Development of a Clinical Prediction Rule for Guiding Treatment of a Subgroup of Patients With Neck Pain: Use of Thoracic Spine Manipulation, Exercise, and Patient Education

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Background and Purpose

To date, no studies have investigated the predictive validity of variables from the initial examination to identify patients with neck pain who are likely to benefit from thoracic spine thrust manipulation. The purpose of this study was to develop a clinical prediction rule (CPR) to identify patients with neck pain who are likely to experience early success from thoracic spine thrust manipulation.

Subjects

This was a prospective, cohort study of patients with mechanical neck pain who were referred for physical therapy.

Methods

Subjects underwent a standardized examination and then a series of thoracic spine thrust manipulation techniques. They were classified as having experienced a successful outcome at the second and third sessions based on their perceived recovery. Potential predictor variables were entered into a stepwise logistic regression model to determine the most accurate set of variables for prediction of treatment success.

Results

Data for 78 subjects were included in the data analysis, of which 42 had a successful outcome. A CPR with 6 variables was identified. If 3 of the 6 variables (positive likelihood ratio=5.5) were present, the chance of experiencing a successful outcome improved from 54% to 86%.

Discussion and Conclusion

The CPR provides the ability to *a priori* identify patients with neck pain who are likely to experience early success with thoracic spine thrust manipulation. However, future studies are necessary to validate the rule.

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Neck pain is a common occurrence with a lifetime incidence ranging from 22% to 70%.[1,2] Over a third of patients will develop chronic symptoms lasting more than 6 months in duration,[3] representing a serious health concern.[4] Over 50% of patients with neck pain are referred for physical therapy and comprise approximately 25% of all patients seeking physical therapy services.[5,6] Although cervical spine thrust manipulation has been advocated as an intervention appropriate for the care of patients with neck disorders, clinicians must consider the benefits relative to the potential risks, especially vertebral artery insult.[7,8] The lack of evidence for premanipulative screening to identify which patients may be at risk has caused some authors to suggest that serious complications, although rare, are unpredictable and that the potential benefits of cervical spine thrust manipulation do not outweigh the inherent risks.[8,9]

Clinical experience and preliminary evidence suggest that thoracic spine thrust manipulation may be useful in the management of patients with neck pain.[10] The biomechanical link between the cervical spine and the thoracic spine suggest that disturbances in joint mobility in the thoracic spine may serve as an underlying contributor to the development of neck disorders. In addition, it has been demonstrated that a significant association exists between decreased mobility of the thoracic spine and the presence of patient-reported complaints associated with neck pain.[11] With inherently lower risk of serious complications, thoracic spine thrust manipulation might be a suitable alternative, or supplement, to cervical spine thrust manipulation. Perhaps this accounts for why some clinicians perform thoracic spine thrust manipulation rather than cervical spine thrust manipulation at much higher rates in patients with neck pain.[12]

Although widely used in patients with neck pain, there are currently no decision-making strategies to identify individual patients with neck pain who are most likely to benefit from thoracic spine thrust manipulation.[10,13,14] Classification provides a means of breaking down a larger entity into more homogenous subgroups of patients based on examination data.[15,16] Moreover, classification is most helpful for physical therapists when it is based on signs and symptoms that match interventions to the subgroup of patients most likely to benefit from them (ie, treatment-based classification).[17]

Clinical prediction rules (CPRs) consist of combinations of variables obtained from self-report measures and the historical and clinical examinations and assist with subgrouping patients into specific classifications. Recently, CPRs have been shown to be useful in classifying patients with low back pain (LBP) who are likely to benefit from a particular treatment approach.[18–20] Although a treatment-based classification system for the management of neck pain has recently been proposed,[21] no studies have investigated the predictive validity of variables from the initial examination to identify patients with neck pain who are likely to benefit from thoracic spine thrust manipulation. Therefore, the purpose of this study was to develop a CPR to identify patients with neck pain who are likely to benefit from thoracic spine thrust manipulation based on a reference standard of patient-reported improvement.

Materials and Methods

We conducted a prospective cohort study of consecutive patients with mechanical neck pain who were referred for physical therapy at one clinical site (Rehabilitation Services, Concord, Hospital, Concord, NH). Inclusion criteria required subjects to be between the ages of 18 and 60 years, with a primary complaint of neck pain with or without unilateral upper-extremity symptoms and a baseline Neck Disability Index (NDI) score of 10% or greater. Exclusion criteria were as follows: identification of any medical "red flags" suggestive of a nonmusculoskeletal etiology of symptoms, history of a whiplash injury within 6 weeks of the examination, a diagnosis of cervical spinal stenosis, evidence of any central nervous system involvement, or signs consistent with nerve root compression (at least 2 of the following had to be diminished to be considered nerve root involvement: myotomal strength, sensation, or reflexes). All subjects reviewed and signed a consent form approved by the Institutional Review Board at Concord Hospital, Concord, NH.

Therapists

Four physical therapists participated in the examination and treatment of subjects in this study. All therapists underwent a standardized training regimen, which included studying a manual of standard procedures with the operational definitions and video clips demonstrating each examination and treatment procedure used in this study. All participating therapists then underwent a 1-hour training session in which they practiced the examination and treatment techniques to ensure that all study procedures were performed in a standardized fashion. Prior to participating in data collection, therapists were visually observed by the principal investigator as being able to successfully perform all examination and treatment procedures on a patient with neck pain. Participating therapists had a mean of 12.3 years (SD=10.0, range=3–23) of clinical experience.

Examination Procedures

Subjects provided demographic information and completed a variety of self-report measures, followed by a standardized history and physical examination at baseline. Self-report measures included a body diagram to assess the distribution of symptoms,[22] a numeric pain rating scale (NPRS),[23] the NDI,[24] and the Fear-Avoidance Beliefs Questionnaire (FABQ). Subjects recorded the location of their symptoms on the body diagram to determine the most distal extent of their symptoms.[22]

The FABQ was used to quantify the subjects' beliefs about the influence of work and activity on their neck pain.[25] The FABQ consists of a work (FABQW) subscale and a physical activity (FABQPA) subscale, both of which have been shown to exhibit a high level of test-retest reliability.[26] The FABQW subscale has been shown to exhibit predictive validity in the identification of patients with LBP who are likely to respond to spinal manipulation,[19,20] but the predictive validity for patients with neck pain is unknown. For this study, the FABQ was modified to replace the word "back" with "neck."[27] Finally, the NDI was used to capture the subjects' perceived level of disability as a result of their neck pain.[24]

The historical examination included questions regarding the mode of onset, nature and location of symptoms, aggravating and relieving factors, and prior history of neck pain. The physical examination began with a neurological screen[28] followed by postural assessment.[29] The operational definitions for postural assessment used in this study were as follows: a subject was identified as having a forward head if the subject's external auditory meatus was anteriorly deviated (anterior to the lumbar spine),[29] and the shoulders were identified as protracted if the acromion was noted to be anteriorly deviated (anterior to the lumbar spine).[29] The examiners were instructed to identify the contour of the spine for the following groups of segments: C7 through T2 (cervicothoracic junction), T3 through T5, and T6 through T10. Each group was recorded as normal (no deviation), as having excessive kyphosis, or as having diminished kyphosis.[30] *Excessive kyphosis* was defined as an increase in the convexity, and *diminished kyphosis* was defined as a flattening of the convexity of the thoracic spine (at each segmental group).[30]

The clinician next measured cervical range of motion and symptom response[31] and assessed the length[28] and strength (force-generating capacity)[29] of the muscles of the upper quarter and endurance of the deep neck flexor muscles.[32] The amount of motion and symptom response were recorded for both segmental mobility testing[28] of the cervical spine and spring testing[33] of the cervical spine and thoracic spine (C2–T9).

The physical examination culminated with a number of special tests typically performed in the examination of patients with neck pain, including the Spurling test,[34] Roos test,[35] Neck Distraction Test,[36] and Upper Limb Neurodynamic Test.[37] Specific operational definitions for each test and criteria defining a positive test are presented in the Appendix.

Of the 80 subjects who were enrolled in the study, 22 underwent a second examination by an additional therapist who was blind to the findings of the first clinician. The 22 subjects who underwent a second evaluation were selected based on the availability of a second clinician to perform the examination. The reliability analysis was performed to evaluate the reliability of the identified potential predictor variables.

Treatment

All subjects received a standardized treatment regimen, regardless of the results of the clinical examination, because treatment outcome served as the reference criterion.[38] Each subject received 3 different thrust manipulation techniques directed at the thoracic spine during each session: a seated "distraction" manipulation, a supine upper thoracic spine manipulation, and a middle thoracic spine manipulation. The first manipulation performed was the "distraction" manipulation. The subject was seated, and the therapist placed his or her upper chest at the level of the subject's middle thoracic spine and grasped the subject's elbows. A high-velocity distraction thrust was performed in an upward direction (Fig. 1).

The upper thoracic spine manipulation was performed with the subject positioned supine and clasping his or her hands across the base of the neck. The therapist used his or her manipulative hand to stabilize the inferior vertebra of the motion segment (the therapist was instructed to target between T1 and T4 with this technique) and used his or her body to push down through the subject's arms to perform a high-velocity, low-amplitude thrust (Fig. 2).

The middle thoracic spine manipulation was performed in the identical fashion as the upper thoracic technique, except the subject grasped the opposite shoulder with his or her hands and the therapist was instructed to target between T5 and T8 with the thrust (Fig. 3). Immediately after performing a manipulation, the treating therapist recorded whether a "pop" was heard. Regardless of the presence of a "pop," the therapist again performed the identical manipulation technique. Therefore, each subject received 6 manipulations per treatment session.

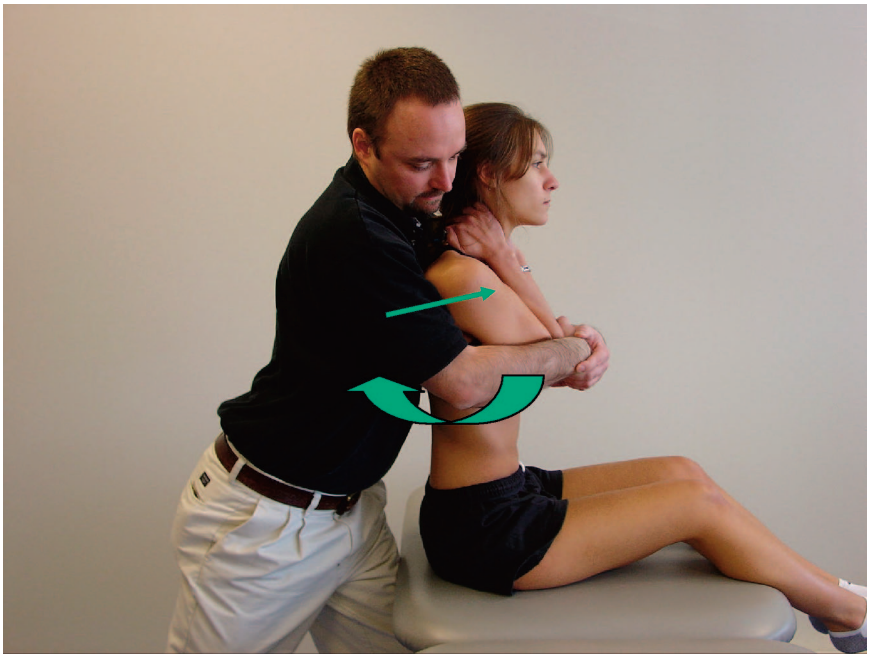

Figure 1.
Seated thoracic spine distraction thrust manipulation used in this study. The therapist uses his or her sternum as a fulcrum on the subject's middle thoracic spine and applies a high-velocity distraction thrust in an upward direction.

Figure 2.
Supine upper thoracic spine thrust manipulation technique used in this study. The therapist uses his or her body to push down through the subject's arms to perform a high-velocity, low-amplitude thrust directed in the direction of the arrow toward T1 through T4.

Following the manipulation techniques, all subjects were instructed in a cervical-range-of-motion (CROM) exercise (10 repetitions performed 3–4 times daily)[39] (Fig. 4) and were advised to maintain their usual activity within the limits of pain. The CROM exercise consisted of the subject placing his or her fingers over the manubrium and placing his or her chin on the fingers. The subject was instructed to rotate to one side as far as possible and return to neutral. This was performed alternately to both sides within pain tolerance. The first treatment session was always performed on the day of the initial examination, and the subject was scheduled for a follow-up visit within 2 to 4 days.

The global rating of change (GROC) served as the reference criterion for establishing a successful outcome. The GROC is a 15-point global rating scale ranging from −7 ("a very great deal worse") to 0 ("about the same") to +7 ("a very great deal better").[40] Intermittent descriptors of worsening or improving are assigned values from −1 to −7 and +1 to +7, respectively.[41,42] It has been reported that scores of +4 and +5 are indicative of moderate changes in patient status and scores of +6 and +7 indicate large changes in patient status.[40] It was determined *a priori* that subjects who rated their perceived recovery on the GROC as "a very great deal better," "a great deal better," or "quite a bit better" (ie, a score of +5 or greater) at the second session were categorized as having a successful outcome, and their participation in the study was complete.

A high threshold for determining a successful outcome was established to maximize the likelihood that the clinical outcome was attributable to meaningful improvements in symptoms due to the intervention as opposed to the passage of time. Sub-

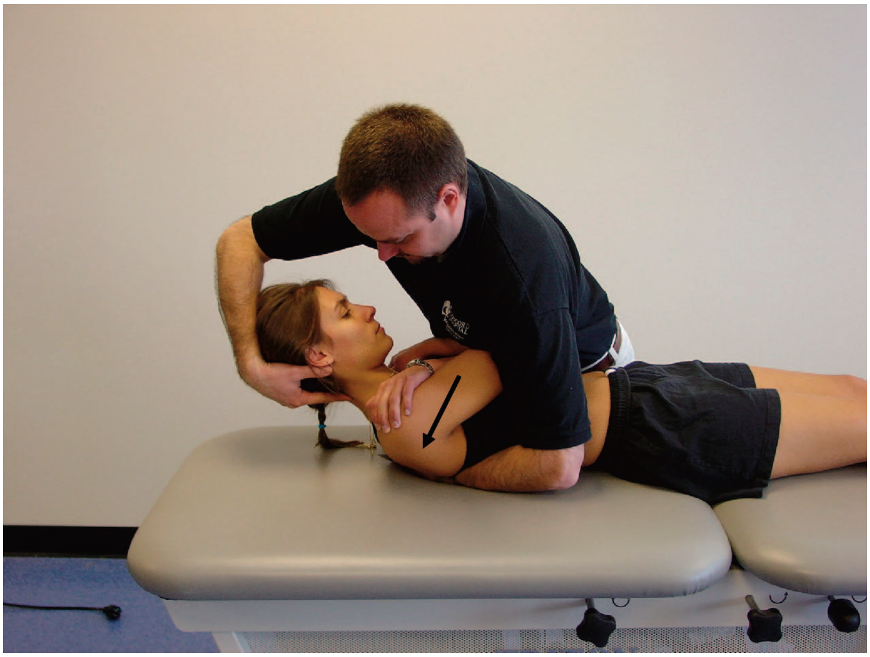

Figure 3.
Supine middle thoracic spine thrust manipulation technique used in this study. The therapist uses his or her body to push down through the subject's arms to perform a high-velocity, low-amplitude thrust directed in the direction of the arrow toward T5 through T8.

jects whose scores on the GROC did not exceed the +5 cutoff at the second session again received the thrust manipulations as in the first treatment and were scheduled for a follow-up within 2 to 4 days. At the start of the third session, subjects again completed the GROC and were judged to have a successful outcome based on the previously described criterion. If the subjects still did not meet the threshold for success, they were categorized as having a nonsuccessful outcome. At this point, their participation in the study was complete, and further treatment was administered at the discretion of their therapist.

In contrast to other studies identifying predictor variables for treatment success in patients with LBP,[18,19] we elected to use perceived recovery rather than a perceived level of disability to determine success as the GROC. This decision is based on the fact that the GROC is considered to be a valid reference standard for identifying clinically important change.[43–45] Perceived recovery also was used as the reference criterion because the NDI has been criticized for not adequately capturing low levels of disability and for not being responsive to small, but clinically important, changes in patients with low levels of initial disability.[46] In addition, a measure of success rate based on patient's perceived recovery has previously been used in trials of patients with neck pain and has been shown to be responsive to changes with physical therapy management programs.[42,46]

Data Analysis

Subjects were dichotomized as having a successful outcome or as having a nonsuccessful outcome based on the treatment response, as indicated on the GROC. The mean NDI and NPRS change scores (and 95% confidence intervals [CIs]) were calculated for the both groups and analyzed using an independent t test to determine whether a difference existed between groups. Individual variables from self-report measures, the history, and the physical examination were tested for univariate relationship with the GROC reference criterion using independent-samples t tests for continuous variables and chi-square tests for categorical variables. Variables with a significance level of $P<.10$ were retained as potential prediction variables.[47] This significance level was selected to increase the likelihood that no potential predictor variables would be overlooked.

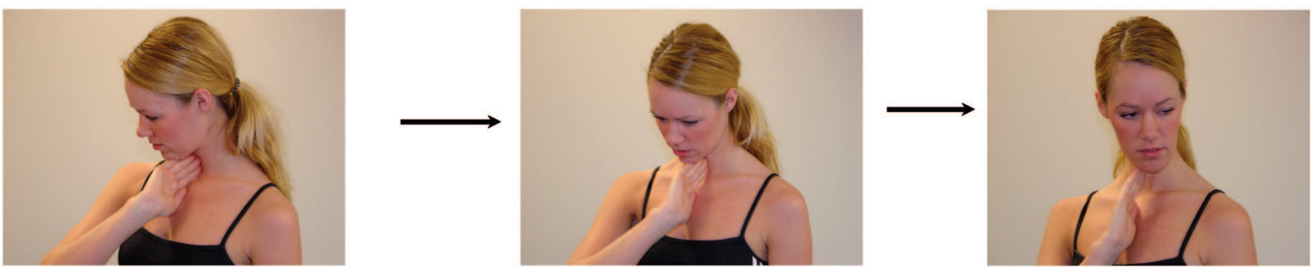

Figure 4.
Active-range-of-motion exercise performed by subjects in the study.

For continuous variables with a significant univariate relationship, sensitivity and specificity values were calculated for all possible cutoff points and then plotted as a receiver operating characteristic (ROC) curve.[48] The point on the curve nearest the upper left-hand corner represented the value with the best diagnostic accuracy, and this point was selected as the cutoff defining a positive test.[48] Sensitivity, specificity, and positive likelihood ratios (LRs) were calculated for potential predictor variables. Potential predictor variables were entered into a stepwise logistic regression model to determine the most accurate set of variables for prediction of treatment success. A significance level of .10 was required for removal from the equation to minimize the likelihood of excluding potentially helpful variables.[47] Variables retained in the regression model were obtained as the CPR for classifying patients with neck pain who are likely to benefit from thoracic spine thrust manipulation, exercise, and patient education for this sample of subjects.

We further analyzed the data to determine whether weighting individual predictors according to the relative size of the beta coefficients increases the prognostic accuracy of the model. Weights were calculated by taking the beta coefficient for each variable in the final model and dividing it by the lowest beta coefficient and then rounding to the nearest integer.[49] Once the weight was formulated, an ROC curve was used to identify the cutoff value that represented the best diagnostic accuracy for the point-based system.[48] Sensitivity, specificity, and positive LRs as well as corresponding 95% confidence intervals were calculated for the cutoff point that maximized the diagnostic utility of the weighting system.

The Cohen kappa (κ)[50] was used to calculate the interrater reliability of categorical data with only 2 possible response options from the patient history and clinical examination. A weighted kappa[51] was used to calculate the reliability of categorical data with 3 response options such as intersegmental mobility assessment techniques as well as the symptom response (increased pain, decreased pain, no change). Intraclass correlation coefficients (ICC[2,1]) and the 95% CIs were calculated to determine the interrater reliability for continuous variables.[52]

Therapists were characterized by years of experience to determine the effect of experience on patient outcomes. Therapists were dichotomized as having 3 or fewer years of experience or more than 3 years of experience. Only one treating clinician had less than 3 years of experience. The percentage of successful outcomes for each group ($\leq$3 years of experience or $>$3 years of experience) was calculated and compared using a chi-square test of independence. The NDI change scores also were calculated and were compared between groups using independent *t* tests.

Results

Between March 2004 and September 2005, 80 subjects were recruited for the study. The total number of subjects screened, reasons for ineligibility, and dropouts are shown in Figure 5. Two subjects failed to return for the second treatment session, and their data were excluded from the analysis. Subject demographics and initial baseline variables from the patient history and self-report measures for the entire sample as well as for the successful outcome and nonsuccessful outcome groups are presented in Table 1. Baseline clinical examination variables for the entire sample and for the successful outcome and nonsuccessful outcome groups are shown in Table 2 for categorical data and in Table 3 for continuous data. Forty-two subjects were categorized as having achieved a successful outcome, and 36 subjects were categorized as having achieved a nonsuccessful outcome. Twenty-three subjects (55%) were classified as having a successful outcome after the initial treatment, and 19 subjects (45%) were classified as having a successful outcome after 2 sessions. The mean number of days between visit 1 and visit 2 was 2.3 (SD=0.7) and 2.3 (SD=0.6) (P=.53) for the successful outcome and nonsuccessful outcome groups, respectively. The mean number of days between visit 1 and visit 3 was 6.3 (SD=1.2) and 6.2 (SD=1.2) (P=.99) for the successful outcome and nonsuccessful outcome groups respectively. Analysis of NPRS and NDI change scores revealed that the successful outcome group experienced significantly greater improvements ($P<.001$) in pain (NPRS change score=2.2, 95% CI=1.4–2.9) and disability (NDI change score=18.6%, 95% CI=13.3–25.0) over the nonsuccessful outcome group.

The 10 potential predictor variables (Tab. 4) that exhibited a significance level of less than .10 were entered into the logistic regression. The cutoff values determined by the ROC curves were 11.5 for the FABQPA subscale, 9.5 for the FABQW subscale, 30 days since the onset of symptoms, and 30 degrees of cervical extension. In addition, the number of prior episodes of neck pain was dichotomized into $<$3 episodes or $\geq$3 episodes. Accuracy statistics for all 10 variables (and 95% CIs) are shown in Table 4. The positive LRs ranged from 1.1 to 6.4, with the strongest predictor being symptom duration of $<$30 days.

The following 6 variables were retained in the final regression model: symptom duration of $<$30 days, no symptoms distal to the shoulder,

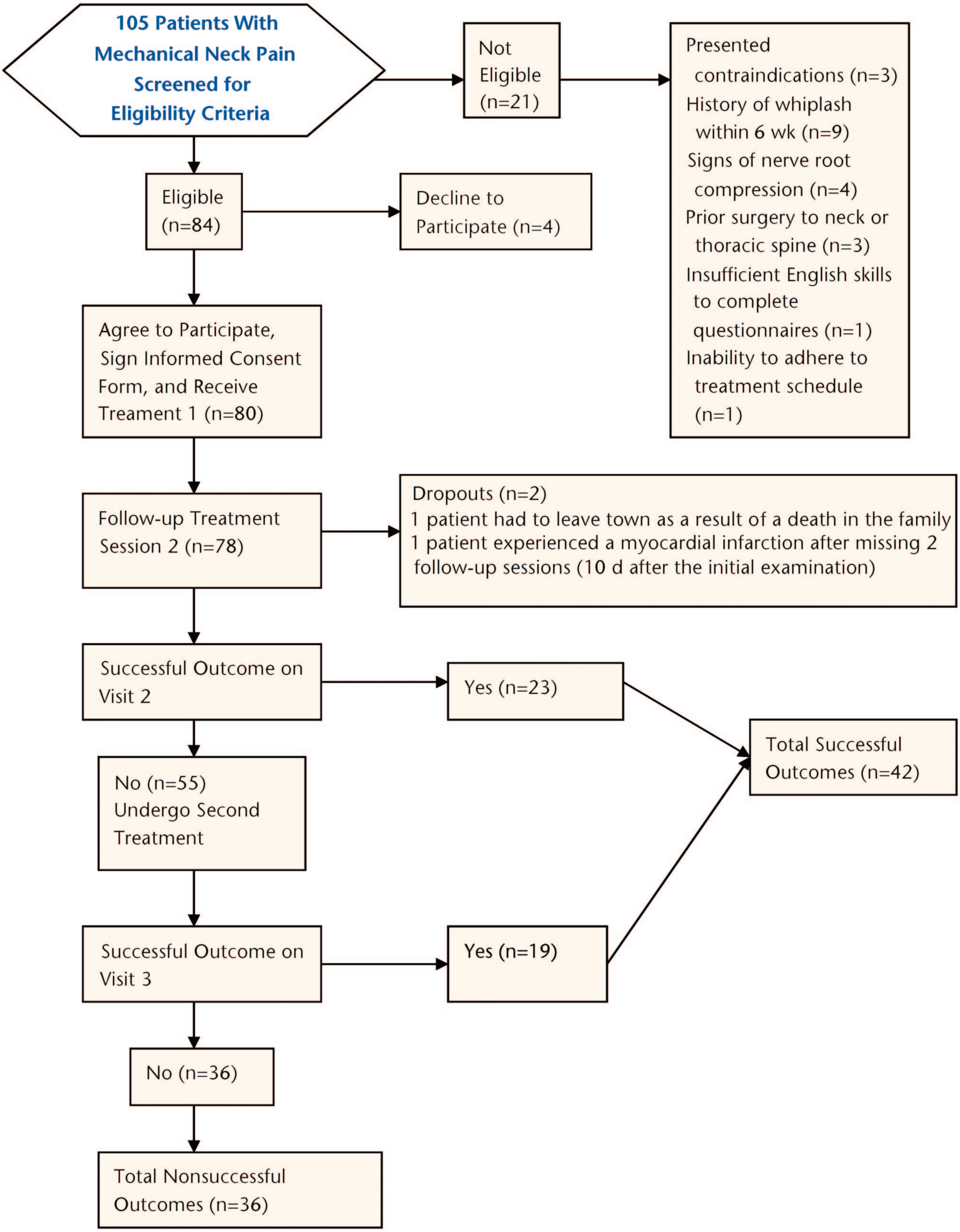

Figure 5.
Flow diagram showing subject recruitment and retention.

Table 1.
Demographics, Baseline Self-report Variables, and Baseline Characteristics of Subjects

Variable[a]	All Subjects (n=78)	Successful Outcome Group (n=42)	Nonsuccessful Outcome Group (n=36)	P
Age, y				
$\overline{X}$	42.0	41.6	42.3	.79[b]
SD	11.3	13.7	8.3	
Range	20–60	20–60	22–56	
Sex				
Female, n (%)	53 (68%)	27 (64%)	26 (72%)	.63[c]
Duration of symptoms, d				
$\overline{X}$	80	54.6	109.6	<.001[b]
SD	70.6	39.6	86.4	
Range	7–395	7–180	21–395	
NPRS				
$\overline{X}$	4.7	4.6	4.8	.86[b]
SD	1.8	1.8	1.8	
Range	1–8	1–8	1–8	
NDI				
$\overline{X}$	34.9	34.5	35.2	.80[b]
SD	10.1	11.3	8.7	
Range	20–58	20–58	22–54	
FABQPA				
$\overline{X}$	12.6	11.8	14.2	.036[b]
SD	4.1	3.8	3.8	
Range	2–22	2–19	6–22	
FABQW				
$\overline{X}$	13.1	10.3	16.2	.01[b]
SD	10.1	8.8	10.8	
Range	0–36	0–28	0–36	
Symptoms distal to the shoulder, n (%)	35 (45%)	12 (29%)	23 (64%)	.083[c]
Mode of onset				
Traumatic, n (%)	32 (41%)	16 (38%)	16 (44%)	.57[c]
Prior history of neck pain, n (%)	26 (33%)	16 (38%)	10 (27%)	.34[a]
Symptoms (n [%]) aggravated by:				
Turning right	52 (67%)	29 (69%)	23 (64%)	.63[c]
Turning left	51 (65%)	28 (67%)	23 (64%)	.80[c]
Looking up	42 (54%)	14 (33%)	28 (78%)	<.001[c]
Looking down	54 (69%)	27 (64%)	27 (75%)	.31[c]
Driving	64 (82%)	33 (79%)	31 (86%)	.39[c]

[a] NPRS=numeric pain rating scale, NDI=Neck Disability Index, FABQPA=Fear-Avoidance Beliefs Questionnaire physical activity subscale, FABQW=Fear-Avoidance Beliefs Questionnaire work subscale.
[b] Analyzed with independent-samples *t* tests.
[c] Analyzed with chi-square tests.

Table 2.
Categorical Variables From the Baseline Clinical Examination

Variable	All Subjects (n=78)	Successful Outcome Group (n=42)	Nonsuccessful Outcome Group (n=36)	*P*
Centralization during cervical motion testing (%)	27	33	20	.17[a]
Peripheralized during cervical motion testing (%)	36	31	42	.33[a]
No. of hypomobile levels identified during spring testing in the cervical spine				
$\overline{X}$	1.4	1.4	1.5	.89[b]
SD	1.4	1.4	1.5	
No. of hypomobile levels identified during spring testing in the thoracic spine				
$\overline{X}$	4.2	4.3	4.1	.73[b]
SD	2.7	2.7	2.8	
Spurling test, positive right (%)	13	12	14	.28[a]
Spurling test, positive left (%)	32	40	22	.14[a]
Cervical distraction test–positive (%)	7.7	7.1	8.3	.84[a]
Forward head posture (%)	94	97	88	.12[a]
Shoulder protraction (%)	73	88	55	.001[a]
Excessive cervicothoracic junction region kyphosis (C7–T2) (%)	74	71	78	.52[a]
Diminished upper thoracic spine kyphosis (T3–T5) (%)	52	56	38	.025[a]
Excessive upper thoracic spine kyphosis (T3–T5) (%)	41	48	33	.20[a]

[a] Analyzed with independent-samples *t* tests.
[b] Analyzed with chi-square tests.

subject reports that looking up does not aggravate symptoms, FABQPA score of <12, diminished upper thoracic spine kyphosis (T3–T5), and cervical extension of <30 degrees (χ^2=55.0, *df*=6, *P*<.001, Nagelkerke R^2=.682). These 6 variables were used to form the most parsimonious combination of predictors for identifying patients with neck pain who are likely to benefit from thoracic spine thrust manipulation. Reliability data for these variables are shown in Table 4. The reliability values for the remainder of the patient history and clinical examination are reported elsewhere.[53]

Fourteen out of 15 subjects who were positive on at least 4 of the criteria and 32 of 37 subjects who were positive on at least 3 criteria were in the successful outcome group. Of the 41 subjects with 2 or fewer variables, 31 were in the nonsuccessful outcome group (Tab. 5). Accuracy statistics were calculated for the numbers of variables present (Tab. 6). The pretest probability for the likelihood of success with thoracic spine thrust manipulation for this study was 54% (42 out of 78 subjects). If a subject exhibited 4 out of the 6 variables, the positive LR was 12.0 (95% CI=2.3–70.8) and the posttest probability of success increased to 93%. If a subject was positive on 3 out of the 6 variables, the positive LR was 5.5 (95% CI=2.7–12.0) and the posttest probability of success was 86%. If only 2 of the 6 variables were present, the positive LR decreased to 2.1 (95% CI=1.5–2.5) and the posttest probability of success was 71%.

The analysis of the point-based system revealed a possible total of 10 points (for the 6 variables). The cutoff that maximized the diagnostic accuracy of the point-based system was 3.5 points. This resulted in a sensitivity of .83 (95% CI=.69–.92), a specificity of .86 (95% CI=.71–.94), a positive LR of 5.9 (95% CI=2.6–13.0), and a posttest probability of 87%.

There was no significant difference in outcomes among therapists with varying levels of experience for either the percentage of successful outcomes or NDI change scores (*P*>.05). The group with ≤3 years of

Table 3.
Continuous Variables From the Baseline Clinical Examination

Variable	All Subjects (n=78)	Successful Outcome Group (n=42)	Nonsuccessful Outcome Group (n=36)	P^a
Cervical flexion (°)[b]				
$\overline{X}$	42.5	41.6	43.5	.49
SD	11.9	12.7	10.9	
Cervical extension (°)[b]				
$\overline{X}$	33.9	28.8	39.8	<.001
SD	12.6	9.4	13.3	
Cervical side bending, right (°)[b]				
$\overline{X}$	31.4	31	31.9	.76
SD	12.9	12.7	13.3	
Cervical side bending, left (°)[b]				
$\overline{X}$	33.4	33.3	33.4	.97
SD	15.5	14.3	17.0	
Cervical rotation, right (°)[c]				
$\overline{X}$	59.6	60.7	58.4	.38
SD	11.8	10.7	13.3	
Cervical rotation, left (°)[c]				
$\overline{X}$	61.2	61.9	60.4	.61
SD	12.2	12.3	12.3	
Deep neck flexor muscle endurance (s)				
$\overline{X}$	6.8	6.0	7.6	.21
SD	5.6	3.6	7.2	

[a] Analyzed with independent-samples *t* tests.
[b] Indicates measurement with a gravity inclinometer.
[c] Indicates measurement with a standard dual-armed goniometer.

experience achieved a success rate of 16/30 (53%), and the group that had >3 years of experience demonstrated a success rate of 26/48 (54%). The NDI change scores were 12.8 (SD=15.7) for the group with ≤3 years of experience and 14.8 (SD=14.6) for the group with >3 years of experience.

Discussion

The LR is the statistic often used to determine the usefulness of a CPR.[19] We selected to report the positive LR because the purpose of this study was to determine the change in probability that patients are likely to experience a successful outcome when they satisfy the criteria of the CPR. Based on the pretest probability in this study (54%) that a subject would respond positively to thoracic spine thrust manipulation, if the subjects exhibited 4 of the 6 criteria (positive LR=12), the posttest probability of success increased dramatically to 93%. However, based on the wide CI associated with positive findings on 4 out of 6 tests (95% CI=2.28–70.8), clinicians can have greater accuracy when determining the likelihood that a patient with neck pain will exhibit a rapid response to thoracic spine thrust manipulation when using 3 out of 6 variables (positive LR=5.5, 95% CI=2.72–12.0) to guide decision making (posttest probability=86%).

In some circumstances, assigning a weight to individual predictors based on the beta coefficients increases the accuracy of prognostic models.[54] However, in some instances, it is possible that translating a prognostic model to a point-based scoring system can decrease the discriminatory power of the index.[55] The cutoff point for the point-based system that maximized the diagnostic accuracy resulted in a positive LR of 5.9 and a posttest probability of 87%, which only exceeded the posttest probability of

Table 4.
Accuracy Statistics With 95% Confidence Intervals (CIs) for Individual Predictor Variables and Interrater Reliability[a]

Variable	Reliability (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	Positive Likelihood Ratio (95% CI)
Symptom duration <30 d	NA	.36 (.22–.52)	.94 (.80–.99)	6.4 (1.60–26.3)
No symptoms distal to the shoulder	NA	.67 (.50–.80)	.53 (.36–.69)	1.4 (0.94–2.2)
FABQPA score <12	NA	.28 (.16–.45)	.91 (.76–.98)	3.4 (1.05–11.20)
FABQW score <10	NA	.55 (.39–.70)	.69 (.52–.83)	1.8 (1.02–3.15)
Prior episodes of neck pain ≥3	.81 (.70–1.00)[b]	.23 (.15–.35)	.83 (.54–.96)	1.9 (1.3–2.7)
Subjects report that looking up does not aggravate symptoms	.80 (.55–1.00)[b]	.67 (.50–.80)	.86 (.70–.95)	4.8 (2.07–11.03)
Subject report of physical exercise >3 times weekly	.92 (.82–1.00)[b]	.65 (.50–.76)	.67 (.46–.83)	1.9 (1.1–3.4)
Cervical extension ROM <30°	.74 (.48–.88)[c]	.62 (.46–.76)	.75 (.57–.87)	2.5 (1.34–4.57)
Decreased upper thoracic spine kyphosis (T3–T5)	.58 (.22–.95)[b]	.54 (.42–.65)	.64 (.48–.78)	1.1 (0.77–1.60)
Shoulder protracted	.83 (.51–1.00)[b]	.65 (.51–.77)	.76 (.52–.90)	2.7 (1.6–3.0)

[a] FABQPA=Fear-Avoidance Beliefs Questionnaire physical activity subscale, FABQW=Fear-Avoidance Beliefs Questionnaire work subscale, ROM=range of motion, NA=not applicable (subjects completed self-report measures only once [included the date of injury] and thus reliability data was not calculated).
[b] Kappa.
[c] Intraclass correlation coefficient.

the equal scoring system of the CPR by 1%. We therefore refrained from using the point-based system because it does not add to the predictive accuracy of the rule and would increase the complexity of the CPR, likely further detracting from the implementation of the rule in clinical practice.[56]

The ability to *a priori* identify patients with neck pain who are likely to experience an early success with thoracic spine thrust manipulation while avoiding the potential risk associated with cervical spine thrust manipulation is useful for guiding clinical decision making for individual patients. The CPR also is useful for identifying patients with neck pain who should perhaps receive other forms of treatment rather than thoracic spine thrust manipulation. In our study, for example, if subjects exhibited only one of the variables, the positive LR was only 1.2, suggesting that the posttest probability of these subjects achieving a successful outcome is not much larger than chance, corresponding to a negligi-

Table 5.
The 6 Variables Forming the Clinical Prediction Rule and the Number of Subjects in Each Group at Each Level[a]

- Symptoms <30 d
- No symptoms distal to the shoulder
- Looking up does not aggravate symptoms
- FABQPA score <12
- Diminished upper thoracic spine kyphosis
- Cervical extension ROM <30°

No. of Predictor Variables Present	Successful Outcome Group	Nonsuccessful Outcome Group
6	2	0
5	3	0
4	9	1
3	18	4
2	7	11
1	3	14
0	0	6

[a] FABQPA=Fear-Avoidance Beliefs Questionnaire physical activity subscale, ROM=range of motion.

Table 6.
Combination of Predictor Variables and Associated Accuracy Statistics With 95% Confidence Intervals

No. of Predictor Variables Present	Sensitivity	Specificity	Positive Likelihood Ratio	Probability of Success (%)[a]
6	.05 (.00–.17)	1.0 (.97–1.00)	Infinite (0.21-infinite)	100 (20–100)
5+	.12 (.04–.25)	1.0 (.94–1.00)	Infinite (0.54-infinite)	100 (39–100)
4+	.33 (.26–.35)	.97 (.89–1.00)	12 (2.28–70.8)	93 (66–99)
3+	.76 (.67–.82)	.86 (.75–.93)	5.49 (2.72–12.0)	86 (74–94)
2+	.93 (.84–.97)	.56 (.46–.61)	2.09 (1.54–2.49)	71 (63–78)
1+	1.00 (.95–1.00)	.17 (.11–.24)	1.2 (1.06–1.2)	58 (55–62)

[a] The probability of success is calculated using the positive likelihood ratios and assumes a pretest probability of 54%.

ble increase of the posttest probability to 58% (Tab. 6).

Six predictor variables were retained in the logistic regression analysis as maximizing the accuracy of predicting patients with neck pain who are likely to respond to thoracic spine thrust manipulation. Although the duration of the current episode was the strongest individual predictor, we used a higher threshold for defining success on the GROC than what has been recommended[40] to provide a greater degree of distinction between subjects who improved dramatically with manipulation and those who were improving over time simply due to natural history of the disorder. In addition, the magnitude of the difference in change scores for both the NPRS and NDI further substantiates that an important clinical change occurred in the group that was identified as having experienced a successful outcome.

The duration of the current episode was identified as the strongest predictor in a CPR for identifying patients with LBP who are likely to experience a rapid and dramatic response to spinal manipulation (positive LR=4.39).[19] The validation of the CPR also demonstrated that a shorter duration of symptoms was predictive for identifying patients who would respond to manipulation (positive LR=4.4).[20] However, duration of symptoms was not predictive of the outcomes associated with the comparison group who received an exercise program (positive LR=1.0), suggesting that a shorter duration is predictive of response to manipulation and not the natural history of the disorder.[20] Further validation studies are needed to determine whether this is also the case with the current CPR.

The FABQ was a predictor variable for identifying patients with LBP who are likely to respond to either spinal manipulation (FABQW)[19,20] or spinal stabilization (FABQPA).[18] In contrast to patients with LBP who are likely to benefit from spinal stabilization who exhibited elevated FABQPA scores (>8),[18] our study identified lower FAPQPA scores (<12) as a predictor of a successful outcome. A correlation between disability and the FABQPA was identified by George et al[27] and Nederhand et al,[57] suggesting that fear-avoidance beliefs exhibit predictive validity in identifying patients with neck pain who may be at risk for chronic disability. Further research is necessary to clarify the role of fear-avoidance beliefs in patients with neck pain.

One common flaw in the development of CPRs is that researchers often do not investigate the reliability of the measures used in their study and thus cannot determine whether predictor variables provide adequate reproducibility to be included in the rule.[58] We investigated the reliability of potential predictor variables and, according to the descriptive criteria provided by Landis and Koch,[59] all variables in the CPR exhibited fair to substantial reliability. We consider these reliability coefficients acceptable to guide clinical decision making in the management of patients with neck pain.

The predictor variables of a decreased upper thoracic spine kyphosis from T3 through T5 and decreased cervical extension may be associated with the biomechanical link between the thoracic spine and the cervical spine. Recent literature identified a correlation between mobility at the cervicothoracic junction and thoracic spine with neck-shoulder pain.[11,60,61] It is also possible that impaired mobility in the thoracic spine may be a contributor to mechanical neck pain.[62–64] Patient reports of "looking up does not aggravate the symptoms" and "no symptoms distal to the shoulder," as recorded on a body diagram, also were identified as predictor variables in the CPR. In contrast, the population that has pain distal to the shoulder that is aggravated by looking up could potentially be a subgroup of patients with cervical radiculopathy rather than solely mechanical neck pain.[65,66] Although symptoms extending into the arm and radicular signs are not associated with a worse prognosis,[67] it has been suggested that patients with more distal symptoms may be more responsive to a different treatment approach such as cervical traction and other distraction-oriented interventions.[21]

We successfully achieved the purpose of developing a CPR that identifies patients with neck pain who are likely to exhibit early success after thoracic spine thrust manipulation. However, this is only the first step in the process of developing and testing a CPR.[68] Although no difference in outcomes occurred among clinicians with varying levels of experience, it should be recognized that data were collected at only one clinical site by 4 physical therapists. Future studies are necessary to validate our results and determine whether similar findings occur in a broader patient population with different treating clinicians. Additionally, a validation study should include a long-term follow-up and a comparison group to further investigate the predictive value of the variables in the CPR. If the rule is validated, an impact analysis of implementation of the rule on clinical practice patterns, outcomes, and costs of care should be investigated.

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Appendix.

Operational Definitions for Special Tests Used in the Study

Test	Performance	Criteria for Positive Test
Spurling test[34]	The patient is seated, and the neck is passively side bent toward the symptomatic side. The examiner applies approximately 7 kg of force through the patient's head with a caudally directed force.	Reproduction of the patient's upper-extremity symptoms
Neck Distraction Test[36]	The patient is positioned supine, and the examiner grasps under the patient's chin and occiput. The examiner flexes the neck to patient comfort and then applies a distraction force of approximately 14 kg.	Reduction or resolution of the patient's upper-extremity symptoms
Upper Limb Neurodynamic Test[37]	The patient is positioned supine, and the examiner places the patient's upper extremity into: (1) scapular depression, (2) shoulder abduction, (3) forearm supination and wrist and finger extension, (4) shoulder external rotation, (5) elbow extension, and (6) contralateral then ipsilateral cervical lateral flexion.	Any of the following constitute a positive test: (1) Symptom reproduction (2) Greater than 10° difference in elbow extension from side to side (3) An increase in symptoms with contralateral cervical side bending or decrease in symptoms with ipsilateral side bending
Roos test[35]	The patient is positioned standing and abducts the arms to 90° with lateral rotation of the shoulder. The patient then opens and closes the hands slowly for 3 min.	The test is considered positive if the patient is unable to maintain the position or reports heaviness and tingling in the arm.