).

2.4 Data analysis

The number and percentages (for categorical variables), means and standard deviations (for continuous variables), or median and 25th and 75th percentile (for ordinal variables) of the demographic and study variables were first computed for descriptive purposes. We then computed Pearson's correlations between the four pain intensity measures. Next, we performed a series of Steiger's (1980) tests [44, 45] to test the hypothesis that the association between the NRS and VAS would be stronger than the associations between any other pair of pain intensity measures.

Finally, we performed three hierarchical regression analyses to evaluate the hypothesized associations between the VRS, FPS-R, and VAS and measures of pain interference, pain catastrophizing, depressive symptoms, and pain unpleasantness, when controlling for NRS ratings, age and gender. In these analyses, the VAS, VRS, and FPS-R pain intensity ratings were the criterion variables. Average pain intensity as measured by the NRS was entered in the first step. In the second step, age and gender were entered as control variables. We then entered the four independent variables (pain unpleasantness, depressive symptoms, pain catastrophizing, and pain interference) as a block in the third and final step. A $p < 0.05$ was used to determine statistical significance. Due to the ordinal nature of VRS and FPS-R, non-parametric analyses (Spearman correlations and ordinal regression) were conducted as a way to determine if the findings would differ if non-parametric analyses were used instead of parametric analyses.

3 Results

3.1 Sample characteristics

A total of 101 participants were enrolled in the study. One of these was excluded from the analyses, as this participant's questionnaire had a substantial amount of missing data. The characteristics of the 100 remaining participants in the study are listed in Table 1. Means and standard

Table 1: Demographic and descriptive variables for the study sample.

	Mean (SD)/Number (%)
Age (years)	48.3 (15.9)
Sex	
Men	53 (53%)
Women	47 (47%)
Race/ethnicity	
Chinese	64 (64%)
Malay	10 (10%)
Indian	20 (20%)
Other race/ethnicity	6 (6%)
Marital status	
Married, living together	59 (59%)
Married, living separately	3 (3%)
Divorced	6 (6%)
Single	28 (28%)
Widow/widower	4 (4%)
Employment status	
Full time	50 (50%)
Part time	6 (6%)
Retired	18 (18%)
Homemaker	11 (11%)
Unemployed	3 (3%)
Not working due to pain	12 (12%)

deviations, and median and interquartile range of the study variables in the sample are presented in Table 2.

3.2 Pearson's correlation analyses

The Pearson's correlation coefficients between each pair of pain intensity ratings are presented in Table 3. The correlation between the NRS and the VAS (r = 0.93, see Table 3) was statistically significantly stronger than the correlation between any other pairs of measures (i.e. NRS/VAS correlation versus: NRS/VRS correlation, z = 5.82, $p = < 0.05$; NRS/FPS-R correlation, z = 5.95, $p = < 0.05$; VAS/VRS correlation, z = 6.71, $p = < 0.05$; VAS/FPS-R correlation, z = 6.89, $p = < 0.05$; and VRS/FPS-R correlation z = 6.91, $p = < 0.05$). None of the other pairs of correlation coefficients were significantly different from one another. The results of the non-parametric analyses examining the associations among the pain ratings were essentially the same as the parametric analyses (see Supplementary Table 1).

3.3 Linear regression analyses

3.3.1 Predicting VAS ratings

Table 4 presents the results of the regression analysis. With VAS as the criterion variable, the findings show a direct positive effect of NRS on VAS in the first step ($\beta = 0.93$; $t = 24.65$, $p < 0.05$). In the second step, neither age nor sex contributed significantly to the prediction of the VAS ratings. In the third step, none of the independent variables, pain unpleasantness, depressive symptoms, pain catastrophizing, and pain interference, were statistically significant.

3.3.2 Predicting VRS ratings

With VRS as the criterion variable, a direct positive effect of NRS on VRS can be seen ($\beta = 0.76$; $t = 11.62$, $p < 0.05$) in the first step (see Table 4). Only age ($\beta = 0.16$; $t = 2.23$, $p < 0.05$), but not sex, was statistically significant in the second step. In the third step, pain interference made a statistically significant ($\beta = 0.19$; $t = 2.30$, $p < 0.05$) unique contribution to

Table 2: Means and standard deviations or median and 25th and 75th percentile of the study variables.

	Mean	(SD)	Median	Percentile	
				(25th)	(75th)
Pain intensity					
– Numerical Rating Scale	5.38	(2.07)	6.00	(4.00)	(7.00)
– Visual Analogue Scale	5.34	(2.19)	5.70	(3.70)	(7.50)
– Verbal Rating Scale	2.86	(0.68)	3.00	(2.00)	(3.00)
– Faces Pain Scale – Revised	5.24	(2.23)	6.00	(4.00)	(6.00)
Pain unpleasantness	5.42	(2.31)			
Pain catastrophizing (PCS)	19.02	(14.91)			
Depressive symptoms (PHQ-9)	7.20	(6.74)			
Pain interference (PROMIS)	60.29	(7.31)			

PCS = Pain Catastrophizing Scale; PHQ-9 = Patient Health Questionnaire – 9; PROMIS = Patient-Reported Outcomes Measurement Information System.

Table 3: Pearson's correlation between the pain intensity scales.

	NRS	VAS	VRS
VAS	0.93[a]		
VRS	0.77[a]	0.73[a]	
FPS-R	0.75[a]	0.72[a]	0.69[a]

NRS = Numerical Rating Scale; VAS = Visual Analogue Scale; VRS = Verbal Rating Scale; FPS-R = Faces Pain Scale – Revised.
[a]$p < 0.05$.

the prediction of the VRS ratings. Pain unpleasantness, depressive symptoms, and pain catastrophizing were not statistically significant in the third step. The results of the non-parametric (ordinal regression) analyses predicting VRS ratings from the same predictors used in the linear regression analyses were essentially the same as those from the parametric analyses (see Supplementary Table 2).

3.3.3 Predicting FPS-R ratings

With FPS-R as the criterion variable, the findings show a direct positive effect of pain NRS on FPS-R in the first step ($\beta = 0.75$; $t = 11.21$, $p < 0.05$; see Table 4). In the second step, age and sex as a block explained 3% of the variance in FPS-R above and beyond NRS. In the third step, only pain unpleasantness made a statistically significant ($\beta = 0.30$; $t = 2.67$, $p < 0.05$) and independent contribution to the prediction of the FPS-R ratings. Depressive symptoms, pain catastrophizing, and pain interference were

Table 4: Results of the linear regression analyses.

Step / Scale	R^2	R^2 change	*F* change	*B* to enter	*t*-value
				Criterion variable: Visual Analogue Scale	
1.	0.86	0.86	607.40[a]		
Pain intensity (NRS)				0.93	24.65[a]
2.	0.86	<0.01	0.34		
Age				0.03	0.74
Gender				−0.03	−0.61
3.	0.87	<0.01	1.15		
Pain unpleasantness				0.07	1.03
Depressive symptoms (PHQ-9)				−0.02	−0.33
Pain catastrophizing (PCS)				−0.06	−1.00
Pain interference (PROMIS)				0.08	1.56
				Criterion variable: Verbal Rating Scale	
1.	0.58	0.58	135.03[a]		
Pain intensity (NRS)				0.76	11.62[a]
2.	0.60	0.02	2.55		
Age				0.16	2.23[a]
Gender				−0.08	−1.15
3.	0.65	0.05	2.94[a]		
Pain unpleasantness				0.03	0.28
Depressive symptoms (PHQ-9)				−0.05	−0.56
Pain catastrophizing (PCS)				0.12	1.27
Pain interference (PROMIS)				0.19	2.30[a]
				Criterion variable: Faces Pain Scale – Revised	
1.	0.56	0.56	125.56[a]		
Pain intensity (NRS)				0.75	11.21[a]
2.	0.60	0.03	3.57[a]		
Age				0.11	1.59
Gender				0.10	1.43
3.	0.65	0.05	3.12[a]		
Pain unpleasantness				0.30	2.67[a]
Depressive symptoms (PHQ-9)				−0.11	−1.24
Pain catastrophizing (PCS)				0.15	1.66
Pain Interference (PROMIS)				0.05	0.60

NRS = Numerical Rating Scale; PCS = Pain Catastrophizing Scale; PHQ-9 = Patient Health Questionnaire – 9; PROMIS = Patient-Reported Outcomes Measurement Information System.
[a]$p < 0.05$.

not statistically significant in the third step. The results of the non-parametric (ordinal regression) analyses predicting FPS-R ratings from the same predictors used in the linear regression analyses were essentially the same as those from the parametric analyses (see Supplementary Table 2).

4 Discussion

Consistent with the study hypotheses, we found that the strongest association among the four pain intensity measures was between the NRS and VAS. We also found, as hypothesized, that the VRS and FPS-R ratings were associated significantly with pain interference and pain unpleasantness, respectively, after controlling for NRS ratings. Also, the VAS was not associated with any of the potential confounding variables evaluated, once NRS ratings were controlled. However, and inconsistent with the study hypotheses, the VRS was not found to be associated with pain catastrophizing and FPS-R was not associated with depressive symptoms, once NRS ratings were controlled. The findings have important implications for the interpretation of pain intensity as measured by the NRS, VAS, VRS, and FPS-R, in clinical and research settings.

The current findings are consistent with the idea that the VAS and NRS are "more pure" (although not necessarily completely "pure" cf. [18, 19]) measures of pain intensity than either the VRS or FPS-R. This idea is supported by the very strong association between the NRS and VAS ($r = 0.93$), indicating that they measure essentially the same thing, as well as by the finding consistent with this strong association that none of the study predictors were associated with the VAS once the NRS was controlled. This finding is also consistent with past research which has shown that the associations between the NRS and the VAS are stronger than their associations with either the VRS or the FPS-R [4, 11, 31]. However, given that the VAS possesses a number of significant limitations not shared with the NRS [8, 46, 47], such as requiring physical equipment (e.g. pen and paper or an interactive device) as well as the need for respondents to have adequate levels of motor skills, visual acuity, and abstract thinking, the NRS can still be considered as the first choice measure of pain intensity when the population to be studied can use it reliably [2].

The study findings also suggest that the VRS and FPS-R, while they share as much as 56% and 59% of the variance with the NRS, respectively, also appear to share variance with pain interference and pain unpleasantness, respectively. These findings are in line with past research which has shown that the VRS ratings are influenced by pain interference (at least when entered as a composite score with other variables) [23], and the FPS can be viewed as representing emotional responses [29, 30].

Thus, when individuals with chronic pain report their pain as being "severe" on a VRS, they may not be merely communicating that the intensity of their pain is of a high magnitude, but also communicating that the pain is interfering with their lives. Similarly, when individuals choose a facial drawing of a higher magnitude on the FPS-R, they may be communicating – at least to some degree – how they are affected emotionally by the pain. This knowledge may help in the interpretation of study findings with respect to the effects of pain treatment on these measures. For example, some of the benefits in "pain intensity" following cognitive behavioral therapy for chronic pain (which involves methods aimed directly at the thoughts associated with pain, the avoidance of unpleasant thoughts and of painful experiences, and the beliefs about pain and their relationship with behavior [48]) as measured by the VRS or the FPS-R may be due, at least in part, to the changes in pain-related domains other than just pain intensity (i.e. pain interference and pain unpleasantness, respectively). Researchers should therefore keep in mind the factors that contribute to these pain intensity ratings when interpreting research studies using the VRS and FPS-R.

Future research should examine the generalizability of this study's results to populations where a VRS or FPS-R may be more appropriate than a NRS or VAS (e.g. some elderly individuals, individuals with severe cognitive impairment or pediatric samples) [9–17, 49]. There is a possibility that the influence of pain interference and pain unpleasantness on the VRS and FPS-R may be even greater among these populations than the population of patients studied here. For example, researchers have found that right hemispheric stroke patients reported that the FPS was more a measure of sadness than pain, while the opposite pattern was found in non-stroke controls [29].

Despite the positive findings with respect to the role that pain interference has on VRS ratings and pain unpleasantness has on FPS-R ratings, the study hypotheses regarding the influence of pain catastrophizing and depressive symptomatology on VRS and FPS-R ratings, respectively, were not supported. The null finding with respect to the VRS was unexpected as a previous study found the potential influence of pain catastrophizing on VRS scores [23]. The difference in findings may be due to the fact that a composite score (containing information about pain catastrophizing and other variables) was

used and pain catastrophizing was assessed with a different measure in the previous study. The null finding with respect to a role for depression in FPS-R ratings was surprising given past research with adults and elderly patients indicating that the FPS-R can be viewed as representing sadness [29, 30]. The null finding in the current study may have been due to a possible floor effect in depression in the sample. As the sample size was relatively small, the null findings with respect to both the VRS and FPS-R may have also been due to limited power.

There are several limitations of this study that should be considered when interpreting the results. First, the sample size ($n=100$) was relatively small. The relatively low sample size may have limited the power to test the study hypotheses; for example, significant associations between catastrophizing and VRS ratings or between depressive symptoms and FPS-R ratings might have emerged had the sample size been larger. Therefore, it would be useful to replicate this study with larger samples. Second, the use of a convenience sample of patients being treated in a pain clinic may have biased the sample in ways that we cannot determine. Thus, replicating the findings in additional samples of individuals with chronic pain would help to determine their reliability. Third, our sample consisted of mostly middle-aged participants who were cognitively intact with primarily chronic lower back and/or knee pain. The extent to which the findings generalize to populations where the VRS and FPS-R are more likely to be needed and used (e.g. very elderly individuals and/or individuals with cognitive deficits) or to populations with other forms of pain is not known. This provides another reason for the need to replicate the findings in additional samples. Fourth, given the fact that the VRS and FPS-R measures are ordinal and may lack ratio qualities, it would be reasonable to question the validity of using parametric analyses with these measures. At the same time, if we had limited the analyses to parametric tests for to predict the VAS scores and non-parametric tests to predict the VRS and FPS-R scores, this would have limited our ability to directly compare the findings across measures or to previous studies which used parametric analyses [11, 23, 50]. To address this issue, we also performed non-parametric analyses. In support of the accuracy of the parametric analysis results, the results of the non-parametric analyses were essentially the same. Finally, the sample consisted mostly of individuals with only mild depression at the most [34]. As alluded to previously, this may have produced a floor effect (restriction of range in depression scores) contributing to the negative findings regarding the influence of depressive symptoms on the FPS-R.

Despite the study's limitations, the results provide important new information regarding the potential influence of domains (other than pain intensity) on VRS, FPS-R, and VAS ratings. The findings suggest that the VAS provides a measure of pain intensity very similar to the NRS that is less influenced by beliefs about pain or distress than the VRS or FPS-R. On the other hand, VRS and FPS-R ratings of pain intensity appear to reflect both pain intensity (as measured by the NRS) as well as pain interference and pain unpleasantness, respectively. Future research is needed to evaluate the generalizability of these findings in older, younger, and cognitively impaired individuals, where the VRS and FPS-R scales are more likely to be used.

Authors' statements

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