Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
Nov-Dec 2021 Page No. 408-420
Article History: Received: 05 October 2021, Revised: 02 November 2021, Accepted: 25 November 2021, Publication: 31 December 2021

Development of a Nomogram for the Identification of Meniscus Injury by Subjective Symptoms

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Abstract:

Background: Our study aimed to construct a nomogram with a scoring system based on subjective symptoms to identify meniscus injury. Methods: This study recruited 157 participants for a cross-sectional study. The doctor used MRI to diagnose each participant's knee joint. We use questionnaires to collect data on 14 subjective symptoms of each patient. Chi-square test and logistic regression were used for statistical analysis to screen for significant symptoms of meniscus injury relative to other knee diseases. We used the nomogram method to score the significant symptoms and build a scoring model. Results: Multivariate analysis showed that Pain Activity (OR = 3.41), Pain Hyperflexion (OR = 4.135), Tend Knee Space (OR = 62.138) were statistically significant risk symptoms for meniscus injury. Knee dislocation (OR = 0.184) was not a significant distinguishing symptom. Analysis of the nomogram model showed that the total score for each symptom ranged from 37 to 219, with corresponding risk rates ranging from 0.10 to 0.95 points. The C-index was calculated to assess the recognition accuracy of this nomogram scoring system was 88.75% (95% CI 85.24%-90.78%). Conclusions: We found that using the nomogram to establish an identification model to distinguish meniscus injury from other knee diseases based on subjective symptoms was effective. This method is a convenient and effective tool to evaluate meniscus injury and support the prevention and self-management of meniscus injury.

Keywords: *Meniscus injury, Subjective symptoms, Nomogram.*

I. INTRODUCTION

The meniscus is the elastic cartilage between the femur and tibia of the knee. It plays a cushioning role and bears the friction of the knee activity. The meniscus often degenerates with age [1]. Trauma to the knee in daily life can easily cause meniscus injury. Therefore, meniscus injury is a relatively common knee disease [2,3,4]. MRI is an important diagnostic tool for the diagnosis of meniscus injury [5,6]. Arthroscopy is the gold standard for meniscus examination, but it is invasive [7]. The analysis of focused subjective symptoms and history is still the cornerstone for the diagnosis of meniscus injuries.

Meniscus injury usually has many objective and subjective symptoms, such as pain, locking, limited movement, and swelling, among others, but these symptoms may also be caused by other knee diseases [8]. Meniscus injury is often accompanied by other knee diseases. Symptom analysis refers to the preliminary diagnosis of a disease based on the physician's experience and assessment of the history and symptoms of the disease. It is a challenge to distinguish meniscus injury from other knee diseases based on subjective symptoms. Anninou A P et al. created a diagnostic model for meniscal injury using a dynamic fuzzy cognitive map that takes the patient history and clinical examination as inputs [9]. In recent years, many studies have used the nomogram for individualized prediction of cancer [10,11] and its risk symptoms [12,13]. Although most studies have focused on disease prediction, a few reports have applied it to identifying diseases, including the identification of knee diseases.

It would be valuable to evaluate meniscus injury of the knee joint through simple and effective methods. This study attempts to identify and distinguish meniscus injury from other knee diseases through subjective symptoms and nomograms.

II. MATERIALS AND METHODS

2.1 Design, recruitment process and participants

This study was a cross-sectional study of subjective symptoms for meniscus injuries. To gather accurate diagnostic information as the gold standard, we mainly recruited experimental subjects from a hospital to obtain an accurate knee diagnosis of each patient as derived from MRIs and comprehensive evaluations by physicians. The study comprised 157 subjects recruited from a hospital from January 2021 to April 2021.

The inclusion criteria for the experimental participants were as follows: patients with a diagnosis of the meniscal injury or some other knee disease by the physician through MRI and necessary definitive examination; this patient was able to provide complete clinical examination data and case information; this patient was aware of the experimental content and voluntarily participated in this investigation.

The exclusion criteria for trial participants were as follows: patients with myocardial infarction, malignant disease, or severe infectious disease; patients with cognitive impairment.

A 14-symptom-based questionnaire was used to collect information on patients' competent symptoms. A face-to-face interview format was used. All participating study personnel was uniformly trained prior to the start of the survey to ensure consistency and accuracy of data. A physician conducted the questionnaire

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interview for each patient. The study complied with the Declaration of Helsinki and was approved by the ethics committee. Informed consent was obtained from all individuals involved in the study.

2.2 Symptoms Questionnaire

The symptoms questionnaire was used to collect information relating to the patients' subjective symptoms with knee diseases. The description of symptoms, the patient history, and the subjective symptoms are usually quite ambiguous and equivocal, and the definition of subjective symptoms of knee diseases is a challenging task. These observations must reflect the disease status effectively and need to be easily understood by people.

According to extensive literature and physician experience, we defined a series of subjective symptoms of knee disease [14]. At least three physicians agreed upon the definition of each symptom. The main 14 subjective symptoms' definitions are shown in TABLE I.

TABLE I. Description of subjective symptoms of meniscus injury diseases.

Symptoms	Description
1. Injury,	Injury: Have you had a recent injury to your knee or was it caused by an injury?
2. Injure Zip	Injure Zip: Did you hear a zip sound when your knee injury occurred?
3. Flexion Limit [15],	Flexion Limit: Are you unable to flex or full flex your knee or do you have difficulty in squatting?
4. Extension Limit	Extension Limit: Are you unable to extend or full extend with your knee or do you have difficulty in squatting?
5. Snapping/ Clicking [16]	Snapping: Do you have a click or hear a click when you move your knee?
6. Locking/ Catching [17]	Locking: Do you feel like your knee gets temporarily stuck at times, so you can't move it any further?
7. Instability [18-19]	Instability: Do you sometimes feel like your knees are going to give out and not be able to support your weight?
8. Knee Dislocation [20]	Knee Dislocation: Do you sometimes feel that there is any misalignment and dislocation in your knee, or a sense of disengagement between the thigh and the calf, including anterior-posterior and rotational dislocations?
9. Stiffness [21]	Stiffness: Do you feel that your knee is stiff and unable to move after a long period of immobility?
10. Swelling [22]	Swelling: Do you have any swelling in your knee?
11.Pain [23], 12.Pain Activity, 13.Pain Hyperflexion	Pain: Do you have any pain in your knee? Pain Activity: Does your knee pain get worse when you perform activities? Pain Hyperflexion: Does your knee pain get worse during knee hyperflexion?
14. Tend Knee Space [24]	Tend Knee Space: Do you feel pain when you press the gap or space or joint line between your knee?

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2.3 Statistical Analysis

To verify and find the significant symptoms that distinguish meniscal injuries from other knee disorders and reduce the computational complexity of symptom selection, we performed the univariate statistical analysis and multivariate statistical analysis, respectively, to find statistically significant symptoms between the meniscal injury and non-meniscal injury groups.

All of the symptoms were categorical variables coded as presence (1) or absence (0). Univariate analysis was performed using a Chi-Square test, and multivariate analysis was performed using logistic regression modeling. We used the chi-square test for univariate analysis and the logistic regression model for multivariate analysis. P-value <0.05 was considered to be statistically significant. We first use univariate analysis to find the statistically significant symptoms from all symptoms and then use multivariate regression analysis to find the statistically significant symptoms from the significant symptoms chosen from univariate analysis.

2.4 Nomogram Analysis

The nomogram is a statistical model. It estimates the impact score for each significant symptom based on the degree of contribution of each significant symptom in the regression model. The total score for the corresponding symptom of the participant is then calculated to obtain the predictive value of hemianopsia. The predictive accuracy of the nomogram model was determined by plotting the consistency index (C-index). We performed an internal validation using the bootstrap method to calibrate the resampling method of the nomogram. A nomogram was constructed for this experiment based on multivariate analysis. The nomogram was subjected to internal validation. The performance of the nomogram was evaluated using the C-index.

III. RESULTS

The study ultimately included 157 patients with knee disease, comprising 81 females and 76 males, with 87 cases of meniscus injury and 70 cases of non-meniscus injury. All statistical analyses were performed using SPSS version 2.1 software and R software v3.6. The nomogram was drawn by the rms package.

3.1 Analysis of Significant Symptoms

As shown in TABLE II, the P-value of the Instability, Pain, Pain Activity, Pain Hyperflexion, and Tend Knee Space variables in the univariate analysis was less than 0.05, indicating that these symptoms were statistically significant and therefore suitable features for the identification of meniscus injury.

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TABLE II. Univariate analysis of subjective symptoms of meniscus injury.

Symptoms		Meniscus Injury No	Meniscus Injury Yes	χ^2	P
Flexion Limit	No	36 (46.8%)	41 (53.2%)	0.287	0.592
	Yes	34 (42.5%)	46 (57.5%)		
Extension Limit	No	49 (41.5%)	69 (58.5%)	1.801	0.18
	Yes	21 (53.8%)	18 (46.2%)		
Snapping	No	37 (52.9%)	33 (47.1%)	3.498	0.061
	Yes	33 (37.9%)	54 (62.1%)		
Locking	No	53 (44.9%)	65 (55.1%)	0.021	0.885
	Yes	17 (43.6%)	22 (56.4%)		
Instability	No	30 (36.1%)	53 (63.9%)	5.079	0.024
	Yes	40 (54.1%)	34 (45.9%)		
Knee Dislocation	No	44 (36.4%)	77 (63.6%)	14.44	< 0.001
	Yes	26 (72.2%)	10 (27.8%)		
Stiffness	No	54 (42.9%)	72 (57.1%)	0.772	0.38
	Yes	16 (51.6%)	15 (48.4%)		
Injure	No	22 (40.7%)	32 (59.3%)	0.493	0.483
	Yes	48 (46.6%)	55 (53.4%)		
Injure Zip	No	56 (45.2%)	68 (54.8%)	0.079	0.779
	Yes	14 (42.4%)	19 (57.6%)		
Swelling	No	41 (42.3%)	56 (57.7%)	0.552	0.458
	Yes	29 (48.3%)	31 (51.7%)		
Pain	No	9 (100%)	0 (0%)	-	0.0011
	Yes	61 (41.2%)	87 (58.8%)		
Pain Activity	No	39 (60.9%)	25 (39.1%)	11.692	0.001
	Yes	31 (33.3%)	62 (66.7%)		
Pain Hyperflexion	No	35 (61.4%)	22 (38.6%)	10.244	0.001
	Yes	35 (35%)	65 (65%)		
Tend Knee Space	No	38 (95%)	2 (5%)	55.215	< 0.001
	Yes	32 (27.4%)	85 (72.6%)		

We analyzed the proportion of significant symptoms obtained from univariate analysis in the meniscus injury group, as shown in Fig 1.

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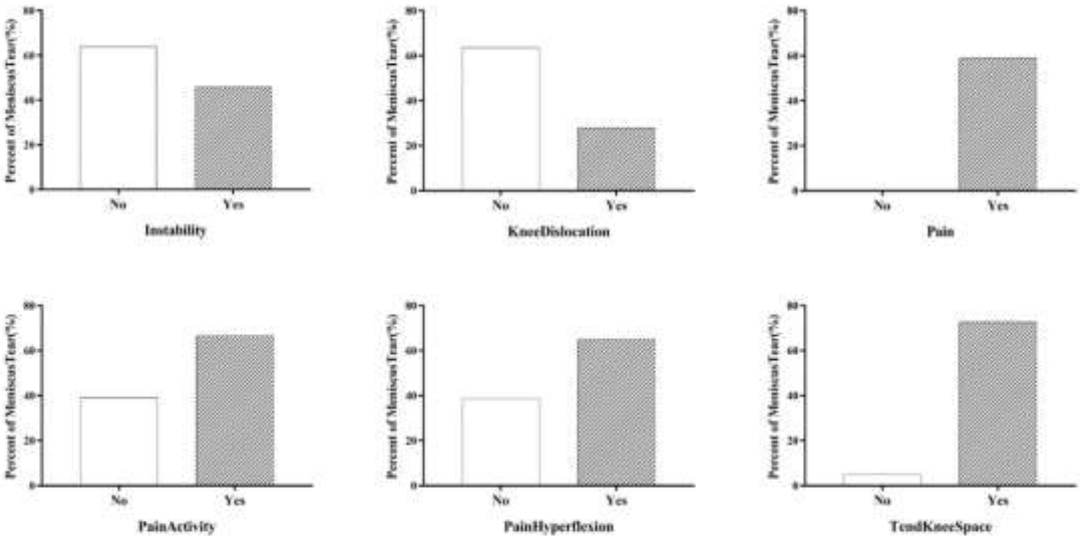

Fig 1: distribution of significant symptoms of meniscus injury.

Next, we conducted a multivariate analysis using a logistic regression model. As the meniscus injury rate of non-Pain was 0, it was not included. The results as shown in TABLE Ⅲ.

TABLE III. Multivariate analysis of subjective symptoms of meniscus injury.

	B	S.E.	Wald	Sig.	OR	95%C.I. for OR	
						Lower	Upper
Instability	-0.59	0.495	1.421	0.233	0.555	0.21	1.462
Knee Dislocation	-1.695	0.557	9.252	0.002	0.184	0.062	0.547
Pain Activity	1.227	0.47	6.819	0.009	3.41	1.358	8.561
Pain Hyperflexion	1.42	0.498	8.137	0.004	4.135	1.559	10.967
Tend Knee Space	4.129	0.812	25.84	<0.001	62.138	12.644	305.363
Constant	-4.077	0.932	19.153	<0.001	0.017		

As shown in TABLE III, the P-values of pain activity, knee dislocation, tend knee space, and pain hyperflexion were less than 0.05, indicating that these symptoms were significant symptoms for identifying meniscus injury.

3.2 Nomogram Analysis and Scoring System

Based on the symptoms identified as statistically significant in the multivariate logistic analysis, we developed a nomogram model for identifying meniscal injuries, as shown in Fig 1. The scoring system and the corresponding probability of the nomogram for identification of meniscus injury are shown in TABLE IV and TABLE V, respectively.

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The dependent variable was the occurrence of meniscal injury and the significant symptoms screened by multivariate logistic regression were used as predictor variables. The score for each significant symptom was calculated and summed to get the sum score. The sum score ranged from 37 to 219, and the relative risk ratios ranged from 0.10 to 0.95. The higher the sum score, the greater the increased risk of meniscal injury.

The constructed meniscal injury nomogram allowed us to calculate the total risk score for having meniscal injury disease for each patient. We used C-index to assess the discriminatory performance of the final model of the meniscal injury scale.

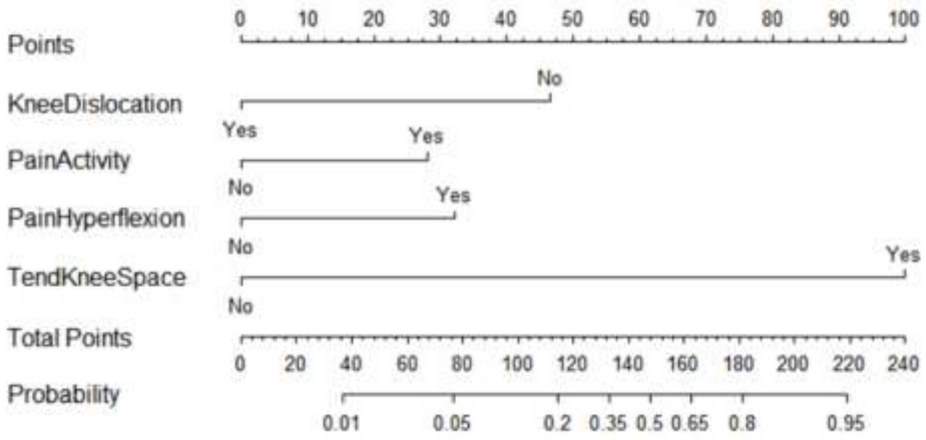

Fig 2: nomogram for identification of meniscus injury in patients with knee disease.

TABLE IV. The scoring system of the nomogram for identification of meniscus injury.

Symptoms		Score
Knee Dislocation	No	46
	Yes	0
Pain Activity	No	0
	Yes	28
Pain Hyperflexion	No	0
	Yes	32
Tend Knee Space	No	0
	Yes	100

As shown in TABLE V, we took 50% as the cut point. Suppose the patient's score was greater than 148, which indicated meniscus injury. The C-index was calculated to assess the identification accuracy of the scoring system of this nomogram. It was determined to be 88.75% (95% CI 85.24%–90.78%). Furthermore, to confirm the accuracy of the above scoring system, the calibration plot shown in Fig 3 was plotted. As can be clearly seen from the figure, the calibration curve and the diagonal lines were essentially aligned and overlapping, which indicates good statistical performance.

TABLE V. The corresponding probability of the scoring system of the nomogram for identification of meniscus injury.

Nomogram score	The probability of Meniscus injury
37	1%
77	5%
95	10%
106	15%
114	20%
121	25%
127	30%
133	35%
138	40%
143	45%
148	50%
153	55%
158	60%
163	65%
168	70%
174	75%
181	80%
190	85%
201	90%
219	95%

IV. DISCUSSION

4.1 Validity of Identification

Using a nomogram to establish an identification model to distinguish meniscus injury from other knee diseases based on subjective symptoms was found to be effective. The C-index was calculated to evaluate the identification accuracy of the scoring system of this nomogram as 88.75% (95% CI 85.24%–90.78%). The structure of the knee is complex, and there are many kinds of diseases associated with the knee. According to the International Classification of Diseases 11th version (ICD-11) [25], there are more than 100 kinds of knee related diseases. Common knee diseases include meniscal injury, knee osteoarthritis, patellar arthritis, patellar instability, anterior cruciate ligament tear, and posterior cruciate ligament tear. There are differences in the treatment and rehabilitation of these knee diseases. Appropriate lifestyle habits can effectively mitigate meniscus injury in the early stage, and its progression can be delayed through appropriate rehabilitation training [26]. Therefore, timely and effective identification of meniscus injury is important and useful.

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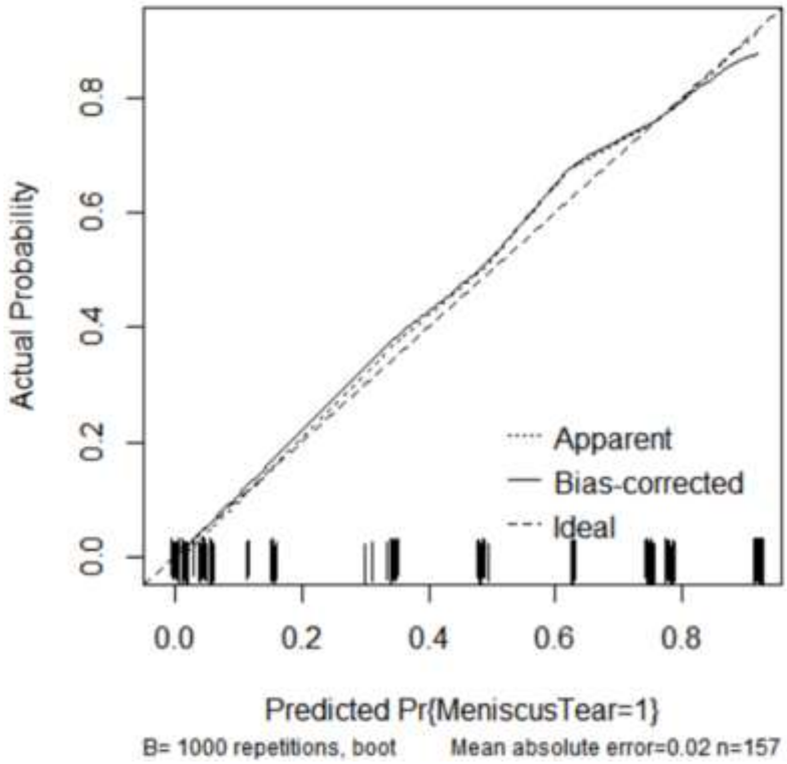

Fig 3: The calibration curve for the predicted and observed probabilities of meniscus injury.

This study analyzed the risk symptoms of meniscus injury and quantitatively evaluated the risk of different symptoms by using the line graph method so as to provide a reliable basis for the prevention or timely treatment of meniscus injury. We first defined the common subjective symptoms caused by knee disease. These subjective symptoms can effectively reflect the characteristics of knee diseases and be easily understood and described by the general population. This study confirmed that these defined subjective symptoms are valid for the identification of meniscus injury. We selected the significant symptoms of meniscus injury that were different from symptoms of other knee diseases in order to simplify the identification model and provide a reference for further exploration of the relationship between meniscus disease and symptoms. The quantitative identification model was constructed using nomograms to analyze the symptoms affecting meniscal injury to further validate the specific weights of the relevant significant symptoms mentioned in earlier studies.

Till date, there have been limited reports of the nomogram‘s use in the identification of meniscus injury in patients with knee disease. Previous studies used logical rules and logistic regression to evaluate the subjective symptoms of knee disease, but the influence of different subjective symptoms on the occurrence of knee disease was different and, therefore, cannot be quantified by the previous analysis methods. The nomogram model is a simple statistical diagnostic model for the probability of clinical events. The model is scored graphically and can help assess the probability of meniscal injury in knee patients. This model is a clinical tool that allows for intuitive, simple, and visual understanding.

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4.2 Subjective Symptoms Analysis

This study found that the presence of all four symptoms was associated with a higher risk of meniscus injury. In this study, approximately 100% of patients with meniscal injury had knee pain, suggesting that pain is an important and possibly fundamental symptom of meniscal injury. Clinically, meniscus injury does cause knee pain [27]. Only local damage to the midbody of the meniscus may not cause pain, but this case is rare. However, pain is also an important symptom of other knee diseases. Pain in the early stages of meniscal injury may not be obvious, and different individuals may have different levels of pain perception and tolerance, which may interfere with screening for meniscal injury based on subjective symptoms.

The specific location of the pain and the aggravating symptoms are of great value in differentiating meniscal injuries. The meniscus is located in the knee joint space. When the meniscus is injured, pressure on the area with the finger can cause significant pain. Therefore, painful joint space compression (Tend Knee Space) is a prominent symptom of meniscal injury [28]. In addition, the specific location of the joint space pain can further identify the location of the meniscal injury, such as midbody, anterior horn, posterior horn, lateral and medial [29]. However, this is not the only symptom, as free body disease also often causes joint space pain.

The meniscus acts as a spacer between the femur and tibia. When the knee joint is weighted, moving, and flexing, the meniscus moves forward and backward, increasing the friction between the femur and tibia, leading to increased pain in the meniscus. Accordingly, pain during activity and pain during hyperflexion are typical symptoms of meniscus injury.

It is widely acknowledged that knee dislocations are not directly related to meniscal injuries of the knee. Although there are knee dislocation symptoms in positive cases of meniscus injury, they may be caused by other underlying knee diseases.

Through the above analysis, it was confirmed that these four salient features are reasonable for the identification of meniscal injuries. By constructing a model after screening these salient features, we found that the model has high screening performance. Other subjective symptoms may be caused by meniscal injury or other knee disorders because of the dense structure of the knee. It was not significant in the screening analysis of meniscus injury, so it was not included in the nomogram model and scoring system. This approach can provide the general public with a simple and intuitive tool for self-diagnosis in public health.

4.3 Limitations

There were some limitations of this study, which were stated below.

(1) Due to the complexity of the knee and its disorders, such as the coexistence of multiple structural injuries, confusion may arise when trying to differentiate the subjective symptoms of specific disorders.

When recruiting patients, we try to select patients with a single diagnosis of meniscal problems compared to patients with other knee disorders, but we cannot completely avoid complications.

(2) This was a subjective study, and there may be some subjective information descriptive error. In addition, the number of symptoms analyzed in this study was limited, and no studies were available that might indicate all symptoms of meniscal injury. Although subjective symptoms were collected and sorted out as much as possible, and patients were asked to recall disease symptoms as accurately as possible in the questionnaire, there may still be some deviations from the basic reality.

(3) Although the model established in this study achieved a performance of 88.75% C-index, it was based on statistical significance. It should be used as only a reference tool rather than a complete substitute for clinical diagnosis. It can only indicate a high possibility of meniscus injury, and further clinical evaluation and treatment are advisable.

V. CONCLUSIONS

Meniscus injury is easy to be confused with other knee diseases. If we can identify meniscus injury through subjective symptoms, we may be able to delay disease progression effectively and treat the disease in time. For this purpose, we introduced a nomogram model using as few subjective symptoms as possible to derive a risk assessment of meniscus injury in the general population with knee discomfort. The model cannot replace MRI to diagnose knee diseases, but it is a useful tool to evaluate meniscus injury. If a person is at a high risk of meniscus injury based on the prediction of our model, then we would suggest the person seek further medical advice and undergo an MRI evaluation to obtain a definitive diagnosis.

ACKNOWLEDGEMENTS

We would like to thank all our participants for their time and effort. We also thank doctors such as Hao Wang (the Fourth Affiliated Hospital of Anhui Medical University), Xin Jin (the First Affiliated Hospital of Anhui Medical University), Zheng Zha (the First People's Hospital of Anqing), Wen Zhao (the Anqing 116 Hospital), and Zhulong Pan (the Anqing 116 Hospital) for their knowledge guidance and data collection assistance.

FUNDING INFORMATION: This research was funded by the Key Project on Anhui Provincial Natural Science Study by Colleges and Universities under Grant “Key technical research of knee function evaluation and rehabilitation training” (No. KJ2019A0555), Key project of Science and Technology Service Network Program of Chinese Academy of Sciences “Construction of chronic disease risk prevention and control service system based on big data”(No. KFJ-STS-ZDTP-079), Major Science and Technology Projects of Anhui Province ” Research and demonstration of key technologies of non-medical sexual health promotion services”(No. 18030801133), the National Natural Science Foundation of China (No. 61701482), Natural Science Foundation of Anhui Province, China (No. 1808085MF191), the Anhui Provincial University Leading Talents Team Fund Grant Project (Anhui Education Secret [2019] No. 16), the National Natural Science Foundation of China (61801006).

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