Barbara AM Snoeker, Aeilko H Zwinderman, Cees Lucas and Robert Lindeboom

A clinical prediction rule for meniscal tears in primary care:

development and internal validation using a multicentre study

Abstract

Background
In primary care, meniscal tears are difficult to detect. A quick and easy clinical prediction rule based on patient history and a single meniscal test may help physicians to identify high-risk patients for referral for magnetic resonance imaging (MRI).

Aim
The study objective was to develop and internally validate a clinical prediction rule (CPR) for the detection of meniscal tears in primary care.

Design and setting
In a cross-sectional multicentre study, 121 participants from primary care were included if they were aged 18–65 years with knee complaints that existed for <6 months, and who were suspected to suffer from a meniscal tear.

Method
One diagnostic physical meniscal test and 14 clinical variables were considered to be predictors of MRI outcome. Using known predictors for the presence of meniscal tears, a 'quick and easy' CPR was derived.

Results
The final CPR included the variables sex, age, weight-bearing during trauma, performing sports, effusion, warmth, discolouration, and Deep Squat test. The final model had an AUC of 0.76 (95% CI = 0.72 to 0.80). A cut-point of 150 points yielded an overall sensitivity of 86.1% and a specificity of 45.5%. For this cut-point, the positive predictive value was 55.0%, and the negative predictive value was 81.1%. A scoring system was provided including the corresponding predicted probabilities for a meniscal tear.

Conclusion
The CPR improved the detection of meniscal tears in primary care. Further evaluation of the CPR in new primary care patients is needed, however, to assess its usefulness.

Keywords
clinical prediction rule; diagnosis; knee; primary health care.

INTRODUCTION

Knee symptoms are the tenth most common reason to visit a primary care physician in the US.[1] It is most important to evaluate at an early stage if a patient needs referral to secondary care, whether intra-articular lesions can be ruled out, and whether symptoms are likely to be resolved with conservative treatment.[1] As meniscal tears in the short term lead to disability in daily functions, absenteeism from work, and inability to perform sports, and in the long term lead to an increased risk of knee osteoarthritis (OA), early diagnosis and treatment of meniscal tears is important.[2,3]

Previous studies indicate that the Joint Line Tenderness (JLT) test[4] and Thessaly test[4,5] are accurate for detection of meniscal tears in secondary care, but not in primary care.[6] A new weight-bearing test, the Deep Squat test, performed better in primary care.[6] Nevertheless, without additional information, it was found that the Deep Squat test had limited sensitivity.[6] As a single test result cannot predict a meniscal tear in primary care,[6] combining the Deep Squat test with other predicting variables may improve its detection of meniscal tears.[7]

In several studies, predictive variables for meniscal tears were identified. Shrier *et al* suggested that effusion can be a useful sign in a young person with an acute meniscal tear, but not in older individuals with a degenerative non-traumatic tear.[5] In a recent systematic review,[8] strong evidence was provided that age >60 years, male sex, work-related kneeling and squatting, and climbing stairs are risk factors for degenerative meniscal tears. Also, strong evidence was found that prolonged waiting time for anterior cruciate ligament (ACL) reconstruction surgery after ACL injury is a risk factor for a medial meniscal tear. For acute meniscal tears there is strong evidence that playing soccer and playing rugby are risk factors. It is unclear, however, whether some risk factors (for example, age, sex, work-related kneeling and squatting, stair climbing, performing sports) also could be usefully combined to detect a meniscal tear. Lowery *et al* evaluated the effectiveness of a composite examination, determining the presence of a meniscal tear.[7] Five variables were included: a history of catching or locking of the knee, pain with forced hyperextension, pain with maximum flexion, pain or audible click with McMurray's test, and joint line tenderness. A positive predictive value of 92.3% was found. Patients were already scheduled for arthroscopy, however, meaning that results are not applicable for primary care screening as the spectrum of disease was not comparable.

If early and correct detection of meniscal tears could be provided, the primary care physician could make a more informed selection for magnetic resonance imaging (MRI) referral and subsequent diagnosis. Patients with low suspicion for a meniscal tear or with degenerative meniscal tears

BAM Snoeker, MSc physical therapist and clinical epidemiologist; **AH Zwinderman**, PhD, professor in biostatistics; **C Lucas**, PhD, physical therapist and professor of clinical epidemiology; **R Lindeboom**, PhD, epidemiologist, Academic Medical Centre, University of Amsterdam, Division of Public Health, Amsterdam, the Netherlands.

Address for correspondence

BAM Snoeker, Academic Medical Centre, University of Amsterdam, Division of Public Health, PO Box 22600, 1100 DD, Amsterdam, the Netherlands.

E-mail: b.a.snoeker@amc.uva.nl

Submitted: 12 November 2014; **Editor's response:** 15 December 2014; **final acceptance:** 6 February 2015.

This is the full-length article (published online 27 Jul 2015) of an abridged version published in print. Cite this article as: **Br J Gen Pract 2015; DOI: 10.3399/bjgp15X686089**

How this fits in

Meniscal tests currently used by GPs and physical therapists in primary care are not highly accurate and a single test result in itself cannot accurately detect a meniscal tear. This study presents a clinical prediction rule (CPR) for correct detection of meniscal tears. Using the CPR, primary care physicians can make informed selection of patients for MRI referral.

can be treated conservatively. Therefore, as part of a full clinical assessment by the primary care physician, the clinical prediction rule (CPR) may improve the management of knee patients.[9,10]

Therefore, the purpose of this study was to develop and validate a prediction model for the detection of meniscal tears in primary care.

METHOD

Study design

Data on the history and physical examination of participants with knee complaints visiting their GP or physical therapist (PT) including the results of MRI were used to develop the CPR. Data were collected from October 2009 until December 2013 in 14 primary care centres in the Netherlands, where 24 GPs and 28 PTs referred participants with knee complaints and suspicion of a meniscal tear to one of the research centres in Leiderdorp. The four meniscal tests were the Thessaly test, JLT test, Deep Squat test, and Squat Lunge test. In earlier data analyses, it was found that only one test result was predictive in primary care, the Deep Squat test.[6] Therefore, only this meniscal test was taken into account for the current study. Patient characteristics were obtained during interview and physical examination (for example, effusion, warm knee, discolouration, and extension of the knee) by an investigator who did not perform any meniscal test. The meniscal test was performed by a physical therapist without knowledge of patient history or MRI results. A radiologist with more than 8 years of experience with musculoskeletal MRI interpreted the MRI studies. The radiologist was blinded to patient history and the meniscal test result.

Participants

Participants were included in the study if they were aged 18–65-years and had knee complaints that had existed for <6 months. The knee complaints had not yet been diagnosed through radiologic examination (for example MRI). Those who had had a knee arthroplasty or other intra-articular knee operations in the past, or MRI contraindications, were excluded.

Predictors for meniscal tears

Potential predictive variables were selected through a systematic literature review, and other literature.[7,8,11] The following candidate predictors were collected: age, sex, BMI, origin of complaints, locked knee (yes/no), giving way, weight-bearing during trauma, performing sports, work-related kneeling or squatting (>1 hour per day), ability to walk the stairs, effusion, warm knee, discolouration of the knee, pain during extension, and Deep Squat test. If a predictor was not interpretable or contradictive according to current knowledge, the predictor was excluded from the model.

Statistical analysis

From all potential predictor variables, the set of most predictive variables was selected using the LASSO (least absolute shrinkage and selection operator), after controlling for multicollinearity of variables (r>0.8).[12,13] To control the shrinkage procedure, a penalty parameter was used. The optimal penalty value λ was determined through bootstrap samples (n = 100) and was chosen for the highest area under the curve (AUC) to develop the 'best model'. The penalty value was increased if necessary to derive a more parsimonious model, the 'tolerance model'. This tolerance model had 2% less AUC than that of the best model. After developing the best model and the tolerance model, discrimination and calibration of both models were compared to choose the final model.

To discriminate between those with and without a meniscal tear on MRI, an ROC-AUC (receiver operating characteristic-area under the curve) with consecutive cut-offs for the predicted probability was used. The AUC is reasonable above 0.7, and strong above 0.8, and was presented with 95% confidence intervals (CIs).[14] A false-negative rate of maximum 15% was deemed acceptable, as the CPR will be used as a screening tool. Calibration of the model, which measures the ability of a model to agree between observed and predicted outcomes, was assessed through goodness-of-fit with a calibration plot.

Internal validation

To correct for over-optimism of the prediction model, bootstrap resampling was used.[13] The model was fitted repeatedly using LASSO regression in 200 bootstrap samples of the same size as the original sample, and was compared with the performance of the model in the original model. After calculating the amount of optimism by the difference between bootstrap AUC and model AUC in the original sample, the optimism corrected AUC was obtained.[13]

All analyses were performed in R Studio statistics program (version 3.0.2), and the caret, glmnet and rms packages in R.

RESULTS

One-hundred and twenty-one participants were included. The Deep Squat test results could not be interpreted for four participants, and they were excluded from the analysis. Therefore, in the development cohort as well as in the internal validation cohort, 117 participants were analysed. Baseline characteristics are summarised in Table 1. MRI confirmation indicated 51 participants with meniscal tears and 66 without meniscal tears. Participants with meniscal tears were significantly older (46.43 years versus 40.36 years) and were more often male (74.5% male with a meniscal tear versus 43.9% male without a meniscal tear). There were also noticeable differences between participants with and without meniscal tears in pain severity on a visual analogue scale (VAS) scale (42.16 versus 53.42 points), performing sports (84.3 versus 72.7%), weight-bearing during trauma (47.1 versus 24.2%), and effusion (78.4% versus 16.6%). Of the 51 meniscal tears, 80.4% were posterior horn tears (Table 1).

In univariate analysis, the candidate predictor variables 'locking' and 'ability to walk the stairs' were not interpretable (Table 2). Ability to walk the stairs was more predictive for the presence of a meniscal tear than if a participant had no ability to walk the stairs, which was counterintuitive. Also, both variables were not significantly different between the two patient groups. Therefore, both variables were excluded from the model.

As no multicollinearity of the remaining variables was found, all other candidate predictor variables were included in the full model. After deletion of predictors guided by the LASSO procedure, only eight predictor variables remained in the final model ('tolerance model'), after the accuracies of the 'best model' and more parsimonious 'tolerance model' were compared through their AUCs (Table 3, Figure 1). The AUC was 0.81 (95% CI = 0.74 to 0.89). After correction for over-optimism, the final model had an AUC of 0.76 (95% CI = 0.72 to 0.80). The calibration of the model was good. The final model includes the variables sex, age, weight-bearing during trauma, performing sports, effusion, warmth, discolouration, and Deep Squat test.

The resulting prediction rule of these variables including a scoring system is shown in Figure 2. Scores from individual participants ranged from 15 to 320 points. The distribution of the prediction scores of individual participants against the predicted probabilities according to the final model is shown in Figure 3. A higher risk score on the CPR indicates a higher predicted probability, and a lower risk score indicates a lower predicted probability for a meniscal

Table 1. Baseline characteristics

Characteristics	Overall (*n* = 117)	Meniscal tear (*n* = 51)	No meniscal tear (*n* = 66)	*P*-value
Age, years, mean (SD)	43.0 (12.2)	46.43 (11.55)	40.36 (12.06)	0.006
Sex, male (%)	67 (57.3)	38 (74.5)	29 (43.9)	0.002
Weight, kg, mean (SD)	81.2 (14.9)	84.63 (11.74)	78.49 (16.54)	0.021
Length, m, mean (SD)	1.76 (0.1)	1.79 (0.08)	1.75 (0.11)	0.006
BMI, mean (SD)	25.9 (3.8)	26.26 (3.07)	25.60 (4.25)	0.337
Pain severity VAS [a], mean (SD)	48.5 (25.6)	42.16 (24.43)	53.42 (25.56)	0.017
Duration of complaints in weeks, median (range)	6 (0.5–27)	8 (0.5–27)	5 (1–27)	0.858
Symptom side, right (%)	59 (50.4)	27 (52.9)	32 (48.5)	0.771
Performing sports, yes (%)	91 (77.8)	43 (84.3)	48 (72.7)	0.204
Weight-bearing during trauma, yes (%)	40 (34.2)	24 (47.1)	16 (24.2)	0.017
Work-related kneeling or squatting >1 hour/day, yes (%)	32 (27.4)	16 (31.4)	16 (24.2)	0.517
Pain during passive extension, yes (%)	75 (64.1)	35 (68.6)	40 (60.6)	0.482
Origin of complaints				
Unknown (%)	76 (65.0)	14 (27.5)	27 (40.9)	0.188
(Rotation) Trauma (%)	41 (35.0)	37 (72.5)	39 (59.1)	
Ability to walk the stairs, no (%)	7 (6.0)	3 (5.9)	4 (6.0)	0.99
Effusion, yes (%)	75 (64.1)	40 (78.4)	11 (16.6)	0.008
Warmth, yes (%)	46 (39.3)	25 (49.0)	21 (31.8)	0.090
Colour red/blue, yes (%)	8 (6.8)	6 (11.8)	2 (3.0)	0.137
Locking, yes (%)	30 (25.6)	8 (15.7)	22 (33.3)	0.051
Giving way, yes (%)	66 (56.4)	31 (60.8)	35 (53.0)	0.515
Meniscal tears, *n* (%)	51 (43.6)	NA	NA	NA
Medial meniscal tears, *n* (%)	40 (78.4)	NA	NA	NA
Lateral meniscal tears, *n* (%)	7 (13.7)	NA	NA	NA
Medial and lateral meniscal tears, *n* (%)	4 (7.8)	NA	NA	NA
Anterior horn tears, *n* (%)	6 (11.7)	NA	NA	NA
Posterior horn tears, *n* (%)	41 (80.4)	NA	NA	NA
Combination of CL and meniscal tears, *n* (%)	11 (9.4)	NA	NA	NA
Combination of chondropathy in medial or lateral compartment and meniscal tear, *n* (%)	20 (17.1)	NA	NA	NA
CL tears, *n* (%)	13 (11.1)	NA	NA	NA
Isolated ACL tears, *n* (%)	3 (23.1)	NA	NA	NA
Isolated PCL tears, *n* (%)	2 (15.4)	NA	NA	NA
No knee pathology, *n* (%)	40 (34.2)	NA	NA	NA

ACL = anterior cruciate ligament. BMI = body mass index. CL = cruciate ligament. PCL = posterior cruciate ligament. VAS = visual analogue scale. For meniscal tears and horn tears, n = 51; for isolated CL tears, n = 13.
[a]VAS pain: 0 = no pain, 100 = worst pain possible in the previous week.

Table 2. Univariate analysis of candidate predictor variables

Variable	OR	95% CI	*P*-value
Sex, male	3.73	1.71 to 8.48	0.001
Age	1.05	1.01 to 1.08	0.009
BMI	1.05	0.95 to 1.16	0.354
Origin of complaints: (Rotation) trauma versus unknown cause	1.83	0.84 to 4.09	0.132
Weight-bearing during trauma	2.78	1.28 to 6.20	0.011
Kneeling >1 hour per day	1.43	0.63 to 3.25	0.392
Ability to walk stairs	1.03	0.22 to 5.45	0.968
Performing sports	2.02	0.82 to 5.35	0.139
Locking	0.37	0.14 to 0.90	0.034
Giving way	1.37	0.66 to 2.90	0.402
Effusion	3.22	1.44 to 7.59	0.006
Warmth	2.06	0.97 to 4.43	0.061
Red/blue colour	4.26	0.93 to 30.04	0.084
Pain during extension	1.42	0.66 to 3.11	0.371
Deep Squat test, positive	2.15	0.98 to 4.89	0.059

OR = odds ratio. OR >1 indicates an increased risk for meniscal tear when a predictor variable is present or has a higher value.

Table 3. Regression coefficients for each predictor in the Best model versus the Tolerance model with stronger penalty value

Covariates	Best model	Tolerance model
(Intercept)	–4.91653467	–2.79919116
Sex	1.28572876	0.84259980
Age	0.05039379	0.02998058
BMI	0.00000000	0.00000000
Origin of complaints	0.00000000	0.00000000
Weight-bearing during trauma	0.72989997	0.49265311
Work-related kneeling and squatting	0.17248521	0.00000000
Performing sports	0.64439602	0.15366088
Giving way	0.00000000	0.00000000
Effusion	0.81467548	0.60284532
Warmth	0.30654251	0.04124769
Colour of knee (red/blue)	0.77047589	0.29820922
Pain during passive knee extension	0.05231282	0.00000000
Deep Squat test	0.19395546	0.03263309

tear. Predicted probabilities ranged from 8.83% to 81.5%. A cut-point of 150 was selected, which produced a sensitivity of 86.1% and a specificity of 45.5%. For this cut-point, the positive predictive value (PPV) was 55.0%, and the negative predictive value (NPV) was 81.1%. Although the c-statistic was 0.76, indicated as a reasonable model for discriminative ability, some overlap between prediction scores for participants with and without meniscal tears occurred.

DISCUSSION

Summary

The final model contained an AUC of 0.76 with a 95% CI = 0.72 to 0.80. A score of 150 points yielded an overall sensitivity of 86.1% and a specificity of 45.5%. For this cut-point, the PPV was 55.0%, and the NPV was 81.1%. With a false-negative rate of 14%, participants with a meniscal tear can be managed efficiently.

Strengths and limitations

Some limitations should be noted. First, arthroscopy was not used as a reference standard, although it is more accurate than MRI. MRI was considered to be a valid and ethical alternative because of its reported accuracy.[15] To indicate whether MRI results were affected, the results of participants receiving arthroscopy after MRI were requested. In the present sample only four of 41 identifiable participants receiving arthroscopy after MRI (9.8%) had a positive finding for a meniscal tear after a negative finding on MRI. Second, it is not certain that participants were consecutively referred to the study research centre. Participants may have directly been referred for MRI by their GP without inclusion in the present study. Another limitation could be that MRI was performed in 18.8% of the cases before the included participants underwent the meniscal tests because of organisational aspects. Participants were asked to wait with requests for their MRI results before undergoing the meniscal tests. Blinding was therefore maintained and also for PTs who performed the test and obtained patient characteristics. Considering the small contribution of only one physical test that was particularly suited to detect posterior horn tears (while the other predictors included in the model are as useful for posterior as for anterior horn

Figure 1. ROC curve 'Best model' versus 'Tolerance model'.

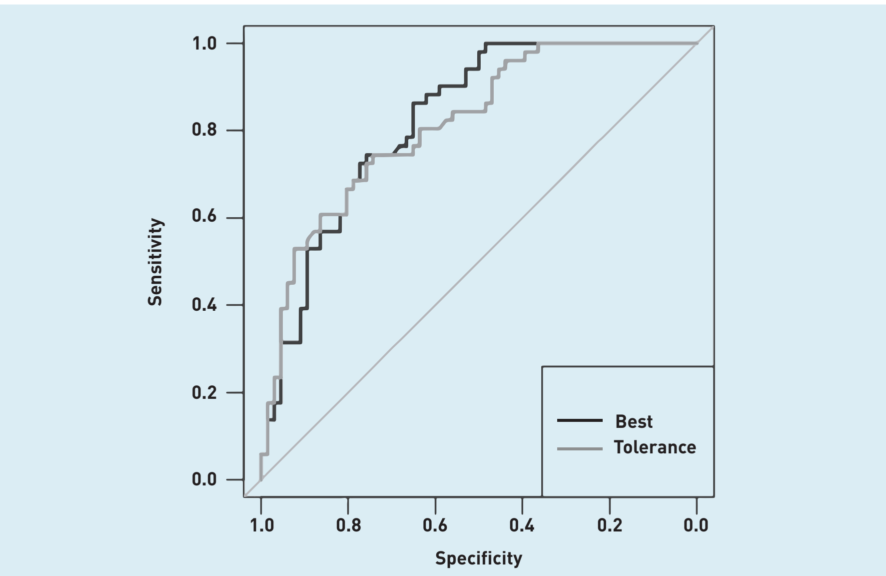


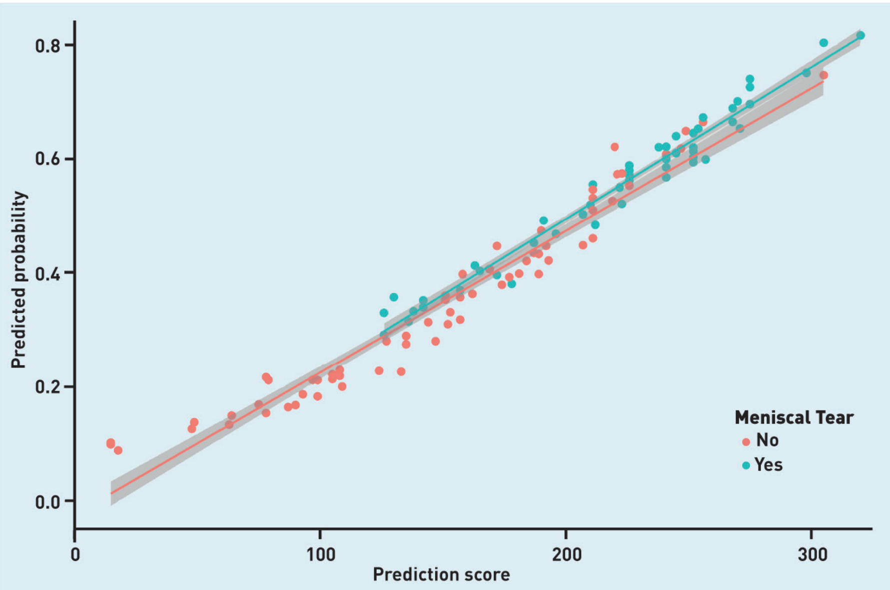
Figure 2. Final CPR model including scoring system. Scoring system relating the predictors of the final model to the probability of presence of a meniscal tear. For example, consider a male patient (which corresponds to 84 points) of 48 years (60 points), without weight bearing during trauma (0 points), who performs sports (15 points), with effusion (60 points), without warmth of the knee (0 points), discolouration of the knee (30 points), and a positive Deep Squat test (3 points). The patient's total point score is 252 points, corresponding to a probability of meniscal tears of about 62%.

Attribute	Value	Points
Sex		
	Female	0 ☐
	Male	84 ☐
Age		
	18–28	0 ☐
	29–38	30 ☐
	39–48	60 ☐
	49–58	90 ☐
	59–65	108 ☐
Weight-bearing		
	No	0 ☐
	Yes	49 ☐
Performance sport		
	No	0 ☐
	Yes	15 ☐
Effusion		
	No	0 ☐
	Yes	60 ☐
Warmth		
	No	0 ☐
	Yes	4 ☐
Discolouration		
	No	0 ☐
	Yes	30 ☐
Deep Squat		
	Negative	0 ☐
	Positive	3 ☐
		Total

Total points:

0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360
0.10		0.13	0.17	0.19	0.22	0.29	0.34	0.40	0.44	0.52	0.57	0.62	0.69	0.75	0.79			

Figure 3. Risk score versus predicted probability.



tears) the CPR appears to be useful for both tears. Last, predictors to derive a more parsimonious CPR were excluded. However, after the reduction of predictor variables the AUC remained largely similar.

A strength of the present study is that it was the first performed to develop and internally validate a CPR for meniscal tears in a primary care setting. The CPR is useful in primary care, where decisions must be made with minimal time. Another strength is that the predictors were selected through LASSO analysis, a method that improves the validation of the model.[12,13]

Comparison with existing literature

An earlier performed systematic review suggested that age and sex are strong factors indicating an association with a meniscal tear.[8] As it was believed that several of the risk factors investigated also could be predictive factors for meniscal tears, in this study next to the variables age and sex, the variables BMI, performing sports, stair climbing, work-related kneeling and squatting, and weight-bearing during trauma were measured.

In other primary studies, weight-bearing during trauma was, similar to the present findings, associated with the presence of a meniscal tear.[11,16] The factor performing sports was a relevant risk factor for meniscal tears from a previous systematic review.[8] As a predictive factor, however, performing sports stands for an increased active life, without the necessity for a moment of trauma during sports. The known risk factors BMI, work-related kneeling and squatting, and stair climbing were not included in the final CPR, because they did not add much to the accuracy with the variables already in the model or because the results could not be interpreted because of counterintuitive findings.

The Deep Squat test is the only physical examination test included in the final model. Previous research stated that a single test could not predict a meniscal tear accurately.[5,7,17–19] In the final model the contribution of this test is low, with only three points added for a positive test result. For a physician, however, it is important to perform a physical examination test for an overall conclusion and patient expectancy.

In a previous study, effusion was a useful sign for a meniscal tear, just as a red or blue colour of the knee, and warmth.[5] These signs were not specified, however, for younger and older participants, or subdivided for acute or degenerative tears. Therefore, the contribution of these signs for different patient groups is unclear.

A typical finding was that locking was not interpretable, as comparatively fewer participants with meniscal tears experienced locking of the knee than participants without meniscal tears, which is in contrast with other reports.[7,11] Participants may not have interpreted the question correctly during history taking, or it could be that the finding was a result of chance.

Implications for research and practice

A CPR was developed and internally validated for detection of meniscal tears in primary care. Variables included in the model are sex, age, weight-bearing during trauma, performing sports, effusion, warmth, discolouration, and Deep Squat test. Correct detection of meniscal tears leads to informed selection for MRI referral by the primary care physician, which in turn may improve management of knee patients. The CPR should be a first step in selecting patients for MRI referral in primary care. In future research the CPR should be externally validated, to assess its accuracy in other primary care settings. Also, the CPR needs further development and validation to distinguish between acute and degenerative meniscal tears. Finally, the use of the CPR in a management pathway should be explored, including time to referral for radiologic evaluation and choice of treatment.

Funding

No funding was received for this research.

Ethical approval

A waiver for this research was received by the Central Committee on Research Involving Human Subjects (CCMO: Centrale Commissie Mensgebonden Onderzoek).

Provenance

Freely submitted; externally peer reviewed.

Competing interests

The authors have declared no competing interests.

Acknowledgements

The authors thank the physiotherapists and staff of Paulides and Partners Physiotherapy from Voorschoten, of Physiotherapy Ommedijk and of Physiotherapy Goudeket from Leiderdorp, the Netherlands, for their effort in this study to attend as a research centre. Thanks also to the staff from Rijnland Hospital at Leiderdorp and Rode Kruis Hospital at Beverwijk, especially the orthopaedics department and the radiology department, for their contribution to this study.

Discuss this article

Contribute and read comments about this article: **bjgp.org/letters**

REFERENCES

1. Grover M. Evaluating acutely injured patients for internal derangement of the knee. *Am Fam Physician* 2012; **85(3):** 247–252.
2. Baker P, Coggon D, Reading I, *et al*. Sports injury, occupational physical activity, joint laxity, and meniscal damage. *J Rheumatol* 2002; **29:** 557–563.
3. Englund M, Roemer FW, Hayashi D, *et al*. Meniscus pathology, osteoarthritis and the treatment controversy. *Nat Rev Rheumatol* 2012; **8(7):** 412–419.
4. Ockert B, Haasters F, Polzer H, *et al*. Value of the clinical examination in suspected meniscal injuries. A meta-analysis. *Unfallchirurg* 2010; **113:** 293–299.
5. Shrier I, Boudier-Reveret M, Fahmy K. Understanding the different physical examination tests for suspected meniscal tears. *Curr Sports Med Rep* 2010; **9(5):** 284–9.
6. Snoeker BA, Lindeboom R, Zwinderman AH, *et al*. A new weight-bearing test for diagnosing meniscal tears in primary care: Deep Squat test. *J Orthop Sports Phys Ther* 2015; in press.
7. Lowery DJ, Farley TD, Wing DW, *et al*. A clinical composite score accurately detects meniscal pathology. *Arthroscopy* 2006; **22(11):** 1174–1179.
8. Snoeker BA, Bakker EW, Kegel CA, Lucas C. Risk factors for meniscal tears: a systematic review including meta-analysis. *J Orthop Sports Phys Ther* 2013; **43(6):** 352–367.
9. DAMASK Trial Team. Effectiveness of GP access to magnetic resonance imaging of the knee: a randomised trial. *Br J Gen Pract* 2008; DOI: 10.3399/bjgp08X342651.
10. DAMASK Trial Team. Cost-effectiveness of magnetic resonance imaging of the knee for patients presenting in primary care. *Br J Gen Pract* 2008; DOI: 10.3399/bjgp08X342660.
11. Wagemakers HPA, Heintjes EM, Boks SS, *et al*. Diagnostic value of history taking and physical examination for assessing meniscal tears of the knee in general practice. *Clin J Sport Med* 2008; **18:** 24–30.
12. Moons KGM, Donders ART, Steyerberg EW, Harrell FE. Penalized maximum likelihood estimation to directly adjust diagnostic and prognostic prediction models for overoptimism: a clinical example. *J Clin Epidemiol* 2004; **57:** 1262–1270.
13. Steyerberg EW. *Clinical prediction models. A practical approach to development, validation and updating*. New York, NY: Springer, 2009.
14. Hosmer DW, Lemeshow S. *Applied logistic regression (second edition)*. New York, NY: John Wiley, 2000.
15. Crawford R, Wally G, Bridgman S, Maffulli N. Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: a systematic review. *Br Med Bull* 2007; **84:** 5–23.
16. Fridén T, Erlandsson T, Zätterström R, *et al*. Compression or distraction of the anterior cruciate injured knee. Variations in injury pattern in contact sports and downhill skiing. *Knee Surg Sports Traumatol Arthrosc* 1995; **3:** 144–147.
17. Konan S, Ravan F, Haddad FS. Do physical diagnostic tests accurately detect meniscal tears? *Knee Surg Sports Traumatol Arthrosc* 2009; **17(7):** 806–811.
18. Ryzewicz M, Peterson B, Siparsky PN, Bartz RL. The diagnosis of meniscus tears: the role of MRI and clinical examination. *Clin Orthop Relat Res* 2007; **455:** 123–133.
19. Scholten RJ, Devillé WL, Opstelten W, *et al*. The accuracy of physical diagnostic tests for assessing meniscal lesions of the knee. *J Fam Practice* 2001; **50(11):** 938–944.