Confirmatory Factor Analysis and Multiple Linear Regression of the Neck Disability Index: Assessment If Subscales Are Equally Relevant in Whiplash and Nonspecific Neck Pain

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Abstract

Objective: Because of previously published recommendations to modify the Neck Disability Index (NDI), we evaluated the responsiveness and dimensionality of the NDI within a population of adult whiplash-injured subjects. The purpose of the present study was to evaluate the responsiveness and dimensionality of the NDI within a population of adult whiplash-injured subjects.

Methods: Subjects who had sustained whiplash injuries of grade 2 or higher completed an NDI questionnaire. There were 123 subjects (55% female, of which 36% had recovered and 64% had chronic symptoms). NDI subscales were analyzed using confirmatory factor analysis, considering only the subscales and, secondly, using sex as an 11th variable. The subscales were also tested with multiple linear regression modeling using the total score as a target variable.

Results: When considering only the 10 NDI subscales, only a single factor emerged, with an eigenvalue of 5.4, explaining 53.7% of the total variance. Strong correlation ($>.55$) ($P < .0001$) between all variables was found. Multiple linear regression modeling revealed high internal consistency with all coefficients reaching significance ($P < .0001$). The 4 NDI subscales exerting the greatest effect were, in decreasing order, Sleeping, Lifting, Headaches, and Pain Intensity.

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Conclusion: A 2-factor model of the NDI is not justified based on our results, and in this population of whiplash subjects, the NDI was unidimensional, demonstrating high internal consistency and supporting the original validation study of Vernon and Mior.
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Introduction

In the 1980s, Fairbank et al.¹ developed a questionnaire for the assessment of disability related to low back pain. Known today as the *Revised Oswestry Disability Index*, it is widely used both in the clinical setting and in research.² It is a self-assessment questionnaire that subjects can quickly complete in a few minutes, and it can be easily scored by therapists or physicians. The format is categorical, but each category is ordinal. Accordingly, the scale is not arithmetically isomorphic, and the scores cannot be considered linearly correlated with disablement. This also raises some questions concerning derivative calculations or the use of parametric statistical methods that are sometimes applied to Neck Disability Index (NDI) scores.³

In 1991, Vernon and Mior³ modified the Revised Oswestry Disability Questionnaire so that it would be responsive to disability related to neck pain and named it the *Neck Disability Index*. The NDI was initially validated in a whiplash patient population and achieved a high degree of internal consistency, reliability, and responsiveness, and has been revalidated in several studies since then.^{3,4} In subsequent years, a number of other questionnaires have been introduced. These include the Whiplash Disability Questionnaire,^{5–7} the Functional Rating Index,⁸ the Northwick Park Neck Pain Questionnaire,^{6,7} the Neck Pain and Disability Scale,⁶ the Copenhagen Neck Functional Disability Index,^{6,9,10} and the EQ-5D.¹¹ But to date, the NDI has been the most extensively used questionnaire in clinical trials and outcome studies.^{6,10,12–40}

The general format of the NDI follows that of the Revised Oswestry Disability Index, with a 10-item subscale design. The subscales include Pain Intensity, Personal Care, Lifting, Reading, Headaches, Concentration, Work, Driving, Sleeping, and Recreation. Each has a 6-level response, with the first representing the normal, nonimpaired or nonsymptomatic state and carrying a score of 0, and the last representing the greatest degree of symptoms or impairment and carrying a score of 5. The 10 subscales are then summed and multiplied by 2, thereby providing a potential range of 0–100, to which the phrase *percent disability* is appended.

The NDI has been used in a wide variety of clinical conditions affecting the cervical spine, and it is assumed by most that it is a nonspecific measure of neck-related conditions.⁴¹ van der Velde et al.⁴² studied the threshold ordering of NDI subscale items and tested the assumption of unidimensionality. They reported that Headaches and Recreation subscales showed statistically significant misfit or deviation from model expectations. They concluded that it is not a unidimensional scale and optimized it by eliminating 2 subscales: Headaches and Lifting. Their pooled data source comprised persons with primarily mechanical (ie, nonspecific) neck pain.

Gabel et al.⁴¹ used confirmatory factor analysis in their study of 1278 pooled subjects which were obtained from 6 separate published studies. They assumed that the NDI is not a condition-specific measure of neck function and considered problematic neck pain subjects as a homogeneous group. They reported that the NDI conformed to a 1-factor structure, although a 2-factor structure approached a level of significance ($P < .07$) based on slight differences between the sexes, as they dichotomized over mental function and physical function constructs.

Headaches are generally reported with high frequency and risk relevance among whiplash subjects,^{43–46} as is lower back pain,^{47–49} which would likely correlate with the Lifting subscale. Among a more general population of persons with mechanical neck pain, lower back pain is not expected to be as common. A question of the relative responsiveness of the NDI across divergent clinical conditions thus arises. Is the NDI a better measure of disability, impairment, or function in whiplash subjects as compared with a population of general mechanical neck pain? Because of previously published recommendations to modify the NDI based upon groups of subjects with mechanical neck pain, the purpose of the present study was to evaluate the responsiveness and dimensionality of the NDI within a population of adult whiplash-injured subjects.

Methods

This investigation included 123 volunteers (55 men, 68 women) who had suffered a whiplash injury for

which they sought medical care. Whiplash grades were 2 and 3. The age of volunteers was normally distributed, with a range from 18 to 68 years. Fifty percent of the volunteers were younger than 40 years. At the time of inception, subjects were asked to self-rate themselves as being either recovered (36%) or nonrecovered (64%). Inclusion criteria included fluency in English and the requirement that they were at least 18 years of age when the injury occurred. Exclusionary criteria included prior cervical spine surgery or serious spinal disease/disorder, chronic neck pain not related to a whiplash injury, and pending litigation. Persons who had suffered spinal cord injury, spinal fracture, or spinal dislocation in their motor vehicle collision were also excluded. Informed consent was obtained, and institutional review board approval was obtained from Walden University. All of the subjects completed the NDI, and these were all checked for completeness and correctness (eg, unanswered items and double responses were not permitted) in accordance with the normal protocol.

After all data were input, we used IBM's SPSS, version 22 (Armonk, NY), to perform a confirmatory factor analysis using principal component analysis (PCA) extraction of the 10 NDI subscales. We then added an 11th variable, sex, and completed a second confirmatory factor analysis. It should be noted that factor analysis and PCA differ in the ways that they deal with error. In the former, the goal is parsimony through the explanation of the maximum *common variance* in a correlation matrix or R-matrix. It deals more realistically with partial correlations. In the latter, error is ignored and the maximum amount of *total variance* is explained. The results of the 2 also have different names. In factor analysis, one speaks of *factors*. In PCA, one speaks of *components*. SPSS,

however, uses the term *component* in its output, so that term will be seen in some of the tables below.

We also performed multiple linear regression modeling of the 10 subscales against the NDI Total score as the target variable using a forward stepwise model selection method.

Results

Confirmatory Factor Analysis

In the initial confirmatory factor analysis, only 1 factor was extracted. The Kaiser-Meyer-Olkin measure of sampling adequacy was .904, indicating a very low presence of partial correlation coefficients. The correlation matrix is shown in Table 1.

The highest correlation (.673) was between Reading and Driving subscales. The total variance explained is shown in Table 2.

In this case, there is only 1 factor. It had an eigenvalue of 5.375, and it contains all 10 subscales, explaining 53.7% of the variance. Additional factors are excluded by convention when their eigenvalues, which are the variances of factors, are less than 1.

The final component (factor) matrix is shown in Table 3. The term *matrix* is assigned by SPSS because there are often multiple factors in a confirmatory factor analysis, but in the present case, because there was only a single factor, it takes the form of a hierarchal list of coefficients or relative values within the linear regression function.

Gabel et al⁴¹ considered sex as an additional variable in their confirmatory factor analysis. We therefore ran a separate analysis which included sex

Table 1 Correlation Matrix

	Pain Intensity	Personal Care	Lifting	Reading	Headaches	Concentration	Work	Driving	Sleeping	Recreation
Pain Intensity	1.000	.364	.638	.501	.459	.433	.484	.565	.562	.495
Personal Care	.364	1.000	.374	.306	.256	.339	.409	.371	.361	.418
Lifting	.638	.374	1.000	.343	.330	.386	.556	.385	.526	.514
Reading	.501	.306	.343	1.000	.546	.498	.552	.673	.519	.699
Headaches	.459	.256	.330	.546	1.000	.318	.456	.586	.487	.489
Concentration	.433	.339	.386	.498	.318	1.000	.515	.508	.381	.460
Work	.484	.409	.556	.552	.456	.515	1.000	.594	.506	.659
Driving	.565	.371	.385	.673	.586	.508	.594	1.000	.567	.629
Sleeping	.562	.361	.526	.519	.487	.381	.506	.567	1.000	.565
Recreation	.495	.418	.514	.699	.489	.460	.659	.629	.565	1.000

Table 2 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.375	53.749	53.749	5.375	53.749	53.749
2	.926	9.255	63.004			
3	.764	7.642	70.646			
4	.663	6.626	77.273			
5	.548	5.475	82.748			
6	.466	4.665	87.413			
7	.422	4.219	91.632			
8	.350	3.503	95.135			
9	.262	2.616	97.751			
10	.225	2.249	100.000			

Extraction method: principal component analysis

as an 11th variable. Sex was shown to correlate very weakly (.182) ($P = .022$) with Lifting in the correlation matrix. There were no other correlations approaching significance. Nevertheless, by including the sex variable, 2 factors were identified, extraction occurred, and rotation was undertaken. In this instance, the first factor again had an initial eigenvalue of 5.375 but now explained 48.86% of the variance. The postrotation explanation of variance was 42.60%. The second factor, which resulted from including the sex variable, had an initial eigenvalue of 1.164, an initial proportional explanation of variance of 10.586%, and a postrotation explanation of variance of 12.022%. The total variance explained by both factors after rotation was 59.449%. Thus, by including the second factor, only 5.7% additional variance could be explained as compared to the 1-factor structure that considered only the 10 NDI subscales.

Multiple Linear Regression Modeling

Because most of the individual subscale scores were between 0 and 3 in our data set, the data were transformed by collapsing categories to maximize the associations with the target variable, NDI Total score. The Studentized residuals were normally distributed. A forward stepwise modeling method was used using the Akaike information criterion as a protocol for entry or removal. Once again, all of the subscales reached significance ($P < .0001$). The 4 subscales exerting the greatest effect were, in decreasing order, Sleeping, Lifting, Headaches, and Pain Intensity.

Discussion

Confirmatory Factor Analysis

Factor analysis looks at correlation matrices and tries to find explanatory constructs within them. For example, a cluster of 3 or 4 variables might correlate in such a way that they might represent a specific dimension. For example, if Pain Intensity and Headaches were strongly correlated with each other, but not so much with other variables, they might be thought of as a *somatic dimension*. If Lifting, Work, and Recreation correlated with each other strongly, but not so much with other variables, they might be thought of as a *physical performance* dimension. If no such clusters are revealed and all variables are strongly correlated with each other, they would be considered unidimensional. That was the case with the NDI subscales in this study.

van der Velde et al.⁴² reported from their pooled data of nonspecific neck pain that the NDI subscales of Headaches and Recreation did not fit their expected model. They reported that there was a multidimensionality in the NDI, and as a remedy, they proposed the elimination of the Headaches and Lifting subscales, leaving an improved NDI-8 questionnaire. But in contrast to their findings, our confirmatory factor analysis indicated that the coefficient for Recreation was the highest of all (.822) in our purely whiplash population (Table 3).

Headaches and Lifting subscales also had relatively high coefficients which are in accord with the clinical

and epidemiological whiplash literature. All of the subscales had values greater than .55 which attest to their performance within the framework of this kind of analysis. Pain Intensity is found at the midpoint on the component (factor) matrix, which might intuitively seem odd, considering that neck pain following whiplash injury is the most prevalent symptom of all; but in factor analysis, the goal is to analyze shared variance among variables. Among those with the highest frequency, the coefficients of a linear function will often not be the highest because of low signal to noise ratio.

Based on our results, none of the subscales, if eliminated, would improve the construct validity or unidimensionality of the NDI. This would imply that the *fit* for whiplash-injured subjects and the *fit* for those with nonspecific neck pain are not equivalent. Not coincidentally, the NDI was originally validated in a whiplash population.³

The 2-factor model which resulted from the second analysis that included sex as an 11th variable explained only an additional 5.7% of variance beyond the 1-factor model. Moreover, customarily, those factors with eigenvalues of less than 1 are disregarded. Thus, with an eigenvalue of 1.164 and a single significant correlation, the 2-factor model has little to recommend it, and we would agree with Gabel et al⁴¹ that a 1-factor model is preferable.

Multiple Linear Regression Modeling

As with the factor analysis, the regression model indicated that all transformed subscales predicted the target variable of NDI Total with high levels of significance for the resulting coefficients. Those with the highest predictive value were Sleeping, Lifting, Headaches, and Pain Intensity, in descending order.

Sleeping problems have been identified as a common complaint among whiplash sufferers. Nieto et al³⁷ reported a frequency of 58.4%. Among those suffering from postconcussion syndrome, the largest proportion of which are the result of motor vehicle collisions, sleep disturbances are second only to fatigue in terms of frequency.⁵⁰ However, sleeping difficulties are also common among persons with nonspecific neck pain. A recent study compared reported sleeping difficulties between a control group and persons with whiplash-related neck pain and a group suffering from mechanical neck pain. Both groups reported significantly greater difficulties than did controls, with 77% of whiplash subjects and 68% of mechanical neck pain

Table 3 Subscale Matrix

Subscales	
Recreation	.822
Driving	.815
Work	.790
Reading	.784
Pain intensity	.754
Sleeping	.753
Lifting	.687
Headaches	.676
Concentration	.656
Personal care	.550

Extraction method: principal component analysis

subjects reporting poor sleep quality.⁵¹ A recent German case-control study of subjects with chronic neck pain and chronic low back pain reported that sleeping difficulties were present in 42.2%.⁵²

Overall, these results suggest that the NDI does have high responsiveness within a whiplash population, and coupled with the report of van der Velde et al,⁴² the results suggest that the NDI's responsiveness within a mechanical or nonspecific neck pain population may be lower as a result of anatomical and pathophysiological differences between the 2 conditions.

If future studies confirm the differences among neck pain subpopulations, a potential solution might be to devise a derivative of the NDI for nonspecific neck pain. This would require substantial additional research and testing. In the meantime, or as an alternative, practitioners and researchers should be mindful of the ways in which different forms of neck pain can influence NDI scores. For example, whiplash subjects might have generally higher scores than nonspecific neck pain subjects, in part, as a reflection of the somewhat higher relevance of some subscales of the questionnaire to whiplash-specific common complaints.

Limitations

Factor analysis becomes increasingly more reliable with larger sample sizes. Our sample was not large, although the Kaiser-Meyer-Olkin value of .904 and the rather high levels of correlation coefficients suggest that the study did have adequate statistical power. Nevertheless, the scores reported here, and even the relative predictive order of subscale coefficients, can be expected to vary somewhat from one sample to another.

Conclusions

The NDI was shown to be unidimensional and have good responsiveness in our study of whiplash subjects. We did not find multidimensionality or poor-fitting constructs among the subscales as others have found when applying the NDI to nonspecific neck pain populations. In fact, our data took a rather opposite trajectory, with a multiple linear regression model indicating that the 2 subscales that van der Velde et al eliminated, Headaches and Lifting, were among those with the highest overall effect.

Our confirmatory factor analysis supported a 1-factor model as the best construct, and it comprised all 10 subscales. The small (5.7%) increment in explained variance afforded by the 2-factor construct which included the variable sex does not justify any modification to the current NDI. Nevertheless, our sample was relatively small ($N = 123$), and additional comparative studies with larger populations of both whiplash and nonspecific neck pain subjects will be needed to more definitely resolve these important questions.

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