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Development of a Clinical Prediction Rule to Identify Patients With Knee Pain and Clinical Evidence of Knee Osteoarthritis Who Demonstrate a Favorable Short-Term Response to Hip Mobilization

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Background and Purpose

The primary purpose of this study was to develop a clinical prediction rule (CPR) for identifying patients with knee pain and clinical evidence of knee osteoarthritis (OA) with favorable short-term response to hip mobilizations. The secondary purpose was to determine the predictive validity of individual clinical tests for identifying these same patients.

Subjects and Methods

Sixty subjects with knee OA, aged 51 to 79 years, completed self-report questionnaires, a clinical examination of the hip and knee, and functional tests and were treated with 4 hip mobilizations. Follow-up testing was completed 2 days later. The reference criterion for determining a favorable response was either (1) a decrease of at least 30% on composite Numerical Pain Rating Scale score obtained during functional tests or (2) a Global Rating of Change Scale score of at least 3.

Results

The CPR developed in this study comprised 5 variables: (1) hip or groin pain or paresthesia, (2) anterior thigh pain, (3) passive knee flexion less than 122 degrees, (4) passive hip medial (internal) rotation less than 17 degrees, and (5) pain with hip distraction. Based on the pretest probability of success (68%), the presence of one variable had a positive likelihood ratio of 5.1 and increased the probability of a successful response to 92% at 48-hour follow-up. If 2 variables were present, the positive likelihood ratio was 12.9 and the probability of success increased to 97%.

Discussion and Conclusion

The results suggest that the CPR developed in this study could improve clinicians' decision making and efficiency in examining and treating patients with knee OA.



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Osteoarthritis (OA) is a disease that causes degeneration of articular cartilage and bony changes at the joints and is the most common cause of disability in the United States.¹⁻³ The knee joint is most commonly affected, with more than 30% of adults over 60 years of age experiencing functional limitations such as difficulty rising from a chair, standing, walking, and using stairs due to knee OA.⁴ The number of people with functional limitations caused by arthritis is projected to climb to 11.6 million by 2020, which will result in additional economic impact and will have a significant effect on our health care systems.⁵ In 2000, the cost associated with medical care related to OA was estimated at \$60 billion annually.⁶

In addition to medication and injection typically administered by primary care physicians or orthopedic surgeons, nonsurgical interventions for knee OA used by physical therapists to alleviate symptoms and improve functional capability may include thermal modalities, electrical stimulation, exercise, and manual physical therapy.^{4,7-10} A randomized controlled trial by Deyle et al⁴ demonstrated promising 1-year outcomes in patients with knee OA who received a combined intervention consisting of manual physical therapy and exercise compared with a control intervention group of patients with knee OA who received subtherapeutic ultrasound. Subjects in that study who received the combined intervention demonstrated a statistically and clinically meaningful improvement in their Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores and 6-minute walk distance at 4 weeks, 8 weeks, and 1 year compared with the control group. At 1 year, 20% of subjects in the control group had received knee arthroplasties compared with 5% in the combined intervention group (number

needed to treat=7). Deyle et al⁴ concluded that a combination of manual physical therapy and exercise resulted in less pain, disability, and surgeries for patients with knee OA.

The authors⁴ attributed the results of that study largely to the manual physical therapy intervention, as the effect sizes of WOMAC subscale scores reported by previous researchers who used an exercise intervention only were much lower (pain scale=8%-27% reduction, functional scale=10%-39% reduction)^{11,12} than those reported by Deyle et al⁴ (64% and 54% reduction, respectively). Furthermore, Deyle et al noted that subjects experienced a significant reduction in pain (20%-40%) after only 2 or 3 treatment sessions. The same positive results of that trial have been replicated in a recently published randomized controlled trial comparing a group of subjects who received the same combined intervention with a more challenging comparison group who received therapeutic exercise only.⁹

The multimodal manual therapy intervention used in the study by Deyle et al⁴ consisted, in large part, of mobilization procedures administered to the ankle, knee, hip, and lumbar spine. Altered knee function as a result of knee OA may affect the hip and result in painful impairments.¹³ Cliborne et al¹⁴ reported that the prevalence of positive findings for several clinical tests of the hip was significantly higher in subjects with knee OA than in similarly aged subjects who were asymptomatic for knee OA. These results suggest that many patients with knee OA have hip impairments, indicating the need to examine the hip in these patients.¹⁴ In the same single-group, pretest-posttest study, Cliborne et al also demonstrated that subjects with knee OA experienced an average decrease in pain, improved range of motion (ROM), and fewer positive

provocative hip test findings following a single intervention of hip mobilizations. These findings are not surprising, because 30% to 40% of people with knee OA also have hip OA, and it is well known that hip structures can refer pain to the knee.¹⁵⁻¹⁷

Cliborne et al¹⁴ found that individual subject response to hip mobilization varies; some individuals with knee OA benefit, whereas others do not. It is unknown whether items from the clinical examination can be used to identify those individuals who might benefit from hip mobilization. If selected findings of the clinical examination predictive of a favorable response to hip mobilization can be identified, it would allow clinicians to conduct a more parsimonious examination with known prognostic value as well as direct clinical decision making and intervention selection for patients with knee OA.

The primary purpose of this study was to develop a clinical prediction rule (CPR) for identifying patients with knee pain and clinical evidence of knee OA who demonstrate a successful short-term response to hip mobilizations. The secondary purpose was to determine the predictive validity of individual clinical tests for identifying these same patients.

Method

Subjects

A total of 60 subjects (33 male and 27 female; mean age=65.8 years, SD=7.2, range=51-79) participated in this study. Subjects were required to be eligible for military health care and to have sufficient English-language skills to comprehend all explanations. All subjects gave informed consent prior to participating in the study.

Although the eligibility criteria used in the studies by Deyle et al⁴ and

Cliborne et al¹⁴ were based on Altman and colleagues' criteria,¹⁸ we simply used Altman and colleagues' criteria for the clinical diagnosis of knee OA versus a more complex classification tree scheme. Subjects were included if they were 50 to 80 years of age, had a primary complaint of knee pain, and met at least 3 of Altman and colleagues' criteria for the clinical diagnosis of knee OA, which include: age greater than 50 years, knee crepitus, palpable bony enlargement, bony tenderness to palpation, morning stiffness that improves in less than 30 minutes, and no palpable warmth of the synovium.¹⁸ Any 3 of these variables results in 95% sensitivity (Sn) and 69% specificity (Sp) for presence of knee OA.¹⁸

Subjects were excluded if they had a primary complaint of low back pain (LBP), a secondary complaint of LBP with pain radiating below the knee, osteoporosis, a history of cancer, a history of hip or knee arthroplasty, cortisone or synthetic fluid injection to the hip or knee within 30 days of their initial examination, a history of prior treatment with hip mobilization to the involved limb within 6 months of their initial examination, or any current condition precluding physical therapy intervention (eg, deep vein thrombosis). One hundred ten potential subjects were excluded from the study based on these criteria. Although not specifically documented as the reason for exclusion, we believe that the majority of these individuals were excluded due to a complaint of primary or secondary LBP.

Only 5 of our subjects were receiving physical therapy related to their knee pain prior to enrollment in our study. The remaining subjects volunteered by responding to a flyer in the Brooke Army Medical Center pharmacy and the Fort Sam Houston refill pharmacy. Duration of symptoms

was greater than 1 year for 47 (78%) of the subjects. As part of the study, all subjects received radiographs and magnetic resonance imaging (MRI) of the hip on the same side as the involved knee that were interpreted by a single radiologist.

Standardized Clinical Examination

History. Subjects were asked 31 questions related to the onset and duration of symptoms; the distribution, behavior, and nature of symptoms; symptom-aggravating and symptom-relieving factors; and prior history of hip or knee interventions.

Physical examination. Sixteen procedures were administered to both limbs and consisted of ROM measurements, mobility assessment of the lumbar and lower thoracic spine, manual muscle testing, the hip distraction test, the hip scour test, the Thomas test, the click test, and the flexion, abduction, and external rotation (FABER) test. For each of these procedures, subjects were asked to rate their pain from 0 to 10 on the Numeric Pain Rating Scale (NPRS) and describe the pain location. The examiners made the following assessments regarding joint mobility: normal, empty, stiff, or loose.¹⁹ The 2 examiners (LLC and PJJ), both doctoral physical therapist students, underwent 7 training sessions during which physical examination procedures were practiced as operationally defined and as they were applied during the study.

Hip Mobilizations

Each subject received 4 hip mobilization procedures: caudal glide, anterior-posterior glide, posterior-anterior glide, and posterior-anterior glide with flexion, abduction, and lateral (external) rotation. The procedures and their operational definitions are described in Appendix 1. The 2 physical therapist students (SDC and RKM) who served as treat-

ing therapists providing the hip mobilizations underwent 7 training sessions, during which hip mobilization procedures were practiced as operationally defined. The training sessions were in addition to their first professional-level instruction. The physical therapist students were judged by faculty members to be proficient in the mobilization procedures used in the study before beginning data collection. Instruction in some or all of these mobilization procedures is common, if not ubiquitous, in many first professional-level programs,²⁰ and instructional material is readily available for practicing therapists.²¹

Instrumentation

Goniometry. The ROM measurements for knee flexion and extension and hip abduction and adduction were obtained using a universal goniometer, which has been demonstrated to be a reliable tool for measuring knee and hip ROM.²² All other hip ROM measurements were measured using a gravity inclinometer, which has been used in previous studies^{14,23} to measure hip motion, with the exception of hip extension, and has been shown to have acceptable intrarater reliability (intraclass correlation coefficients [ICC(3,1)] = .92-.96).

NPRS and self-report health outcome measures.

The subjects used the NPRS to rate their pain during examination tests and functional activities. The NPRS is an 11-point scale, with 0 representing no pain and 10 representing excruciating pain. This scale has been shown to have acceptable measurement properties (reliable, generalizable, and internally consistent) for the measurement of pain intensity in both clinical and experimental settings as well as in patients with both extremity and spinal disorders.^{24,25} The WOMAC is a questionnaire consisting of 24 questions that ask subjects

to rate their pain, difficulty, and stiffness during various functional activities. The Patient Specific Functional Scale (PSFS) requires subjects to identify 3 activities that they have difficulty performing due to their condition. Subjects rate their ability to perform each activity on a scale from 0 to 10, where 10 indicates they are able to perform the activity at the same level as before the injury and 0 indicates they are unable to perform the activity. The WOMAC and PSFS have acceptable measurement properties when used with patients who have hip and knee OA as well as other lower-extremity disorders.^{26,27} The Global Rating of Change Scale (GRCS) is a measure of patient perception that asks subjects to rate the change in their symptoms. The GRCS has 15 possible answers ranging from 7 (“a very great deal better”) to -7 (“a very great deal worse”), with 0 representing no change. This scale has been used to effectively monitor symptom progression in patients with other painful disorders.²⁸

Procedure

After the subjects signed an informed consent document, they completed the WOMAC and PSFS, answered various historical questions, and underwent the physical examination. All tests were completed on all subjects and documented on the data collection form. The order of the examination procedures was varied sequentially for each subject by the start position of supine, prone, or side-lying in order to prevent a possible order effect.

Interrater reliability of the physical examination procedures was assessed on a subset of 25 subjects enrolled in the study. One examiner took each subject’s history and performed the physical examination. Following a 2-minute rest period, the second examiner repeated the physical examination in the same order as

the first examiner. The second examiner was unaware of the results of the first examination.

After completion of the physical examinations, each subject was given a 2-minute rest and then performed a squat test and a sit-to-stand task from a standard-height office chair. These 2 functional tests were done to stress the lower extremity and to reproduce pain associated with disorders of the knee or hip.¹⁴ The operational definitions of these functional tests are shown in Appendix 2. During the squat test, the examiner recorded the angle of knee flexion at which the subject first experienced pain. Subjects were asked to report pain level on the NPRS and pain location while each task was performed.

After another 2-minute rest break, each subject was treated with all 4 hip mobilizations from one of the treating therapists with a grade IV intensity for 3 sets of 30 seconds, with a 30-second rest period between sets.²⁹ Grade IV intensity is defined as “a small-amplitude movement stretching into stiffness or muscle spasm” at end-range.^{29(p171)} All subjects were treated with all hip mobilization techniques using the same dose parameters, regardless of the findings of the physical examination, and treating therapists attempted to increase hip motion with each set. To prevent a possible order effect, the order of mobilizations was varied sequentially for each subject by the 4 different hip mobilizations.

At the end of the first session, subjects were instructed to maintain normal daily activities within their pain tolerance and to avoid activities that exacerbated their symptoms. In addition, subjects were asked to perform repeated, pain-free hip flexion ROM for 2 sets of 30 seconds while in a supine position twice daily. Subjects returned approximately 48 hours later for a second session, at

which time they completed a final WOMAC, final PSFS, and GRCS. The same physical examination administered during the first session was repeated. The same 2 functional tests were repeated, and associated pain ratings were recorded. This second examination was performed to ensure that conditions were similar to those of the initial test session before recording the pain ratings from the functional tests. The second session was scheduled as close as possible to the same time of day as the initial session. The subjects’ participation for this portion of the study was considered complete following the second session.

Data Analysis

Data were analyzed using SPSS for Windows (version 11.5).^{*} Descriptive statistics were computed for subject demographics and self-report measures. Interrater reliability was reported using Cohen kappa coefficients for nominal data³⁰ and ICC(2,1) with corresponding standard errors of measurement (SEM) for continuous variables.³¹ Ninety-five percent confidence intervals (CIs) were calculated for all reliability coefficients.³² The following qualitative interpretations for kappa coefficients, as described by Fleiss,³³ were used: excellent=.75 to 1.0, fair to good=.40 to .74, and poor=.39 and below. Portney and Watkins³⁴ have suggested that ICC values below .50 are indicative of poor reliability, values from .50 to .75 are indicative of moderate reliability, and values above .75 indicate good reliability. Because ICC values can be affected by a restriction in range, coefficients of variation of method error (CV_{ME}) also were computed to assess test-retest variation in scores.³⁴

^{*} SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Subjects were considered to have a favorable short-term response to hip mobilizations based on either of 2 reference criteria determined *a priori*: (1) a decrease of at least 30% on the composite NPRS score obtained during the 2 functional activities or (2) a GRCS score of at least 3. The composite score was computed by summing the NPRS scores obtained for both functional tests. Response to hip mobilizations (success or non-success) at the second session was used as the reference criterion standard. A 1- to 3-point increase on the GRCS may be considered the minimal clinically important difference (MCID).³⁵ Jaeschke et al defined the MCID as “the smallest difference in score in the domain of interest which patients perceive as beneficial and which would mandate, in the absence of troublesome-effects and excessive cost, a change in the patient’s management.”^{35(p408)} The MCID for the NPRS has been reported by other authors²⁴ for a variety of conditions and appears to be fairly consistent at 1.6 to 2.0. Two reference criteria were used to minimize the possibility of a floor effect and capture different constructs of interest. The purpose of the use of the WOMAC and the PSFS was to determine the correlation between the self-report measures used as the reference criteria and self-report measures that quantify function and disability.

We calculated Sn and Sp using 2×2 contingency tables to determine predictive validity for all individual patient history and clinical examination items. Multilevel response items such as joint mobility and pain location were split into dichotomous variables for the purposes of statistical analysis. These variables were dichotomized according to those subjects who were positive for a specific joint end-feel or pain location versus those subjects who were negative for the item. When a zero cell value

was encountered, 0.5 was added to all cell values in the table to permit further calculations.³⁶ In order to calculate Sn and Sp for all variables, continuous variables were dichotomized using receiver operating characteristic (ROC) curves to determine cutoff values.³⁷ The cutoff value that minimized false-positive results (ie, highest Sp) was selected.

Following calculation of Sn and Sp, likelihood ratios (LRs) and their associated 95% CIs were calculated. Likelihood ratios combine the information of Sn and Sp into a single summary index. The positive likelihood ratio (+LR) was calculated as $Sn/1-Sp$, and the negative likelihood ratio (-LR) was calculated as $1-Sn/Sp$.³⁸ The predictive accuracy of clinical examination variables was considered acceptable if the +LR was 2.0 or more or if the -LR was 0.5 or less. These cutoff values were proposed by Jaeschke et al³⁹ to indicate small, but sometimes important, changes in probability.

A binary logistic regression model was used to develop a CPR for identifying which subjects successfully respond to hip mobilizations. Only variables with acceptable predictive accuracy as defined above were considered for entry into the model.⁴⁰ To prevent model misspecification, the number of potential predictor variables entered into the model was further limited to those with an absolute natural log likelihood ratio (either +LR or -LR, whichever absolute value of the natural log was greater) that exceeded 1.45.⁴⁰ A backward stepwise logistic regression was used, with *P* values of .15 and .10 used as criteria to enter and exit the model, respectively. These liberal *P* values were chosen in order to prevent potentially useful variables from being excluded from the model.⁴¹ The Hosmer-Lemeshow summary goodness-of-fit statistic was used to assess the fit of the model to

the data and tested the hypothesis that the model fit the data.⁴² Higher *P* values indicated a better fit.⁴² Variables selected by the regression model as indicative of success comprised the CPR. The Sn, Sp, LRs, and 95% CIs for the number of positive findings in the CPR were calculated as previously described for other dichotomous variables.

Two-tailed paired *t* tests ($\alpha=.05$) were used to determine whether differences existed between premobilization composite NPRS scores and composite NPRS scores obtained 48 hours afterward. No adjustments were made to the alpha level to control the family-wise error rate due to the exploratory nature of the study.

The correlation between the WOMAC and PSFS scores at baseline and at follow-up was computed using the Spearman rank correlation coefficient, as were correlations among the WOMAC score change, PSFS score change, composite NPRS score change, and GRCS score at the follow-up session.

Results

All 60 subjects completed the study. At the follow-up, 41 subjects (68%) were considered to have a favorable short-term response to hip mobilizations as determined by the previously mentioned reference criteria. Thirty-three subjects were considered to have a successful response based only on the composite NPRS reference criteria, and 28 subjects were considered to have a successful response based only on the GRCS reference criteria. Descriptive statistics for the self-report questionnaires and composite NPRS scores are presented in Table 1.

A clinically meaningful and statistically significant difference ($P<.05$) in baseline composite NPRS scores existed between those subjects who had a successful response (compos-

Table 1.

Descriptive Statistics for Self-report Questionnaires and Composite Numerical Pain Rating Scale (NPRS)^a

Variable	Composite NPRS	WOMAC	PSFS	GRCS
Baseline, overall	4.1±4.4 (0-16)	106.9±41.5 (29-218)	4.6±1.7 (1.3-7.7)	n/a
Baseline, success group	5.39 (0-16)	112.54 (29-218)	4.49 (1.3-7.7)	n/a
Baseline, nonsuccess group	1.21 (0-5)	94.63 (34-165)	4.95 (2-7.7)	n/a
48-hr follow-up, overall	2.0±2.9 (0-14)	73.5±46.7 (2-183)	5.5±2.5 (1.3-9.7)	2.3±2.7 (-4-7)
48-hr follow-up, success group	2.0 (0-14)	69.39 (2-183)	6.05 (1.3-9.7)	3.27 (-4-7)
48-hr follow-up, nonsuccess group	1.95 (0-8)	82.32 (26-164)	4.39 (1.3-9.7)	0.11 (-4-2)
Overall difference (baseline - follow-up)	2.1±3.5 ^b (-4-14)	33.0±36.8 ^b (-41-142)	-0.9±2.5 ^b (-7.7-4.3)	n/a

^a Values are mean±standard deviation, with range shown in parentheses. WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, PSFS=Patient-Specific Functional Scale, GRCS=Global Rating of Change Scale, n/a=not applicable.

^b P<.05.

Table 2.

Reliability Values^a

Test/Measure	ICC(2,1)	95% CI	SEM	CV _{ME} (%)
Hip flexion, ROM	.56	.21-.78	6.16°	6
Hip extension, ROM	.20	-.22-.55	4.45°	24
Hip MR, ROM	.76	.53-.89	6.07°	39
Hip LR, ROM	.29	-.12-.62	10.21°	30
Knee flexion, ROM	.87	.73-.94	8.21°	4
Knee extension, ROM	.69	.41-.85	3.48°	154
Hip abduction, ROM	.54	.19-.76	6.08°	16
Hip adduction, ROM	.37	-.03-.67	4.4°	20
FABER test, ROM	.57	.23-.79	7.48°	13
Hip flexion, NPRS	.60	.29-.80	1.23	107
Hip extension, NPRS	-.08	-.47-.33	0.98	256
Hip MR, NPRS	.28	-.11-.60	1.48	171
Hip LR, NPRS	.59	.27-.80	1.25	197
Knee flexion, NPRS	.64	.16-.85	1.47	67
Knee extension, NPRS	-.04	-.39-.33	1.68	188
Hip abduction, NPRS	.38	.01-.66	1.65	115
Hip adduction, NPRS	.93	.84-.97	0.57	185
Scour test, NPRS	.07	-.33-.45	2.20	106
Lumbar springing (T12-L3), NPRS	.61	.30-.81	1.25	104
Lumbar springing (L4-S1), NPRS	.68	.40-.84	1.31	70

^a ICC=intraclass correlation coefficient; 95% CI=95% confidence interval; SEM=standard error of measurement; CV_{ME}=coefficient of variation of the method error; ROM=range of motion; NPRS=Numerical Pain Rating Scale; FABER=flexion, abduction, and external rotation; MR=medial (internal) rotation; LR=lateral (external) rotation.

ite NPRS score=5.4) and those who had a nonsuccessful response (composite NPRS score=1.2). Clinically meaningful and statistically significant differences (*P*<.05) in self-report measures and composite NPRS scores were found at the 48-hour follow-up period. A clinically meaningful and statistically significant difference (*P*<.05) in GRCS scores also was found between those subjects who had a successful response (GRCS score=3.3) and those who had a nonsuccessful response (GRCS score=0.1). The MCID for the GRCS was met for the entire sample (GRCS score=2.3) and for those subjects who were considered to have a successful response (GRCS score=3.3). In addition, the MCID for the composite NPRS was met for those subjects who were considered to have a successful response (composite NPRS score=3.4). Six subjects had more pain (average increase of 2.3 points on the composite NPRS score) with the functional tests at the 48-hour follow-up than they did at baseline, and 6 subjects reported on the GRCS that their condition had worsened (average of -2.5 points) since the treatment. Only 2 of the 6 subjects who reported more pain on the composite NPRS also reported a worsening of their condition on the GRCS.

Table 3.
Kappa Reliability Values

Test/Measure	Kappa	95% CI
Hip flexion, end-feel	.41	.14-.68
Knee extension, end-feel	.25	-.18-.68
Knee flexion, end-feel	.31	-.53-1.15
Hip abduction, end-feel	.15	-.14-.44
Hip adduction, end-feel	.00	-.39-.39
Hip distraction, end-feel	.13	-.24-.50
Hip distraction, pain	-.06*	-.13-.02
FABER test, end-feel	.39	.12-.66
FABER test, pain	.39	.14-.64
Thomas test, result	.18	-.17-.53
Thomas test, pain	-.06	-.12-.00
Hip MR, end-feel	.20	-.07-.47
Hip LR, end-feel	-.02	-.37-.33
Hip extension, end-feel	-.13	-.48-.22
Lumbar springing (T12-L3), end-feel	.68	.39-.97
Lumbar springing (L4-S1), end-feel	.39	.02-.76
Gluteus medius muscle, MMT	.50	.17-.83
Click test, pain	-.06	-.16-.04

^a 95% CI=95% confidence interval; FABER=flexion, abduction, and external rotation; MMT=manual muscle test; MR=medial (internal) rotation; LR=lateral (external) rotation. *percentage of agreement=88%.

Reliability

Reliability for continuous clinical examination variables varied widely. The ICC(2,1) values ranged from -.08 to .93 (Tab. 2) and associated SEM values ranged from 0.57 to 10.21. The CV_{ME} values ranged from 4% to 256%. Kappa values for categorical variables are shown in Table 3 and ranged from -.13 to .68. Only the reliability values for the involved limb are presented because reliability values were similar for the uninvolved limb.

Test Item Predictive Validity and CPR

A total of 73 variables met the requirement of having a +LR greater than 2.0 or a -LR less than 0.5. Eleven variables with absolute natural log likelihood values greater than 1.45 were entered into the regres-

sion model. The Sn, Sp, LRs, and 95% CIs for these 11 variables are listed in Table 4. Five of these variables were from the history, and 6 variables were from the physical examination. The results of the Hosmer-Lemeshow test indicated the model fit the data ($P=1.0$). The following 5 variables were retained by the logistic regression model and comprised the CPR:

- pain or paresthesia in the ipsilateral hip or groin region (hip or groin region defined as the region from the greater trochanter along inguinal ligament to the pubic ramus),
- pain in the ipsilateral anterior thigh (anterior thigh region defined as the region distal to the inguinal ligament to the superior pole of the patella on the anterior or ventral side),

- ipsilateral knee flexion passive ROM less than 122 degrees,
- ipsilateral hip medial (internal) rotation passive ROM less than 17 degrees in the prone position, and
- pain with ipsilateral hip distraction.

Operational definitions for CPR physical examination variables are presented in Appendix 3. The hip distraction test is depicted in Figure 1, and the hip medial rotation test is depicted in Figure 2.

Based on the pretest probability of success (68%) and calculated +LR, the presence of one variable has a +LR of 5.1 (95% CI=1.79-14.56) and increases the probability of a successful response to hip mobilizations from 68% to 92%. If 2 variables are present, the +LR is 12.9 (95% CI=0.8-205.6) and the probability of success increases from 68% to 97%. Requiring more than 2 variables did not improve the +LR, and no subject had a positive result for more than 3 variables. The item with the highest single +LR was pain or paresthesia in the ipsilateral hip or groin region with a +LR of 8.1 (95% CI=0.49-133.4) and posttest probability of 95%. Table 5 shows the percentage of subjects with positive results for each prediction variable. Passive knee flexion less than 122 degrees and passive hip medial rotation less than 17 degrees were the most prevalent findings.

Correlation of Self-report Measures

The correlation between WOMAC scores and PSFS scores at baseline and at 48 hours showed an inverse relationship that was fair (-.34 and -.37, respectively, $P<.5$). Table 6 shows the correlations between score changes for the WOMAC, PSFS, composite NPRS, and GRCS.

Discussion

The variables contained within the CPR are not surprising given the

Table 4.
Variables Entered Into Stepwise Regression and Their Predictive Validity^a

Variable	Sn (95% CI)	Sp (95% CI)	Positive LR (95% CI)	Negative LR (95% CI)
Ipsilateral anterior thigh pain ^b	0.27 (0.13-0.4)	0.95 (0.85-1.05)	5.1 (0.71-36.68)	0.77 (0.62-0.96)
Intermittent hip or groin pain	0.15 (0.05-0.26)	0.98 (0.91-1.04)	6.19 (0.37-104.56)	0.87 (0.75-1.00)
Strengthening exercises aggravate knee pain	0.20 (0.04-0.37)	0.96 (0.85-1.07)	4.91 (0.29-83.68)	0.83 (0.65-1.06)
Location of hip or groin pain bilaterally	0.18 (0.06-0.29)	0.98 (0.91-1.04)	7.14 (0.43-118.98)	0.84 (0.72-0.99)
Difference in hip MR ROM between LEs	0.98 (0.93-1.02)	0.11 (-0.03-0.24)	1.09 (0.93-1.28)	0.23 (0.02-2.40)
Empty end-feel on ipsilateral hip flexion ROM	0.13 (0.03-0.23)	0.98 (0.91-1.04)	5.24 (0.30-90.17)	0.89 (0.78-1.02)
Pain with ipsilateral hip distraction ^b	0.13 (0.03-0.23)	0.98 (0.91-1.04)	5.24 (0.30-90.17)	0.89 (0.78-1.02)
Pain at knee on ipsilateral hip extension ROM	0.11 (0.01-0.20)	0.98 (0.91-1.04)	4.29 (0.24-75.8)	0.92 (0.81-1.04)
Ipsilateral knee flexion passive ROM <122° ^b	0.32 (0.17-0.46)	0.95 (0.85-1.05)	6.02 (0.85-42.76)	0.72 (0.57-0.91)
Ipsilateral hip MR passive ROM <17° ^b	0.32 (0.17-0.45)	0.95 (0.85-1.05)	6.02 (0.85-42.76)	0.72 (0.57-0.91)
Pain or paresthesia in ipsilateral hip or groin ^b	0.20 (0.08-0.32)	0.98 (0.91-1.04)	8.10 (0.49-133.4)	0.82 (0.69-0.97)

^a Sn=sensitivity, Sp=specificity, LR=likelihood ratio, 95% CI=95% confidence interval, MR=medial (internal) rotation, ROM=range of motion, LE=lower extremity.

^b Variable is part of clinical prediction rule.



Figure 1.
Hip distraction test.

prevalence of concomitant hip OA in people with knee OA and the sensory innervation of the hip and knee.¹⁵⁻¹⁷ Two predictor variables, hip or groin pain and limited hip medial rotation, are closely related to Altman and colleagues' criteria for clinical diagnosis of hip OA.¹⁵ The variable "limited knee flexion" may be indicative of more severe joint involvement in general and, therefore, of more potential for response to intervention. The only provocative test retained in the CPR, pain with hip distraction, was highly specific but present in only 5 subjects. All 5 subjects had a successful response to hip mobilizations. Although hip distraction might be expected to be an easing factor when applied to a hip contributing to a patient's symptoms, it may have the opposite effect if the distensibility of periarticular soft-tissue structures is impaired. The combination of any 2 CPR variables is the best predictor of

Patients With Knee Pain and OA Who Respond to Hip Mobilization

which patients with knee OA will respond to hip mobilizations. In this study, the 95% CIs associated with the Sn, Sp, and LRs for most variables were wide. As a result, point estimates are imprecise and should be interpreted cautiously. A study using a larger sample is needed to increase the precision of 95% CIs.

The reliability of clinical measurements in our study varied from poor to good, which is consistent with findings for clinical examination procedures in previous studies.^{23,43} The reliability of data for the 2 measures included in the CPR—hip medial rotation and knee flexion—was good (ICC = .76 and .87, respectively). The CPR variable “pain with hip distraction” had poor reliability, which most likely was due to the low prevalence of positive findings (percentage of agreement = 88%). The differences in our reliability ratings for the 3 hip examination items compared with those reported by Cliborne et al¹⁴ may have been due to the intrarater reliability assessed in the study by Cliborne et al versus the interrater reliability assessed in our study.

Although previous research has shown that some patients with hip OA⁴⁴ as well as some patients with knee OA^{4,14} benefit from hip mobilizations or manipulation, none of these studies identified findings useful for patient selection. Our findings are similar to those of previous studies,^{23,45} which have shown that a combination of clinical examination findings may improve the ability to identify which patients may benefit from a particular intervention. However, due to the design of this study (single-group, pretest-posttest), we cannot establish a cause-and-effect relationship between intervention and outcome, although the brief follow-up period of this study minimized the influence of maturation effects on our results. Our study is



Figure 2.
Hip medial (internal) rotation test

the first to develop a CPR identifying which patients with knee pain and clinical evidence of knee OA are most likely to benefit from hip mobilizations.

In our sample, all subjects except 1 had either radiographic or magnetic resonance imaging findings of mild hip OA, with 3 subjects demonstrating moderate hip OA and 1 subject with severe hip OA findings. Other imaging abnormalities included gluteus medius tendinopathy, heterotopic ossification, labral tears and paralabral cysts, subchondral edema,

hydroxyapatite deposition of the gluteus medius and iliopsoas tendons, osteitis pubis, and L5-S1 degenerative disk disease. These findings indicate that the proportion of people with knee OA who have concomitant hip OA may be higher than previously reported. In addition, it appears these individuals may respond favorably to hip mobilizations with regard to clinical knee symptoms despite having a variety of concomitant radiographic hip abnormalities.

The majority of our subjects (55%) met all 6 of Altman and colleagues'

Table 5.
Percentage of Subjects Who Were Positive for Each Prediction Variable^a

Variable	Percentage of Subjects Positive for Variable
Pain with ipsilateral hip distraction	8
Ipsilateral knee flexion passive ROM <122°	23
Ipsilateral hip MR passive ROM <17°	23
Pain or paresthesia in ipsilateral hip or groin	13
Ipsilateral anterior thigh pain	20

^a MR = medial (internal) rotation, ROM = range of motion.

Table 6.
Spearman Rank Correlation Coefficients Between Self-report Measures^a

	GRCS	Composite NPRS Change	WOMAC Change
PSFS change	.51	-.28	-.46
WOMAC change	-.51	.33	
Composite NPRS change	-.43		

^a WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, PSFS=Patient Specific Functional Scale, GRCS=Global Rating of Change Scale, NPRS=Numerical Pain Rating Scale.

clinical criteria for knee OA,¹⁸ 25% met 5 of the criteria, and the remaining 20% met 4 of the criteria. Based on their pain and ROM measurements, the severity of knee OA symptoms experienced by the subjects in our study ranged from mild to moderate. Previous studies¹⁵⁻¹⁷ have shown that 30% to 40% of people with knee OA also have hip OA. The number of subjects in our study who benefited from hip mobilizations was substantially larger (68%). Indeed, a number of subjects who had hip pathology, as shown on radiographic and magnetic resonance imaging, experienced a successful response to hip mobilizations. Although hip imaging findings were available, we did not specifically determine whether subjects who participated in our study had a clinical diagnosis of concomitant hip OA, and radiographic evidence alone is not sufficient to establish symptomatic hip OA.¹⁵ The presence of significant pathoanatomic hip abnormalities observed in patients with minimal specific complaints of hip pain appears to be similar to that observed with imaging of the spine.^{46,47} Many of these changes may simply be age related and considered “normal” unless correlated with relevant clinical findings. This needs to be investigated further. The high initial success rate that we observed may have been attributable to a placebo effect, therapeutic touch, or a number of other explanations besides hip mobilizations.

Seventeen percent of our subjects reported some level of transient irritation following hip mobilizations (ie, either increased pain on the functional tests or a worsened GRCS score). However, no subjects reported a rating of lower than moderately worse on the GRCS or an increase of more than 4 points on the composite NPRS. This aggravation may have been the result of increased and prolonged soreness from the hip mobilizations or some other intervening factor. Small-amplitude grade IV mobilizations, as applied in our study, are thought to produce more local soreness compared with large-amplitude grade III mobilizations.²⁹

The reference criterion against which examination items are determined to be predictor variables for a CPR needs to be clinically relevant. Although pain and overall patient perception may be of less interest than disability, the composite NPRS and GRCS scores had a fair-to-moderate correlation (.28-.51) with scores on both the WOMAC and the PSFS. This finding indicates that hip mobilizations may have a positive effect on other patient-oriented outcomes in addition to pain and patient perception. Overall, subjects in this study had 31% improvement on the WOMAC and 16% improvement on the PSFS at 48 hours after hip mobilizations. Overall, subjects also demonstrated 45% improvement on the composite NPRS for the func-

tional tests at 48 hours after hip mobilizations.

The value of a CPR for clinical decision making may be questioned given the high pretest probability of success (68%) of a subject responding to hip mobilizations. However, treating a person with the 4 common hip mobilizations used in this study can take up to 15 minutes. In addition, some subjects experienced a temporary increase in pain following mobilizations. Transient discomfort and soreness following manual physical therapy intervention for musculoskeletal disorders is common, and similar transient side effects have been reported for patients with mechanical back and neck disorders after receiving manual physical therapy intervention.⁴⁸ Physical therapists are likely to see increasing numbers of patients with characteristics similar to those of the subjects in this study as our population ages and the prevalence of people with knee OA increases. Therefore, use of a CPR such as the one developed in this study, if validated, could improve clinical decision making by maximizing a clinician’s time and the benefit derived by patients. The goal of a CPR is to correctly identify those individuals with or without the condition of interest. The logistic regression model used to formulate the CPR does so in a parsimonious fashion by selecting the minimal number of test items that will result in correct classification. This process includes negative LRs in order to maximize accuracy. Negative LRs have been included in other CPRs which have been either developed or validated.^{36,45}

This study has several limitations. A cause-and-effect relationship between intervention and outcome cannot be established based on our study design. Although all study participants had knee pain and a clinical diagnosis of knee OA, most subjects

recruited for participation in this study were not actively seeking treatment. This could reflect a spectrum bias of patients with mild-to-moderate knee OA and may limit generalization of our findings to those individuals who have been referred for treatment and are in the care of a physical therapist. Because our subjects had relatively low pain scores or no pain scores at all on the baseline functional tests, a floor effect may have been present that could have minimized the effect size of the hip mobilizations. This may have been a result of our study's functional tests not being provocative enough or not specifically provocative for a subject's primary complaint. The functional squat test was not provocative because the examiners had to stop many subjects according to the operational definition before they had any pain. The short time sitting in the sit-to-stand test may not have allowed subjects to acquire the pain or stiffness that they might develop after sitting for an extended period. However, the GRCS reference criteria allowed subjects who had no pain at baseline on the functional tests to still be considered to have had a successful response to hip mobilizations. In addition, the long-term benefits of hip mobilization are unknown secondary to our study's short follow-up time of 48 hours, but the short-term relief of pain may improve a patient's ability to perform therapeutic exercise. Given the short follow-up period in our sample of subjects with knee OA, it is possible that other factors, unrelated to the mobilization treatment, may have affected the short-term outcome. Further validation of the rule is needed in subsequent studies that include longer-term follow-up periods.

Finally, traditional power calculations in a study of this type are not applicable. However, unstable risk or probability estimates are a con-

cern when the prediction model is "overfitted" (ratio of observed events to predictor variables is low [less than 1:10]), as was the case in this study.⁴⁹ Therefore, our results should be considered preliminary. A validation study is needed to further define the relationship between a positive response to hip mobilization and the predictor variables of the CPR developed in this study.

Formulation of a CPR is a 3-step process, and this study represents the first step—CPR development. The second step, a validation study, is necessary before this study's CPR can be applied in the clinic with confidence. If validated, the third step of CPR development is impact analysis assessing whether clinicians and patients benefit from the CPR. A validation study similar in design to that used in the study by Childs et al⁴⁵ would permit both validation of the CPR and establishment of intervention effectiveness.

Conclusion

Hip mobilizations are a noninvasive, relatively inexpensive intervention that appears to provide short-term benefit in patients with knee pain and clinical evidence of knee OA who present any combination of 2 CPR variables. In our study, the intervention of hip mobilizations most likely affected hip dysfunction contributing to knee symptoms. The CPR developed in this study, if validated, could improve clinicians' decision-making capabilities and efficiency in managing patients with this relatively common condition.

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data analysis. Dr Currier, Dr Boyles, and Dr Wainner provided project management. Dr Currier and Dr Carow provided subjects. Dr Cliborne, Dr Boyles, and Dr Wainner provided facilities/equipment.

The Institutional Review Board of Brooke Army Medical Center approved the study protocol.

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Appendix 1.

Operationally Defined Hip Mobilization Procedures

Caudal glide: With the patient positioned supine, a mobilization belt is placed as proximally along the thigh as possible. The patient's affected hip is flexed slightly past 90 degrees until slight resistance is felt. The physical therapist imparts a caudally directed, passive accessory glide force to the proximal hip. The amount of hip flexion, rotation, and abduction and adduction may be adjusted to find the position that the treating therapist believes most effectively stretches the hip joint and is tolerated by the patient. This is based on the therapist's assessment of joint feel during the mobilizations.



Anterior-posterior glide: With the patient positioned supine, the foot on the side of the affected hip is brought across midline to the lateral side of the opposite knee. A mobilizing force is imparted through the long axis of the femur to the posterolateral hip capsule using passive accessory glides. The amount of hip flexion may be adjusted to find the position that the treating therapist believes most effectively stretches the hip joint and is tolerated by the patient. This is based on the therapist's assessment of joint feel during the mobilizations.



Posterior-anterior glide: With the patient positioned prone and the knee flexed, the therapist supports the patient's thigh. A mobilizing force is imparted to the hip through the proximal femur using passive accessory glides from posterior to anterior. The amount of medial (internal) and lateral (external) rotation is varied to find the position that the therapist believes most effectively stretches the hip joint and is tolerated by the patient. This is based on the therapist's assessment of joint feel during the mobilizations.



Posterior-anterior glide with flexion, abduction, and lateral rotation: With the patient positioned prone, the therapist positions the affected hip on the table using a combination of flexion, abduction, and lateral rotation; this can be adjusted to find the position that the therapist believes most effectively stretches the hip joint and is tolerated by the patient. A pillow may be placed under the patient's abdomen if the position is not tolerated initially. The therapist contacts the femur just distal to the greater trochanter. A mobilizing force is imparted to the hip through the proximal femur using passive accessory glides from posterior to anterior.



Appendix 2.

Operational Definitions for Functional Tests

Squat test: The patient is standing with the feet aligned on 2 strips of tape placed on the floor 21.6 cm (8.5 in) apart in parallel lines. The big toe should be at the end of the tape. With the patient in upright stance, the physical therapist “zeros out” the inclinometer at the tibial tuberosity on the side of the affected knee. While looking straight ahead, the patient is instructed to keep the trunk upright and squat as if trying to drop

the buttocks between the feet. The patient is instructed to lower the buttocks as far as possible, keeping the knees in line with the second toe and the heels on the floor. Maximum squat is achieved when the patient reports being unable to go further due to pain, the patient is noticed beginning to lean forward, or the patient’s heels begin to lift off the ground. Once maximum squat is achieved, range of motion is measured and recorded to the nearest

degree, the location of pain is determined, and a Numeric Pain Rating Scale score is obtained.

Sit to rise from chair: Have the patient sit in hard chair with no handrails. With the patient sitting up tall and crossing arms, have the patient stand from that position. Have the patient rate pain on the Numeric Pain Rating Scale and describe the location of the pain.

Appendix 3.

Operationally Defined Procedures for Physical Examination Variables in the Clinical Prediction Rule

Knee flexion: The patient is positioned supine. The examiner first assesses the noninvolved knee. The hip is maintained in neutral adduction and abduction, and the knee is passively moved to a position of maximum flexion. The examiner next assesses flexion in a similar manner on the involved knee. Before measurements are taken, an assessment of mobility of the involved knee (normal, empty, stiff, loose) is made. The effect of the movement on the patient’s symptoms also is recorded (Numeric Pain Rating Scale [NPRS] score and location of pain). Next, the range of motion (ROM) is measured for each knee using a universal goniometer. The fulcrum is centered over the lateral epicondyle. The proximal arm is placed along the midline of the thigh in line with the greater trochanter, and the distal arm is placed along the midline of the leg in line with the lateral malleolus. The knee then is passively flexed to R1, which is defined as the point where resistance is first met, and ROM is recorded.²³

Hip distraction: The patient is positioned supine. The examiner first assesses the noninvolved hip. The examiner grasps the lower extremity with both hands, one above the knee and the other around the leg while supporting the leg between the examiner’s arm and trunk. The back of the patient’s shirt is raised to allow for skin contact on the table. The leg is held in a position of hip flexion (approximately 30°), with slight abduction and lateral (external) rotation. The examiner leans backward to create a distraction force. After assessing the noninvolved side, the involved side is assessed with the same technique. The examiner judges the mobility of the involved hip (normal, empty, stiff, loose) and determines the effect of the distraction on the patient’s symptoms (NPRS score and location of pain).

Hip medial (internal) rotation: The patient is positioned prone with feet hanging off the table so as not to induce knee flexion. The examiner first assesses the noninvolved hip. The hip is maintained in neutral flexion and extension and adduction and

abduction. The knee is flexed to approximately 90 degrees, and the hip is passively moved to a position of maximum medial rotation. The examiner next assesses hip medial rotation in a similar manner on the involved hip. Before measurements are taken, an assessment of mobility of the involved hip (normal, empty, stiff, or loose) is made. The effect of the movement on the patient’s symptoms also is recorded (NPRS score and location of pain). Next, the examiner places the measured thigh parallel to the trunk by picking up the thigh and placing it in neutral medial and lateral rotation and then picking up the opposite thigh and placing it in 15 degrees of abduction. The ROM is measured for each hip using an inclinometer. The inclinometer’s distal end is placed at the midpoint of the lateral malleolus and is zeroed with the examiner’s dominant eye. The hip is passively moved into medial rotation to R1, looking for the opposite side of the pelvis beginning to rise off the table simultaneously, and then ROM is recorded.²³