**The wild-goose chase—No predictable patient subgroups who benefit from meniscal surgery: patient-reported outcomes of 641 patients 1 year after surgery**

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**ABSTRACT**

**Background:** Despite absence of evidence of a clinical benefit of arthroscopic partial meniscectomy (APM), many surgeons claim that subgroups of patients benefit from APM.

**Objective:** We developed a prognostic model predicting change in patient-reported outcome one year following arthroscopic meniscal surgery to identify such subgroups.

**Methods:** We included 641 patients (age 48.7 years (SD 13), 56% men) undergoing arthroscopic meniscal surgery from the Knee Arthroscopy Cohort Southern Denmark (KACS). 18 preoperative factors identified from literature and/or orthopedic surgeons (patient demographics, medical history, symptom onset and duration, knee-related symptoms, etc.) were combined in a multivariable linear regression model. The outcome was change in KOOS4 (average score of 4 of 5 KOOS subscales excluding the activities of daily living subscale) from pre-surgery to 52 weeks after surgery. A positive KOOS4 change score constitutes improvement. Prognostic performance was assessed using R2 statistics and calibration plots and was internally validated by adjusting for optimism using 1000 bootstrap samples.

**Results:** Patients improved on average 18.6 (SD 19.7, range -38.0 to 87.8) in KOOS4. The strongest prognostic factors for improvement were (i) no previous meniscal surgery on index knee, and (ii) more severe preoperative knee-related symptoms. The model’s overall predictive performance was low (apparent R2=0.162, optimism adjusted R2=0.080) and it showed poor calibration (calibration-in-the-large=0.205, calibration slope=0.772).

**Conclusion:** Despite combining a large number of preoperative factors presumed clinically relevant, change in patient-reported outcome one year following meniscal surgery was not predictable. This essentially quashes the existence of ‘subgroups’ with certain characteristics having a particularly favourable outcome after meniscal surgery.

**Keywords:** Arthroscopy, meniscus, prognosis, patient-reported outcomes, knee

**What are the new findings?**

* A combination of the major preoperative clinical factors proposed to be important for outcome after meniscal surgery, including mechanical symptoms and traumatic meniscal tears, poorly predicts change in patient-reported outcome after meniscal surgery.

**How might it impact on clinical practice in the future?**

* Preoperative factors have limited utility in clinical practice to identify patients who may have favourable or unfavourable outcome after meniscal surgery.
* The results question the existence of presumed subgroups of patients with certain characteristics having a particular favourable outcome after meniscal surgery.

**INTRODUCTION**

Arthroscopic partial meniscectomy (APM) for patient-reported knee pain or functional impairment shows no clinically relevant benefit over sham surgery or in addition to exercise therapy for middle-aged and older patients.1-4 APM is also associated with a risk of adverse events5 6 and the procedure has been reported to carry with it increased risk of worsening of cartilage damage and knee replacement surgery as compared to knees with meniscal tears left *in situ.*7

Critics of the studies that underpin these conclusions--that APM is largely unhelpful for degenerative meniscal tears and potentially harmful for patients with knee pain--argue that randomized trials often include narrowly selected patients and therefore may not entirely reflect daily clinical practice. If subgroups of patients that have a particular benefit from APM really do exist, what might these subgroups be?

Surgeons often argue that younger patients with traumatic meniscal tears and/or a locked knee benefit the most from meniscal surgery,8 9 but these patients were not included in previous randomized trials.1 10-15 Furthermore, trials often lack power for detecting differences in treatment effects among subgroups of patients.16 A recent systematic review aimed to summarize the existing evidence on patient-specific factors’ association with patient-reported outcomes after arthroscopic meniscal surgery.17 Findings were inconclusive, and the combined ability of factors to predict outcome was not evaluated.17

Therefore, to identify those who might improve after APM, we combined the most logical prognostic factors to develop and validate a prognostic model to predict patients’ change in their self-reported outcome one year following arthroscopic meniscal surgery.

**METHODS**

The Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) guideline18 was followed to report this study.

**Data source and patients**

For the development and validation of the prognostic model, we used all patients included in the Knee Arthroscopy Cohort Southern Denmark (KACS).19 KACS is a prospective cohort following patients undergoing knee arthroscopy for a meniscal tear. Patients were consecutively recruited at four public hospitals in the Region of Southern Denmark between February 1st 2013 to January 31st 2014, and at one of the original four hospitals from February 1st 2014 to January 31st 2015. Inclusion criteria in KACS were age 18 years and above, assigned for knee arthroscopy by an orthopedic surgeon on suspicion of a meniscal tear (based on clinical examination, injury history, and magnetic resonance imaging (MRI) if considered necessary), able to read and understand Danish, and having an e-mail address. Patients were excluded if not having a meniscal tear at surgery, having previous or planned reconstruction of the anterior or posterior cruciate ligament (ACL or PCL) in either knee, fracture(s) to the lower extremities within the last 6 months, or not being able to reply to questionnaires because of mental impairment.19

Written informed consent was obtained from all patients. The regional scientific ethics committee of Southern Denmark waived the need for ethical approval after reviewing the outline of KACS.19 The KACS cohort was pre-registered at ClinicalTrials.gov (NCT01871272).

**Outcome**

The outcome measure was the Knee injury and Osteoarthritis Outcome Score (KOOS).20 KOOS is a validated and often used knee-specific patient-reported outcome in studies concerning meniscal surgery.10 12 15 20 21 The score consists of five subscales covering pain, symptoms, activities of daily living (ADL), sport and recreation function (Sport/Rec), and knee-related quality of life (QoL). Each subscale ranges from 0 to 100 with 0 representing extreme knee problems and 100 representing no knee problems.20 KOOS was completed using online questionnaires emailed to patients within 2 weeks prior to surgery (median 7 days, interquartile range 3 to 10 days) and at 12 and 52 weeks after surgery.

In the present study, the outcome was the change score from pre-surgery to 52 weeks after surgery in the mean score of KOOS4 with a positive KOOS4 change score constituting improvement. KOOS4 is an aggregated mean score of four of the five KOOS subscales - Pain, Symptoms, Sport/Rec, and QoL - but excludes the ADL subscale that is known to display ceiling effects in younger and more active populations.21 KOOS4 has been used in previous trials assessing the effect of knee surgery.15 22

**Prognostic factors**

Potential prognostic factors were gathered from patients prior to surgery as part of the same online questionnaire containing the preoperative KOOS. Among all available factors in KACS, we considered 26 factors for the prognostic model. These were identified from published literature suggesting an association with outcome after meniscal surgery17 23 24 and/or considered important by orthopedic surgeons.8 9 Due to a desire to develop a parsimoniousprognostic model that could be manageable in clinical practice, eight factors were omitted before model building. The omission of these was based on high correlations with other factors, and thus possible redundancy/overlap in prognostic information,25 or limited external validity (online supplementary table 1). As a result, 18 prognostic factors were included in the prognostic model (online supplementary table 2), with response categories shown in table 1 and 2.

**Statistical analysis method**

Missing data

Under the assumption of data being missing at random (MAR),26 we imputed missing values using multiple imputation with chained equations.27 The multiple imputation model included all 18 prognostic factors, the outcome, three interaction terms (i.e. age and knee catching/locking, age and knee extension deficit, and age and symptom onset), and as auxiliary variables the pre-surgery and 12 weeks KOOS4 scores. Multivariable fractional polynomials were used to explore whether nonlinear terms were appropriate for the continuous prognostic factors (i.e. age, BMI, pre-surgery and 12 weeks KOOS4 scores).28 29 The ‘ice’-package30 in Stata version 15.1 was used to generate a number of imputed data sets equal to the largest proportion of missing in any factor under consideration.27

Model development

Multivariable linear regression was used to develop a prognostic model that included all 18 a priori-definedprognostic factors (Model I), and a reduced model based on statistical significance (Model II).

Before fitting the models, and without knowledge of associations with outcome, categories were combined into certain categorical prognostic factors to eliminate sparse categories and retain a ratio of ≥20 patients per estimated model parameter.25 Also, some ordinal categorical factors had categories combined if linearity with outcome could not be assumed (visually examined using scatter plots), otherwise they were handled as continuous in the models. Multivariable fractional polynomials were used to consider nonlinear associations between continuous factors and outcome,28 29 as opposed to categorization, which has been shown to be suboptimal.31 32

Models were fitted using the combined imputed data sets and model coefficients were estimated using Rubin’s rules.33 Based on a previous study,34 and clinical reasoning, we included three interaction terms (i.e. age and knee catching/locking,34 age and knee extension deficit, and age and symptom onset) in the models. Their significance was tested as a group using multiple parameter Wald test and all terms were removed, and the models refitted, if group significance level was p>0.20. For the reduced model (Model II), backward stepwise elimination was performed in the combined imputed data sets to eliminate factors with p>0.20 based on a likelihood-ratio test using the ‘mfpmi’-package’35 in Stata version 15.1.28 29

As secondary models, using the same approach as above, we developed a full and reduced model for patients aged 40 years or younger (Model Iyoung and Model IIyoung) and patients aged 41 years or older (Model Iold, and Model IIold), respectively. Furthermore, as sensitivity analyses, all models were also developed using only patients with complete data.

Prior to analyses, prognostic factors were investigated for collinearity by calculating variance inflation factors (VIFs). The level of collinearity was not considered problematic if mean VIF was ≤5 and individual VIFs were ≤10.36 For all models, the underlying assumptions of linearity, homoscedasticity, and normality of residuals were assessed using scatter and Q-Q plots.

Performance measures

We evaluated the models’ overall predictive performance using the R2 statistic, which is a measure of the proportion of variance explained by the models.37 Calibration, i.e. the models’ ability to give unbiased estimates of the predicted outcome, was assessed using three measures of calibration in a hierarchical order as defined by Van Calster et al.:38 [1] *Mean calibration* (calibration-in-the-large), which is the difference between the mean observed outcome and the mean predicted outcome. Values less than or greater than 0 indicate average under- or overestimation of the outcome, respectively. [2] *Weak calibration* (calibration slope), which reflects the average strength of the predictor effects and is the regression coefficients between predicted outcomes and observed outcomes. A value less than or greater than 1 indicates that the model systematically overestimates, or underestimates predicted outcomes, respectively, and [3] *Moderate calibration*, which is the agreement between observed outcomes and predicted outcomes and was assessed graphically using a calibration plot. If well calibrated, predictions should lie around the 45o line of the calibration plot.

Robust methods (i.e. the median) were used to combine R2 statistics and calibration slopes across imputed data sets,39 while the developed models’ calibration-in-the-large and calibration plot were evaluated on patients with complete data.

Internal validation

We used the bootstrap resampling technique37 to adjust the apparent R2 for any optimism and estimate the optimism adjusted calibration slope. The latter was also used as a uniform shrinkage factor to adjust the effects of predictors (i.e. regression coefficients) for potential over- or under-fitting, to make the models better calibrated for similar future patients.25 In the bootstrap procedure we repeated the entire modelling process, including variable selection in the reduced models, in 1000 bootstrap samples drawn with replacement from the original sample.40 The models were fitted in each bootstrap replicate and tested on the original sample to estimate optimism in model performance. All analyses were performed in Stata version 15.1 (StataCorp, College Station, TX).

**Patient involvement**

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for recruitment, design, or implementation of the study. No patients were consulted to advise interpretation or writing up results.

**RESULTS**

**Patients**

A total of 641 patients were included in the KACS cohort (table 1). With the exception of one participant having missing data for previous meniscal surgery, no patients had missing data in any of the prognostic factors. The outcome at 52 weeks was missing in 76 (12%) patients (Figure 1). These patients were on average a little younger than those with complete follow-up, but similar in all other characteristics (online supplementary table 3).

Most patients had resection of the meniscus (n=600), while 33 had it repaired and the rest received a combination of the two surgical procedures (n=8). Baseline knee symptoms and KOOS4 scores are presented in table 2. The average improvement in KOOS4 from before surgery to 52 weeks after surgery was 18.6 (SD 19.7) for the whole cohort, 16.2 (SD 20.1) and 19.2 (SD 19.5) for the young (≤40 years) and older (>40 years) patients, respectively.

**Model development**

We generated ten imputed data sets for the development of the main models (Model I and II) and the models including patients aged 41 or older (Model Iold and Model IIold), respectively.27 Due to a larger proportion of patients with incomplete follow-up among the younger patients (19%, Figure 1), twenty imputed data sets were generated for the development of the models that included patients aged 40 or younger (Model Iyoung and Model IIyoung). Continuous factors were modelled as linear in all models (no non-linear trends identified), while the handling of specific ordinal categorical factors differed between models (table 3 and 4).

**Model specification**

Of the 18 prognostic factors included in the full model (Model I), only nine were retained in the reduced model (Model II) (table 3). In both models the strongest prognostic factors in terms of statistical significance were previous meniscal surgery, level of education, and knee-related symptoms such as difficulty twisting/pivoting and inability to straighten the knee fully (table 3). A positive regression coefficient indicates improvement in KOOS4, and a negative value indicates deterioration. The specification of the secondary models that included patients aged 41 or older (Model Iold and Model IIold) were similar to the main models’, whereas the models that included patients aged 40 or younger (Model Iyoung and Model IIyoung) deviated somewhat with fewer factors retained in the reduced model (table 4). For the complete prognostic models including equations, see online supplementary table 4 and 5.

**Model performance**

The apparent R2 ranged from 0.13 to 0.42, but the internal validation revealed considerable optimism in all models. After adjusting for optimism, R2 values ranged from 0.04 to 0.10 (Figure 2). In all models calibration was poor with only *mean calibration* being satisfactory (i.e. calibration-in-the-large close to 0), whereas *weak* and *moderate calibration* were low as all models systematically overestimated predicted outcomes (i.e. calibration slope <1) and had little agreement between observed and predicted KOOS4 change scores (Figure 2). Sensitivity analyses including only patients with complete data did not alter the results much (online supplementary table 6 and 7 and figure 1).

**DISCUSSION**

Recent randomized trials have strongly questioned the effectiveness of APM for degenerative meniscal tears. There is widespread debate about the use of APM and the existence of particular subgroups of patients benefitting from the procedure.41-44 Therefore, and to try identify any such subgroups who might benefit from APM, we developed a prognostic model.

We included a large number of factors considered important for the outcome after surgery and, importantly, factors often used as pivotal indications for knee arthroscopy. Yet, our developed models failed to accurately predict change in patient-reported outcome after meniscal surgery and identify patients with certain characteristics having a particular outcome after meniscal surgery.

The majority of patients included in the development of the prognostic models were middle-aged or older, reflecting current clinical practice.45-47 These patients typically have a degenerative meniscal tear,45 48 often in combination with other degenerative changes such as knee OA.48 49 Symptoms are therefore likely to result from the multiple and complex processes of OA rather than the meniscal tear *per se*.50 This may in part explain why the main models and models that included only patients aged 41 or older failed to predict change in patient-reported outcome after a procedure targeting the meniscus. On the other hand, younger patients more often have a traumatic meniscal tear (e.g. sports-related trauma) in an otherwise normal joint48 51 making symptoms more likely to originate from the meniscal tear or be a consequence of loss of meniscus function. This might explain the better apparent predictive performance observed for the models that included only patients aged 40 or younger. However, due to the small sample size these models were severely overfitted and should be regarded as exploratory, needing to be confirmed.

Some previous studies have investigated if APM was more effective in subgroups of patients with traumatic meniscal tears or mechanical symptoms, but failed to show any additional benefit of APM for these patients.14 52 53 Our results confirm this, but in addition to those studies, we included several other factors and used data from a large clinical cohort that included a heterogeneous population in which the average improvement after surgery is comparable to the average improvement observed in previous trials.2-4 Our results do not support the existence of specific subgroups of patients with certain preoperative characteristics having larger improvements in patient-reported outcomes after meniscal surgery. As a consequence, the observed variations in effect in this cohort and the surgical arm of previous randomized trials2 3 may be due to random variation rather than a sign of the existence of specific subgroups with a particular effect of meniscal surgery.

**Limitations**

This study has some limitations. Although we included a large number of factors considered to be important for the outcome after meniscal surgery,17 23 some important prognostic factors might have been missed. For instance, radiographic knee osteoarthritis has been reported to be associated with worse outcome after meniscal surgery,17 23 but radiographs were not available in this study. Information from preoperative magnetic resonance imaging (MRI) of the knee was also not available, thus specific characteristics of the meniscal tear could not be included in the models. This may be a limitation for especially the models predicting the outcome in younger patients. For middle-aged and older patients, however, use of MRI imaging to diagnose a meniscal tear is generally not recommended,54 55 as meniscal tears are frequent incidental findings on MRI in asymptomatic adults with uncertain clinical relevance.56 57 Other potential prognostic factors that are missing are workers’ compensation and self-reported fitness level, which have been found to be associated with outcome after meniscal surgery in a few low quality studies,17 23 but this information was not available in the KACS cohort.19 Importantly however, prognostic factors not included in the present models need to be strongly associated with the outcome and only weakly associated with already included factors to substantially improve the predictive performance of any of the models.37 This makes it less likely that the developed models’ performance would improve considerably with the inclusion of potentially missing prognostic factors.

We cannot rule out the possibility of misclassifications of prognostic factors affecting the prognostic performance of models. However, the degree of misclassification is likely low as all prognostic factors were self-reported using online questionnaires.

Sample sizes were sufficient in most models to maintain a ratio of 15-20 participants per model parameter, as recommended.25 Despite this, predictive performance diminished considerably after adjustment for optimism, reflecting that none of the included factors were strongly predictive of outcome.

Due to the poor performance of all models no external validation was indicated.58 Nevertheless, we believe our findings have high external validity,59 as distribution of age and sex of included patients are similar to the underlying population that had meniscal surgery in the same period in Denmark (The Danish National Patient Register, www.esundhed.dk) and to what has previously been reported for patients undergoing meniscal surgery in Denmark and the United States.45 60

**CONCLUSION**

Despite considering a large number of clinically relevant factors collected preoperatively, change in patient-reported outcome one year following meniscal surgery was not possible to predict. Our results do not support the existence of subgroups with certain characteristics having a particularly favourable outcome after meniscal surgery.

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**Contributors**

Concept and design:KP, JBT, JE, GP, ME, LSL.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: KP, JBT.

Critical revision of the manuscript for important intellectual content:All authors.

Approval of final submitted version of manuscript: All authors.

**Competing interests**

All authors have completed the ICMJE Form for Disclosure of Potential Conflicts of Interest.

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**Ethical approval**

Written informed consent was obtained from all patients. The regional scientific ethics committee of Southern Denmark waived the need for ethical approval.

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**TABLES**

**Table 1.** Baseline patient characteristics

|  |  |  |  |
| --- | --- | --- | --- |
|  | **All (n=641)** | **40 years or younger (n=150)** | **41 years or older (n=491)** |
| **Variables** |  | **Range** |  | **Range** |  | **Range** |
| ***Demographics*** |
| Age, years (SD) | 48.7 (13) | 18 to 76 | 30.6 (7) | 18 to 40 | 54.2 (9) | 41 to 76 |
| Sex, female, n (%) | 280 (44) |  | 50 (33) |  | 230 (47) |  |
| BMI, kg/m2 (SD) | 27.3 (4.4) | 18.9 to 47.2 | 26.4 (4.2) | 18.9 to 44.1 | 27.5 (4.5) | 18.9 to 47.2 |
| Educational level, n (%) |  |  |  |  |  |  |
|  Elementary school | 104 (16) |  | 16 (11) |  | 88 (18)  |  |
|  High school | 34 (5) |  | 21 (14) |  | 13 (3) |  |
|  Vocational education | 227 (35) |  | 49 (33) |  | 178 (36) |  |
|  Short cycle education | 63 (10) |  | 13 (9) |  | 50 (10) |  |
|  Medium cycle education | 120 (19) |  | 23 (15) |  | 97 (20) |  |
|  Bachelor degree | 43 (7) |  | 17 (11) |  | 26 (5) |  |
|  Master degree | 31 (5) |  | 8 (5) |  | 23 (5) |  |
|  PhD | 2 (0) |  | 1 (1) |  | 1 (0) |  |
|  Other | 17 (3) |  | 2 (1) |  | 15 (3) |  |
| Participation in physical activity prior to injury, n (%) |  |  |  |  |  |  |
|  Sport at competitive level | 61 (9) |  | 35 (23) |  | 26 (5) |  |
|  Recreational sport | 152 (24) |  | 45 (30) |  | 107 (22) |  |
|  Light sport | 160 (25) |  | 23 (15) |  | 137 (28) |  |
|  Heavy household work | 100 (15) |  | 18 (12) |  | 82 (17) |  |
|  Light household work | 153 (24) |  | 24 (16) |  | 129 (26) |  |
|  Minimal household work | 11 (2) |  | 4 (3) |  | 7 (1) |  |
|  No household work | 4 (1) |  | 1 (1) |  | 3 (1) |  |
| Physical activity at work, n (%) |  |  |  |  |  |  |
|  Very light (mainly desk work) | 136 (21) |  | 35 (23) |  | 101 (20) |  |
|  Light (light industrial, salesman, office  etc.) | 108 (17) |  | 25 (17) |  | 83 (17) |  |
|  Moderate (cleaning, kitchen, mail etc.) | 216 (34) |  | 46 (31) |  | 170 (35) |  |
|  Hard (heavy industrial, farmer etc.) | 100 (15) |  | 30 (20) |  | 70 (14) |  |
|  Unemployed | 81 (13) |  | 14 (9) |  | 67 (14) |  |
| ***Medical history*** |
| Previous surgery on index knee, n (%)a | 117 (18) |  | 26 (17) |  | 91 (19) |  |
| Back problems, no (%) | 189 (29) |  | 28 (19) |  | 161 (33) |  |
| Feeling sad, no (%) |  |  |  |  |  |  |
|  All of the time | 3 (1) |  | 0 (0) |  | 3 (1) |  |
|  Most of the time | 9 (1) |  | 6 (4) |  | 3 (1) |  |
|  A good bit of the time | 35 (5) |  | 10 (7) |  | 25 (5) |  |
|  Some of the time | 92 (14) |  | 22 (15) |  | 70 (14) |  |
|  A little of the time | 196 (31) |  | 50 (33) |  | 146 (30) |  |
|  None of the time | 306 (48) |  | 62 (41) |  | 244 (50) |  |
| Knee alignment, n (%) |  |  |  |  |  |  |
|  Pronounced varus | 6 (1) |  | 4 (3) |  | 2 (1) |  |
|  Slightly varus | 59 (9) |  | 14 (9) |  | 45 (9) |  |
|  Normal | 528 (83) |  | 121 (80) |  | 407 (83) |  |
|  Slightly valgus | 46 (7) |  | 10 (7) |  | 36 (7) |  |
|  Pronounced valgus | 2 (0) |  | 1 (1) |  | 1 (0) |  |
| n.: number, SD: Standard deviation, BMI: body mass index. a1 missing observation in older age group. |

**Table 2.** Baseline knee symptoms of included patients

|  |  |  |  |
| --- | --- | --- | --- |
|  | **All (n=641)** | **40 years or younger (n=150)** | **41 years or older (n=491)** |
| **Variables** |  | **Range** |  | **Range** |  | **Range** |
| ***Meniscal tear characteristics*** |
| Duration of symptoms, n (%) |  |  |  |  |  |  |
|  0-3 months | 129 (20) |  | 41 (27) |  | 88 (18) |  |
|  4-6 months | 181 (28) |  | 24 (16) |  | 157 (32) |  |
|  7-12 months | 135 (21) |  | 31 (21) |  | 104 (21) |  |
|  13-24 months | 94 (15) |  | 20 (13) |  | 74 (15) |  |
|  More than 24 months | 102 (16) |  | 34 (23) |  | 68 (14) |  |
| Symptom onset |  |  |  |  |  |  |
|  Slowly evolved | 208 (32) |  | 29 (19) |  | 179 (36) |  |
|  Semi traumatic | 260 (41) |  | 51 (34) |  | 209 (43) |  |
|  Traumatic | 173 (27) |  | 70 (47) |  | 103 (21) |  |
| ***Knee-related symptoms*** |
| Knee catching/locking, n (%) |  |  |  |  |  |  |
|  Never | 301 (47) |  | 61 (41) |  | 240 (49) |  |
|  Rarely | 102 (16) |  | 18 (12) |  | 84 (17) |  |
|  Sometimes | 135 (21) |  | 35 (23) |  | 100 (20) |  |
|  Often | 87 (14) |  | 30 (20) |  | 57 (12) |  |
|  Always | 16 (2) |  | 6 (4) |  | 10 (2) |  |
| Able to straighten knee fully, n (%) |  |  |  |  |  |  |
|  Always | 349 (54) |  | 68 (45) |  | 281 (57) |  |
|  Often | 133 (21) |  | 41 (27) |  | 92 (19) |  |
|  Sometimes | 70 (11) |  | 18 (12) |  | 52 11) |  |
|  Rarely | 32 (5) |  | 7 (5) |  | 25 (5) |  |
|  Never | 57 (9) |  | 16 (11) |  | 41 (8) |  |
| Frequency of knee pain, no (%) |  |  |  |  |  |  |
|  None | 10 (2) |  | 3 (2) |  | 7 (1) |  |
|  Monthly | 31 (5) |  | 12 (8) |  | 19 (4) |  |
|  Weekly | 71 (11) |  | 29 (19) |  | 42 (9) |  |
|  Daily | 412 (64) |  | 78 (52) |  | 334 (68) |  |
|  Always | 117 (18) |  | 28 (19) |  | 89 (18) |  |
| Knee pain walking on stairs, n (%) |  |  |  |  |  |  |
|  None | 51 (8) |  | 19 (13) |  | 32 (7) |  |
|  Mild | 140 (22) |  | 45 (30) |  | 95 (19) |  |
|  Moderate | 211 (33) |  | 45 (30) |  | 166 (34) |  |
|  Severe | 186 (29) |  | 27 (18) |  | 159 (32) |  |
|  Extreme | 53 (8) |  | 14 (9) |  | 39 (8) |  |
| Difficulty twisting/pivoting knee, n (%) |  |  |  |  |  |  |
|  None | 13 (2) |  | 6 (4) |  | 7 (1) |  |
|  Mild | 48 (7) |  | 15 (10) |  | 33 (7) |  |
|  Moderate | 89 (14) |  | 25 (17) |  | 64 (13) |  |
|  Severe | 228 (36) |  | 51 (34) |  | 177 (36) |  |
|  Extreme | 263 (41) |  | 53 (35) |  | 210 (43) |  |
| Knee instability, n (%) |  |  |  |  |  |  |
|  Not unstable | 107 (17) |  | 22 (15) |  | 85 (17) |  |
|  Unstable, but not affecting activities | 64 (10) |  | 14 (9) |  | 50 (10) |  |
|  Unstable, slightly affecting activities | 125 (19) |  | 30 (20) |  | 95 (19) |  |
|  Unstable, moderately affecting activities | 127 (20) |  | 22 (15) |  | 105 (22) |  |
|  Unstable, highly affecting activities | 199 (31) |  | 57 (38) |  | 142 (29) |  |
|  Unstable, preventing all activities | 19 (3) |  | 5 (3) |  | 14 (3) |  |
| KOOS, mean (SD) |  |  |  |  |  |  |
|  KOOS4 | 45.7 (15.3) | 2.7 to 87.7 | 47.7 (16.8) | 2.7 to 87.4 | 45.1 (14.8) | 5.4 to 87.7 |
|  Pain | 54.9 (18.5) | 0.0 to 100.0 | 58.9 (20.2) | 0.0 to 100.0 | 53.6 (17.8) | 8.3 to 97.2 |
|  Symptoms | 60.0 (18.6) | 3.6 to 100.0 | 60.6 (19.2) | 10.7 to 100.0 | 59.8 (18.4) | 3.6 to 100.0 |
|  ADL | 63.7 (19.5) | 2.9 to 100.0 | 69.8 (19.6) | 7.4 to 100.0 | 61.8 (19.0) | 2.9 to 100.0 |
|  Sport/Rec | 26.3 (21.9) | 0.o to 100.0 | 31.1 (23.3) | 0.0 to 90.0 | 24.9 (21.3) | 0.0 to 100.0 |
|  QoL | 41.6 (15.4) | 0.0 to 87.5 | 40.2 (16.1) | 0.0 to 75.0 | 42.0 (15.2) | 0.0 to 87.5 |
| n.: number, SD: Standard deviation, KOOS: Knee injury and Osteoarthritis Outcome Score, ADL: activities of daily living, Sport/rec: sport and recreational activities, QOL: knee-related quality of life. |

**Table 3.** Results from multivariable linear regression models including all patients.

|  |  |  |
| --- | --- | --- |
|  | **Multivariable model I (n=641)a** | **Multivariable model II (n=641)a** |
| **Variables** | **β coefficient (95% CI)** | **p-value** | **β coefficient (95% CI)** | **p-value** |
| Model intercept | -4.15 |  | -7.44 |  |
| Age, years | 0.13 (-0.01 to 0.26) | 0.063 |  |  |
| Sex (Female) | -0.01 (-3.42 to 3.40) | 0.995 |  |  |
| BMI, kg/m2 | -0.32 (-0.69 to 0.06) | 0.096 |  |  |
| Educational level (ref: Elementary/High school) |  | 0.023 |  | 0.025 |
|  Vocational/Short education | 5.47 (1.39 to 9.54) |  | 5.32 (1.39 to 9.24) |  |
|  Medium duration/Bachelor/Master/PhD/Other | 2.41 (-1.91 to 6.72) |  | 2.76 (-1.41 to 6.92) |  |
| Participation in physical activity prior to injury (ref: Light/Minimal/No household work) |  | 0.142 |  | 0.115 |
|  Light sport/Heavy household work | 2.78 (-0.97 to 6.54) |  | 3.04 (-0.65 to 6.74) |  |
|  Competitive/Recreational sport | 4.29 (-0.04 to 8.61) |  | 4.21 (0.14 to 8.29) |  |
| Physical activity at work (ref: Very light/Light/Unemployed) |  | 0.518 |  |  |
|  Moderate | -1.21 (-4.74 to 2.31) |  |  |  |
|  Hard | 1.69 (-3.21 to 6.60) |  |  |  |
| Previous surgery on index knee | -7.57 (-11.91 to -3.23) | 0.001 | -7.84 (-11.94 to -3.73) | <0.001 |
| Back problems | -3.59 (-7.02 to -0.17) | 0.040 | -3.27 (-6.66 to 0.12) | 0.059 |
| Feeling sad (ref: None of the time) |  | 0.820 |  |  |
|  A little of the time | -1.07 (-4.67 to 2.53) |  |  |  |
|  All/Most/A good bit/Some of the time | 0.08 (-4.15 to 4.31) |  |  |  |
| Knee alignment (ref: Normal) |  | 0.662 |  |  |
|  Slightly/Pronounced varus | -2.41 (-8.04 to 3.23) |  |  |  |
|  Slightly/Pronounced valgus | -1.10 (-7.22 to 5.01) |  |  |  |
| Duration of symptoms (ref: 0-3 months) |  | 0.433 |  |  |
|  4-6 months | 2.20 (-2.38 to 6.77) |  |  |  |
|  7-12 months | -1.24 (-6.27 to 3.78) |  |  |  |
|  More than 12 months | 1.56 (-3.14 to 6.26) |  |  |  |
| Symptom onset (ref: Slowly evolved) |  | 0.098 |  | 0.029 |
|  Semi traumatic | 0.58 (-3.12 to 4.29) |  | 0.16 (-3.45 to 3.77) |  |
|  Traumatic | -3.60 (-7.89 to 0.69) |  | -4.63 (-8.71 to -0.55) |  |
| Knee catching/lockinga | 0.40 (-1.06 to 1.85) | 0.593 |  |  |
| Able to straighten knee fullya | 1.86 (0.51 to 3.22) | 0.007 | 2.02 (0.70 to 3.35) | 0.003 |
| Frequency of knee paina | 2.44 (0.18 to 4.71) | 0.035 | 2.39 (0.15 to 4.63) | 0.036 |
| Knee pain walking on stairs (ref: None/Mild) |  | 0.050 |  | 0.037 |
|  Moderate | 3.14 (-1.03 to 7.30) |  | 3.43 (-0.68 to 7.53) |  |
|  Severe/Extreme | -1.44 (-6.13 to 3.26) |  | -1.15 (-5.57 to 3.27) |  |
| Difficulty twisting/pivoting kneea | 2.74 (0.92 to 4.56) | 0.003 | 3.17 (1.39 to 4.96) | 0.001 |
| Knee instability (ref: Not unstable/Unstable, but not affecting activities) |  | 0.316 |  |  |
|  Unstable, slightly/moderately affecting  activities | -0.83 (-4.57 to 2.91) |  |  |  |
|  Unstable, highly affecting/preventing all  activities | 2.08 (-2.23 to 6.39) |  |  |  |
| n: number, CI: confidence interval, BMI: body mass index.aBased on 10 imputed data sets. bHandled as continuous using the original categories, assuming linearity. The coefficients are per category increase. Interaction terms omitted from the models (p=0.590). |

**Table 4.** Results from multivariable linear regression for models including young and older patients, respectively.

|  |  |  |
| --- | --- | --- |
|  | **40 years or younger (n=150)** | **41 years or older (n=491)** |
|  | **Multivariable model Ia** | **Multivariable model IIa** | **Multivariable model Ib** | **Multivariable model IIb** |
| **Variables** | **β coefficient(95% CI)** | **p-value** | **β coefficient(95% CI)** | **p-value** | **β coefficient (95% CI)** | **p-value** | **β coefficient(95% CI)** | **p-value** |
| Model intercept | -0.29 |  | -8.48 |  | -0.14 |  | -13.21 |  |
| Age, years | 0.52 (-0.14 to 1.18) | 0.119 | 0.64 (0.13 to 1.16) | 0.015 | 0.10 (-0.11 to 0.31) | 0.343 | 0.13 (-0.07 to 0.33) | 0.208 |
| Sex (female) | -1.67 (-9.98 to 6.63) | 0.689 |  |  | 0.27 (-3.61 to 4.15) | 0.891 |  |  |
| BMI, kg/m2  | -0.28 (-1.15 to 0.58) | 0.516 |  |  | -0.34 (-0.74 to 0.06) | 0.098 |  |  |
| Educational level (ref: Elementary/High school)c | 1.65 (-4.03 to 7.33)  | 0.565 |  |  |  | 0.073 |  | 0.065 |
|  Vocational/Short education |  |  |  |  | 4.40 (-0.47 to 9.27) |  | 4.36 (-0.42 to 9.14) |  |
|  Medium duration/Bachelor/Master/PhD/Other |  |  |  |  | 0.21 (-4.87 to 5.30) |  | 0.24 (-4.74 to 5.22) |  |
| Participation in physical activity prior to injury (ref: Light/Minimal/No household work)d |  | 0.777 |  |  | 2.41 (-0.08 to 4.90) | 0.057 | 3.10 (0.70 to 5.50) | 0.012 |
|  Light sport/Heavy household work | 0.27 (-10.31 to 10.85) |  |  |  |  |  |  |  |
|  Competitive/Recreational sport | -2.48 (-11.91 to 6.96) |  |  |  |  |  |  |  |
| Physical activity at work (ref: Very light/Light/Unemployed) |  | 0.971 |  |  |  | 0.454 |  |  |
|  Moderate | 0.07 (-8.31 to 8.46) |  |  |  | -0.81 (-4.77 to 3.16) |  |  |  |
|  Hard | -1.13 (-11.79 to 9.52) |  |  |  | 2.97 (-2.76 to 8.70) |  |  |  |
| Previous surgery on index knee | -13.96 (-25.04 to -2.88) | 0.015 | -13.87 (-24.72 to -3.01) | 0.014 | -6.17 (-10.68 to -1.66) | 0.007 | -7.13 (-11.48 to -2.77) | 0.001 |
| Back problems | -9.62 (-19.52 to 0.28) | 0.057 | -8.97 (-17.53 to -0.42) | 0.040 | -2.83 (-6.47 to 0.81) | 0.128 | -2.65 (-6.27 to 0.96) | 0.150 |
|  Feeling sad (ref: None of the time)d |  | 0.833 |  |  | 0.17 (-2.15 to 2.48) | 0.889 |  |  |
|  A little of the time | 0.57 (-7.72 to 8.87) |  |  |  |  |  |  |  |
|  All/Most/A good bit/Some of the time | 2.80 (-6.40 to 11.99) |  |  |  |  |  |  |  |
| Knee alignment (ref: Normal) |  | 0.460 |  | 0.279 |  | 0.689 |  |  |
|  Slightly/Pronounced varus | 0.06 (-12.26 to 12.38) |  | 0.22 (-10.79 to 11.22) |  | -2.34 (-8.57 to 3.90) |  |  |  |
|  Slightly/Pronounced valgus | -9.20 (-23.49 to 5.09) |  | -10.78 (-23.71 to 2.15) |  | 1.30 (-5.39 to 8.00) |  |  |  |
| Duration of symptoms (ref: 0-3 months) |  | 0.080 |  | 0.041 |  | 0.352 |  |  |
|  4-6 months | -0.60 (-11.85 to 10.65) |  | -1.66 (-11.76 to 8.45) |  | 0.82 (-4.38 to 6.02) |  |  |  |
|  7-12 months | 1.90 (-8.28 to 12.09) |  | -0.08 (-9.48 to 9.65) |  | -3.34 (-9.07 to 2.38) |  |  |  |
|  More than 12 months | 10.16 (0.32 to 19.99) |  | 9.67 (-0.15 to 19.49) |  | -2.02 (-7.62 to 3.59) |  |  |  |
| Symptom onset (ref: Slowly evolved) |  | 0.895 |  |  |  | 0.119 |  | 0.163 |
|  Semi traumatic | 0.09 (-10.31 to 10.51) |  |  |  | 0.43 (-3.72 to 4.59) |  | 0.77 (-3.21 to 4.75) |  |
|  Traumatic | -1.71 (-11.71 to 8.30) |  |  |  | -4.30 (-9.30 to 0.70) |  | -3.64 (-8.44 to 1.16) |  |
| Knee catching/locking (ref: Never)d |  | 0.441 |  |  | -0.98 (-3.57 to 1.61) | 0.456 |  |  |
|  Rarely/Sometimes | 5.67 (-3.10 to 14.45) |  |  |  |  |  |  |  |
|  Often/Always | 3.96 (-7.51 to 15.43) |  |  |  |  |  |  |  |
| Able to straighten knee fully (ref: Always)e |  | 0.054 |  | 0.018 | 2.15 (0.65 to 3.66) | 0.005 | 2.42 (0.97 to 3.87) | 0.001 |
|  Often/Sometimes | -5.98 (-14.47 to 2.52) |  | -5.06 (-12.59 to 2.47) |  |  |  |  |  |
|  Never/Rarely | 7.18 (-4.43 to 18.79) |  | 9.08 (-0.70 to 18.86) |  |  |  |  |  |
| Frequency of knee painf | 1.68 (-3.36 to 6.72) | 0.510 |  |  | 2.79 (0.14 to 5.44) | 0.039 | 2.70 (0.10 to 5.30) | 0.042 |
| Knee pain walking on stairs (ref: None/Mild)c | 5.29 (-0.71 to 11.30) | 0.083 | 6.23 (1.35 to 11.10) | 0.013 |  | 0.050 |  | 0.062 |
|  Moderate |  |  |  |  | 0.98 (-3.91 to 5.86) |  | 1.27 (-3.49 to 6.03) |  |
|  Severe/Extreme |  |  |  |  | -4.38 (-9.79 to 1.02) |  | -3.65 (-8.70 to 1.40) |  |
| Difficulty twisting/pivoting kneef | 2.74 (-0.96 to 6.45) | 0.145 | 2.89 (-0.33 to 6.11) | 0.078 | 2.45 (0.31 to 4.59) | 0.025 | 2.71 (0.60 to 4.82) | 0.012 |
| Knee instability (ref: Not unstable/Unstable, but not affecting activities) |  | 0.728 |  |  |  | 0.207 |  |  |
|  Unstable, slightly/moderately affecting activities | -3.96 (-14.08 to 6.16) |  |  |  | 0.69 (-3.53 to 4.90) |  |  |  |
|  Unstable, highly affecting/preventing all activities | -2.53 (-13.24 to 8.19) |  |  |  | 3.99 (-0.78 to 8.77) |  |  |  |
| n: number, CI: confidence interval, BMI: body mass indexaBased on 20 imputed data sets. bBased on 10 imputed data sets. cHandled as continuous in the models including young patients using the combined categories. dHandled as continuous in the models including older patients using the combined categories. eHandled as continuous in the models including older patients using the original categories. fHandled as continuous in all models using the original categories. For all categorical variables handled as continuous linearity is assumed, and coefficients are per category increase. Interaction terms omitted from all models (p=0.288 for the models including young patients, and p=0.810 for the models including older patients). |

**FIGURE LEGENDS**

**Figure 1.** Study flowchart. “y” denotes young patients (≤40 years) and “o” denotes old patients (>40 years).

**Figure 2**.Calibration plots comparing the distribution of observed and model predicted KOOS4 change scores, respectively, and performance measures for all models. A well-calibrated model would be indicated by all predicted values being close to the black identity line.